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Defining Formative Electronic Assessment in Undergraduate Mathematics: A Reflective Approach

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Abstract. Formative electronic assessment of mathematics on the Learning Management System is unique. The purpose of this study was to delineate the process of formative assessment in mathematics through the students' experiences during remote online learning. Formative assessment is part of learning and helps students to monitor their progress. Data were analysed by identifying themes from the narratives. It emerged that the e-assessments that are manually written and graded by the instructor were the best mode of assessment for undergraduate mathematics. With timely feedback, formative electronic assessment placed students in a position whereby they took more responsibility for their learning. As such, students had positive perceptions towards formative electronic assessment during remote e-learning and were prepared to proceed with it in future. The study concluded that while some students proclaimed to have the expertise in the use of e-assessments, most students did not have the expertise in using e-assessment tools, as formative e-assessments were not generally offered in other modules. Participants echoed the sentiments that instructor expertise in formative electronic assessment design should be unquestionable to promote enhanced mathematics assessments that should enable presenting the steps taken to arrive at the answers.

Keywords: formative assessment; electronic assessment; undergraduate students; e-learning; mathematics

1. Introduction

Teaching and learning in higher education focus on developing an individual student into an independent learner. To achieve this, teaching and learning are in constant transformation as new players, pedagogies and paradigms constantly re-define higher education (Oliver, 2018). This state of affairs has been stimulated by the exponential growth of digital technologies, increasing globalisation, and calls

to bring about social justice in higher education. Humanity is at the threshold of rapid technological advancements that have the potential to change the way people work, live and learn. Higher education globally is evolving, witnessing recent increases in the number of blended courses. and of late, fully online courses (Xu & Mahenthiran, 2016).

Electronic learning (e-learning) is learning that is facilitated by digital technologies. It encompasses multiple activities that include the use of the learning management system (LMS) platform like Moodle or Blackboard (Buzzetto-More & Alade, 2006). LMSs have been implemented widely in higher education for a long time (Stone & Zheng, 2014). They are highly interactive interfaces that are student-centred and accessible to many students with internet connection anytime, and from anywhere. The downside of LMSs is that they require familiarisation by both students and instructors (Bradford & Porciello, 2007) and incur huge running costs. LMSs support all kinds of assessment in higher education (Koneru, 2017), which involves the introduction of test builders and authorising tools which make it possible for tests, quizzes and assignments to be created by course instructors (Timmis et al., 2016). However, being web-based, LMSs are unfavourable to users with limited internet access.

Starting in 2020, the COVID-19 pandemic caused worldwide disruptions to all levels of education, which necessitated several tertiary education institutions to migrate entirely to full e-learning (Elzainy et al., 2020; Camilleri, 2021). These e-learning platforms took the form of (a)synchronous online instruction using Microsoft Teams, Google Meet, Zoom and others, in efforts to ensure that learning continued during the times of compulsory school closures (Chen et al., 2021). The proliferation of full online instruction necessitates new and complementary tools for assessment (Prieto et al., 2012). The absence of physical contact between students and instructors necessitated innovative techniques of assessment of students' learning (Baleni, 2015). Assessment is one of the factors that promote a student-centred educational model, thus, it becomes a key factor in promoting effective learning. According to Timmis et al. (2016), the way institutions create and use assessment encapsulates their conceptualisation of teaching and learning.

Kundu and Bej (2021) define e-assessment as the use of the computer and/or the internet to create, deploy, grade and deliver feedback to students on any of the three forms of assessment, namely prior to learning (diagnostic), of learning (summative), and for learning (formative). This study was limited to formative assessment as a driving force for teaching and learning in higher education. Buzzetto-More and Alade (2005, p. 251) define formative as "an ongoing process that involves planning, discussion, consensus building, reflection, measuring, analysing, and improving, based on the data and artefacts gathered about a learning objective." Formative assessment is the bedrock for the ongoing process of learning and teaching (Buzzetto-More & Alade, 2006). This culminates in formative electronic assessment (FEA), which is the focus of this study.
The Blackboard LMS offers two key types of assessment, which are tests and assignments. These two constitute e-assessment in this study. Blackboard tests refer to instructor-created assessment where the deployment and marking are

automated (Boitshwarelo et al., 2017). Online tests (OTs) have objective questions the responses to which are pre-determined, and take the form of multiple-choice, true or false, matching and fill-in-blank. On the other hand, online assignments (OAs) accommodate longer subjective questions that are deployed and submitted electronically, but are manually marked by the instructor. The decision to use OTs or OAs depends on the learning outcomes and the discipline. In mathematics, most questions require step-by-step solution processes that make online tests undesirable, especially from the students' perspective.

The COVID-19 pandemic compelled higher education institutions to engage in novel teaching methodologies to continue delivering their curricula (Camilleri, 2021). This necessitated e-assessment in sync with the expanded programmes in e-learning. FEA plays a crucial intermediate role of reinforcing e-learning and prepares students for summative e-assessment (Boitshwarelo et al., 2017). Whereas e-learning has been adopted firmly in the higher education spaces, FEA still is used sporadically and discretionally by individual instructors. Despite increasing technologies in people's daily lives, instructors have been slow to adapt e-assessment modes and practices (Timmis et al., 2016). These assessments require time, special skills and technical knowhow, which some instructors lack, to ensure e-assessment of high quality. Based on the response to mathematics courses that were assessed online, this study pursued the delineation of the process of formative assessment through students' experiences during remote online learning. The research questions for this study were, (i) "To what extent do undergraduate mathematics students deal with Blackboard FEA in mathematics?"; (ii) "How do students perceive formative electronic assessment practices in undergraduate mathematics during full online learning?" and (iii) "What are the online assessment modes that are preferable in mathematics?" This study focused on formative assessment that occurs during learning, in contrast to summative assessment that comes after learning. A literature search revealed no studies on formative assessment as a bridge to e-learning and online summative assessment.

2. Literature review

By its very nature, formative assessment plays a key role in learning. A study by Sosibo (2019) examined the possibilities of students' active engagement with content, using self-assessment to broaden the horizon of autonomous learning. However, the formative self-assessments were not online, in contrast to this study. The traditional pen-and-paper self-assessment tasks were administered to a case of 30 preservice teachers. Interview transcriptions were coded, and emergent themes were identified in the analysis of data. Data in the form of instructor scores were analysed statistically. The results highlighted the need to increase self-assessment opportunities across all courses as a way of promoting student-centred assessment approaches. The contribution of Sosibo's (2019) study was to boost students' autonomous learning, thereby overcoming feelings of dissatisfaction and anxiety associated with formal assessment. Furthermore, Prieto et al. (2012) integrated a locally-made online test as an alternative to self-assessment in mathematics for computer science students. Both instructors and students had a positive attitude towards the practical use of the tool. Prieto et al.

(2012) introduced complementary testing software for mathematics, composed of multiple-choice questions (MCQs). The present study harboured the same sentiments, but shifted the focus to instructor-made FEA to help students interact with content meaningfully.

Fontanillas et al. (2016) conducted a study to analyse students' perceptions about the e-assessment approach to pursue the advantages of students' active role in e-assessment. This was done towards the end of a course in an online open university. An online questionnaire was administered to students to elicit their perceptions and roles in e-assessment. Fontanillas et al. (2016) revealed that students were highly satisfied participating in e-assessment activities, which resulted in some improvements in the learning process. In all, students' active involvement in learning is envisaged, which leads to huge student benefits. Similarly, Chen et al. (2021) took further the idea of students' active engagement with content through FEA. Students were subjected to frequent tasks, quizzes and tests in a fully online English course. Thereafter, they sought students' perceptions on the engagements using oral records and a questionnaire. The results indicated that students had positive perceptions regarding FEA and were actively engaged in all the online activities, which led to an improvement in the scores gained in the activities. The significance of this study is the vital link of a-synchronous instruction to asynchronous assessment, which grants instructors opportunities to design frequent and progressively challenging formative assessment activities geared at improving achievement of learning outcomes.

In another study, Baleni (2015) investigated how FEA facilitates teaching, learning, and the manner wherein both instructors and students benefit therefrom. An online questionnaire was used to gather students and instructors' experiences on how FEA operates. The results revealed that FEA could nurture and enrich students' commitment through perceived students- and assessment-centred approaches. Baleni (2015) highlighted the significance of instructor-made e-assessment activities which are tailored to the needs of the course and the students. Studies by Boitshwarelo et al. (2017) and Buzzetto-More and Alade (2006) also illustrated the tremendous capacity of digital technologies to be catalysts to drive and assess students' learning to prepare them for twenty-first century learning. The results revealed that assessment requires planning and foresight so that FEAs are valuable tools that optimise assessment in the digital age in which we are living. It can be deduced that online tests are best suited for formative purposes, thereby making technology play a significant role in delivering and evaluating learning outcomes.

This study was structured on the e-learning theoretical framework proposed by Apricio et al. (2016). The goal of the e-learning systems theoretical framework is to determine the participants, the technology used and the services offered related to e-learning in a study. These pillars guided this study to identify the stakeholder groups and their interaction with the e-learning systems. Firstly, the stakeholders consisted of instructors and students who provided and received the service rendered. Secondly, the technologies used in e-learning provided support in integrating content, communicating and collaborating. However, in this study

students were individuals interacting with e-assessment tasks that had no collaboration involved. The LMS was the technology used to deliver service and focus on students' interaction with mathematics. The LMS tracked and delivered content to students, assessed students 'learning and reported student progress. Finally, e-learning services encourage instructor-made learning activities that support learning that corresponds with the content and instructional strategies. Instructional strategies for FEA are facilitation and individualised learning. The activities entail pre-tests and main tests as part of FEA. Pedagogical models for FEA are autonomous learning.

3. Methodology

A case of one South African university was considered to give an in-depth exploration of undergraduate mathematics students' experiences in FEA. According to Creswell and Creswell (2018), a case study is a detailed description of phenomena in natural settings. Two year-long undergraduate mathematics courses were considered at a time when all instructions and assessments were fully online and remote. The enrolment for two courses was 37 Level 2 and 180 Level 3 students in 2021, but not all these had sat for e-assessment in a mathematics content. Mathematics was chosen due to its multi-step computational nature and the first author was the instructor of the two courses. For students to learn through assessment, the instructor administered four formal tests to each group. The researchers devised pre-tests for each of the formal tests that they sat for prior to the main tests. Pre-tests were meant to familiarise students with the dynamics of e-assessment as they worked towards formal formative and summative assessments. Initially, all the assessments were OTs and later OAs.

Eleven students responded to an online open-ended questionnaire distributed in Google form. The questionnaire briefly sought participants' perceptions to online assessment, for example, *"Which topics in mathematics are not suitable for online assessment?"* A preliminary data analysis of the questionnaire responses was done to identify aspects that needed further inquiry. Thereafter, telephonic semi-structured interviews were conducted to probe students' deeper experiences in FEA. The interview questions were higher-order so that the interviewer could ask probing questions after initial responses where necessary. One of the questions was, "*How do you see the future of online assessment in mathematics in the post-pandemic era?*" The use of two instruments was part of triangulation of data to ensure data trustworthiness. The researchers undertook a narrative inquiry into the experiences of 23 conveniently selected students. The sample, thus, comprised 10 second-year and 13 third-year students. The participants were selected through convenient sampling. The narrative approach allows for a rich description of these experiences and an exploration of the meanings that the participants derive from their experiences. Data were analysed qualitatively by identifying themes emerging from students' narrations. The analysis of the data to identify themes followed on the case study research (Creswell and Creswell, 2018). As the students told their stories, the researchers were able to construct meaning. Narratives, seemingly, are the best way for participants to relate their experiences (Merriam, 2009).

To execute FEAs in OT mode, diverse items were used as illustrated in Figures 1 to 4. MCQs were the most commonly used (Boitshwarelo et al., 2017) and an example is shown in Figure 1.

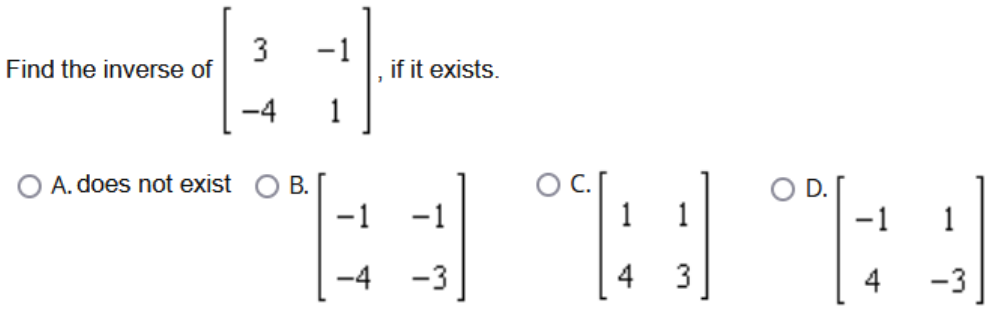

Figure 1: An MCQ item in the OTs

Fill-in items were popular too in OTs, which can be single or multiple, as shown in Figures 2 and 3 respectively.

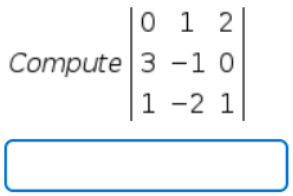

Figure 2: A single fill-in item

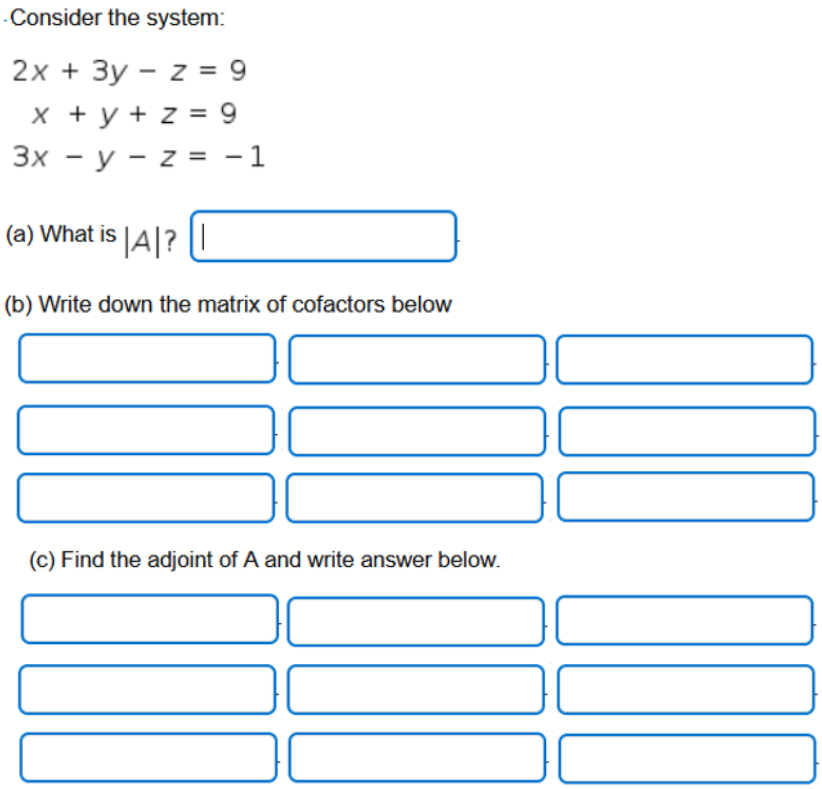

Figure 3: A multiple fill-in item

Finally, OTs had True/False items (shown in Figure 4).

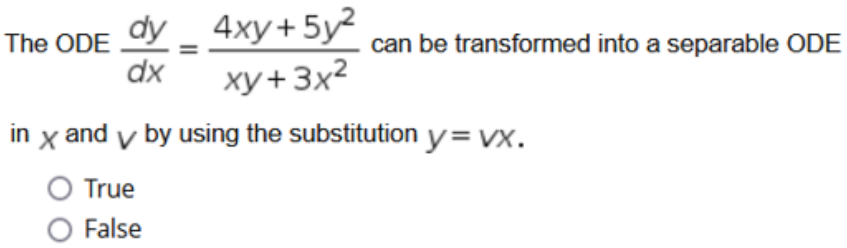

Figure 4: A true/false item in the OT

A mixture of these items was used in the OTs. The examples were drawn from an OT on Matrices under Linear Algebra. We did not put the sample items for OAs since these take ordinary long questions, typical of a mathematics test.

4. Results

The researchers analysed the narratives of the participants in both the questionnaires and interview transcriptions, and the themes which emerged ranged from general online digital resource concerns to mathematics specific deliberations. For purposes of anonymity, the participants were coded 'T1', 'T2' and so on until 'T23', where the ordering did not carry any significance. The emergent themes are presented in the ensuing section.

4.1. Provision of resources by the institution

The sustainability of the institution (U1) to provide digital resources was key to e-learning. Respondent T13 indicated in the questionnaire that even though U1's provision was rudimentary, it was sufficient, "*U1 is one of the underprivileged institutions but they are trying their level best to meet the standard*". In support of this, T12 posited that U1 managed to have made available the basic tools for online learning and assessment, that is, laptops and data for students, "*Yes, but we do have laptops and smart phones*". The LMS and Microsoft Teams' applications were in place as an institutional provision. Moreover, all students monthly received data from the institution and for those who were based on campus; the institutional Wi-Fi provided a robust network to work on. T12 cited the availability of smart-phones in e-learning. These were not supplied by U1 but proved to be very popular with the participants. Acquisition and ownership of smart phones did not put too much pressure on U1. In fact, the availability of personal smart-phones broadened the base of accessibility to online resources, despite their small screen sizes.

Digital resources may not be sufficient owing to the rapid push that drove institutions into full online education. All students agreed that it was the COVID-19 pandemic that caused U1 to adopt full e-learning. According to T21 and T16, e-learning was never implemented during the pre-COVID-19 era, even though the LMS was there:

> *T21: Online learning was never used before in our institution.*
> *T16: Though we already had Blackboard, we did not use it for almost all the assessments, but now we use it even for our final examination.*

According to T16, e-assessment was absent too, which may be due to contact teaching and learning in the pre-pandemic era. The instructors during that time used the LMS as a repository for lecture notes and related course information. T17 corroborated, "*For example, we were using Blackboard to get notes and assignment questions sometimes, but we were not writing tests over there.*" Some students, like T6, said U1 planned to adopt e-assessment; "*We were going to use but not now. Maybe some time later. The process was not going to be fast as it is now.*" Thus, COVID-19 forced U1 and other institutions to switch to full e-learning with such rapidity that provision of resources could not keep pace. Hence, some of the challenges, including inadequate provision of tools of trade to students that were highlighted.

4.2. Proceeding with e-Assessment in future

Having experienced the devastating effects of the COVID-19 pandemic, institutions must be cautious in their future approaches to teaching, learning and assessment, as no one knows for certain what the future might hold for humanity. This sentiment was confirmed by T6 who commented that even if humanity wakes-up and finds COVID-19 is gone, e-learning must proceed all the same, "*I think let us continue with Microsoft Teams and Blackboard because we will never know what will happen tomorrow*". T13 supported proceeding with e-learning in future due to the large capital outlay that has already been put in place, "*We can continue because we already have Teams and Blackboard*". Some students were undecided on whether to proceed with e-assessment, as shown in the dialogue with T3 below where R represents the researcher:

> *R: For 2022, do you think we must continue using Teams and Blackboard?*
> *T3: I am not sure. But, yes, all I can say is we are not 100% perfect in using Blackboard. Some they complain even if it's not problem of network. But for next year, I think we will have gotten used to it, so we may use Blackboard.*

The lack of a clear-cut decision was due to the lack of skills in using online tools. Students' skills in using online tools are discussed in the next sub-section. At U1, teaching and assessment took place on Teams and Blackboard respectively.

4.3. Expertise in using e-Assessment tools

Use of online tools for assessment entails logging in to the LMS and navigating to the assessment location. Thereafter, students should be able to open, and give responses to test items within the given time and submit the test solutions. That it was easy to use the online tools was confirmed by 15 students and the dialogue with T4 went as follows:

> *R: Any problems with Blackboard?*
> *T4: I didn't have any problem with Blackboard.*
> *R: Some students complain that the computer submitted their work. Is it possible?*
> *T4: It's not possible because it depends on the network connection that you have.*

Participants like T7 had no problems because they had written OTs in the previous year(s). To some participants like T6, the skills grew with practice: "*For now I am OK. But at the beginning it was difficult.*" Finally, T13 said, "*It is indeed one of the easiest things*". Quite expectedly, modern-day students are dextrous at using technological devices, the skills of which appeal more to the young generation.

The remaining eight participants admitted to having some difficulties with online tools. T14 had challenges with logging-in and for T23, it was the absence of technical support when students encountered problems, as shown in the hand-written questionnaire response in Figure 5.

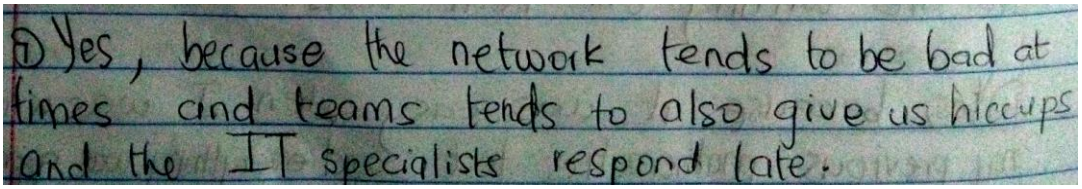

Figure 5: Absence of technical support by the relevant department (T23)

In some cases, students were left alone without any technical support, especially if the problems were encountered during odd hours.

4.4. FEAs in other courses

If students sat for FEAs in other courses, it would obviously alleviate their challenges with online tools in mathematics. However, it was not the case with most of the participants. T3 indicated mathematics was the only course where they sat for FEA. On the other extreme, T19 and T20 said they wrote FEAs in all the courses they were studying. FEA, thus, was offered in some subjects, the most common being physical sciences and life sciences. In reality, it is common practice for mathematics and sciences instructors to share and collaborate as a community of practice on issues like assessment. Other general teacher education courses were not cited, except psychology that was mentioned by T8. The mathematics curriculum course was also cited by T14, T15, T17 and T22. The other courses, like geography and accounting had two participants each, while business studies registered only one. Nonetheless, only a few students studied mathematics and the latter subjects . It turned out that the choice to administer FEAs was the prerogative of the course instructor due to a lack of policy, hence huge disparities in FEA administrations. All the assessment policies were for the pre-pandemic era. Expertise in test creation and deploying plays a key role in motivating instructors to engage in FEA, which is described in the next sub-section.

4.5. Instructor expertise in FEA design

The computational nature of mathematics and the unique answering process of questions in mathematics justify further inquiry into FEA. Answers must be precise, accommodative to alternative responses and the method used by the student should be explicit. To achieve this in FEA requires diligence and skill, which requires due training. It was not the case at U1 since the entire e-Learning move was hurried through, in response to the state lockdown measures. T22 was quick to point out that mark allocation should start on the steps to the answer: "*Allocate the marks for the calculations and not for the final answer only*". Pertaining to fill-in objective questions, T10 said, "I *don't know if I should put only the answer or the whole thing. I am not sure*". T3 explained his concerns about the format of the answers, over and above the correctness and wrongness of the answer in the dialogue below:

T3: It's like when you write $x = 13$ *but then the only thing I wrote is 13. Then I get it incorrect by just leaving out* x.
R: Yes, I agree with you. The way you write may cause you to lose marks.
T3: It's only the way you write but the answer is correct!
R: As a lecturer I try to accommodate all the possible answers for example, accepting both 2 or two.

To guard against the concerns above, instructor expertise in information and communication technology (ICT) are required to incorporate all possible answers and to guide students on how to write the answers. These were some of the inescapable dynamics of e-assessment in mathematics faced by the course instructor. Most of the concerns were related to OTs, so a shift to OAs alleviated the dissents. After introducing OAs, no more concerns were raised by students as the assessment type yielded results that were a true reflection of the students' understanding of the concepts taught. In light of this, participants had little to say concerning improvements needed to be effected to FEA. This is explained in the next sub-section.

4.6. Instructors' improvements to FEAs

When FEA started, students were introduced to OTs, of which some had prior experience from other courses. These auto-scored assessments proved to be so unpopular with students that their calls for improvements were centred on what T21 said, "*At least, there must be something for calculating steps to see where you went wrong rather than just a final answer*". "*Allocate the marks for the calculations and not for the final answer only*", is what T22 suggested. Precisely, T3 reiterated the issue of objective questions when he said, "*Improve answering options for fill-in*". Indeed, the instructor made efforts to address that by including multiple fill-in questions that bore partial crediting. Nevertheless, seemingly, it was not enough.

Other calls for improvements of both OTs and OAs had to do with the need for familiarisation with online test-taking in mathematics. The instructor knew about this need and made provision for pre-tests before each formal assessment task. But T23 wanted more pre-tests, as shown in Figure 6.

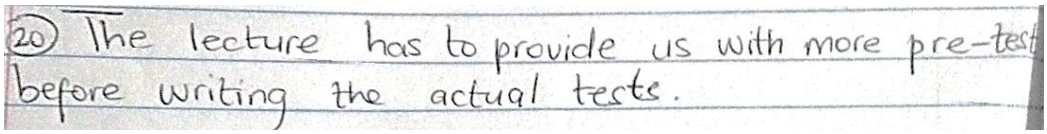

Figure 6: Call for improvements of pre-tests (T23)

Moreover, T1 confirmed the call for mock tests by saying, "*You should send videos on how to write a test on Blackboard because most of us cannot do*".

Some students also called for increasing the duration of the tests, which applied to both OTs and OAs, both of which had the same time allocation. T15 said the instructor should, "*Maximize the time and attempts he allocates for each test*". In addition, T11 said, "*Give us enough time to write*". However, these wishes for improvements were incompatible with efforts to reduce possible cheating as students sit for FEAs remotely. Minimising duration and granting only a single

attempt are some of the techniques advisable to counter cheating, which is not easy to eradicate entirely in remote FEA. Finally, six participants commented that they were content, so there was no need for improvements concerning FEAs under OAs mode. For instance, T13 said, "*According to my personal view everything is in order, nothing needs to be improved*".

4.7. Choice between OT and OA

Students were also faced with the decision to choose between OTs and OAs as a mode of assessment in mathematics. This centred on the type of topics, responses and marker. Questions with pre-determined responses are not suitable for all topics in mathematics since they reward marks for the final answer only. According to T21, mark allocation should include steps in the solution process. Moreover, T14 said, "*Some of the modules like Mathematics are not good for online assessment because it deals with proofs and calculations. It should be manually written*". In addition, marking of long and subjective responses requires a human marker, which was supported by T3: "*It's better for you to mark Sir, that's why I said assignment is best. This thing of computer; I don't trust it at all*". The dialogue with T3 below sums it up:

> *T3: Even if you make it a test for me ... there is no problem.*
> *R: But a test is marked by a computer but an assignment is marked by a human being.*
> *T3: Yahh, I think assignment is the best because last time we were complaining about online test I remember.*
> *R: And after online assignment, were there complains from students?*
> *T3: No. I didn't hear anything.*

At first T3 was indecisive but later supported OAs after witnessing many complaints from students. Moreover, T7 said, "*It has to do with issues like 0.5 and ½. The computer may mark it wrong.*" The computer scoring is as good as the instructor who designs the test, hence T8 said, "*… but the computer marks according to what it is fed*". The fact is that accurate coding of instructions to the computer is another skill that most instructors do not possess.

With the limited resources at U1, it was advantageous for students to sit for OAs because they could also use smart phones as a medium to write. The phone was only used to download the question paper and to upload the files containing responses. However, for OTs, a laptop or desktop with a sizeable screen and a constant internet connection are required for the duration of the test. Any disruption in internet connectivity terminates the test and the system auto-submits the students' responses completed up to the time of disturbance. T11 said, "*… online tests give us problems when we face network problems and they submit while you [are] not finished writing and end up failing*". Hence, in the context of disadvantaged institutions, OAs relatively promote learning.

4.8. The trade-offs between cooperative learning and independent learning

The participants were cognisant of the trade-offs between cooperative and independent learning in the e-learning environment. By the nature of remote e-learning, students were confined to their personal spaces with limited opportunities for peer and instructor interaction. This makes learning clumsy, as

corroborated by T16, "*Mathematics needs to be learnt in pairs or even groups; you cannot just study alone and write, I believe the module is very hard and complicated to me*". As the campus was not entirely closed to students in 2022, some students managed to form micro-groups to assist one another. To this effect, T3 commented, "*I am already in right now because there are some of my classmates with whom we study as a group*". To students who could not congregate physically or electronically, some explored prospects of independent learning. T7 and T8, respectively, said, "*I practise alone if I am preparing for a test and I create my own solutions before going to the original solutions and correct myself. It's easy to remember when you were corrected by yourself; not by someone else. It's easy to remember a mistake that you have done before*", and " *… it is preparing us for postgrad studies. I like the idea Sir. With postgrad we won't be attending classes*". To foster independent learning through FEAs, the researchers created more opportunities that are individual through pre-tests. Students took these as mock tests before the main formal test. All students praised pre-tests as a way to familiarise with FEA and improve grades, as indicated by T10:

> *… gives us a clue on the kind of questions that we may expect. Sometimes we study and we are not sure in which format the question will be. It also helps us to know how much we know and how much we don't know. If you get a low mark, then you know you are not ready. I have to study more. If there is no pre-test, you study and think that you are ready when in actual fact you may not be. I also need to see my mistakes so that on the day of the test I don't have to repeat those mistakes*.

Having not written FEAs in mathematics previously, pre-tests also proved to be very useful.

5. Discussion

Humanity stands at the brink of a technological revolution called the fourth industrial revolution (4IR). This fundamentally changes the way people live, work and relate to one another. When compared to previous industrial revolutions, the 4IR is evolving at an exponential rate. Even though ICT skills are prevalent in the digital age we are living in, special skills to sit for the FEAs grew with experience for most participants. Students in higher education easily embraced internet-mediated assessment in mathematics. E-assessment is fast becoming a standard mode of formative and summative assessment in higher education institutions around the world (Sangwin, 2013). With the rapid effects of the digital transformations and the COVID-19 pandemic, it is likely that remote internet-mediated resources are bound to take core position in the delivery of education (Marpa, 2021). In that regard, students did not resent e-assessment upon realising that that was the only way for them to complete their studies.

Furthermore, students were motivated to learn mathematics, which is generally known to be unpopular with students (Alrabai, 2017). When students are actively engaged in learning, they become motivated to learn. FEAs are naturally individualistic; thus, instructors should strive to actively engage students. Students need to be made aware of the crucial role that autonomy plays in the learning process (Alrabai, 2017). When students realise this role, they can use FEA to guide, regulate and monitor their own learning (Dann, 2014). Moreover, FEA is

designed to inform both student and course instructor about the progress of the students. When designed well, the administration of FEA should reduce students' dependence on the instructor. Students benefitted from accessing the assessment synchronously from any geographical location and receiving immediate feedback (Sikurajapathi et al., 2020).

The students indeed disapproved OTs based on practice, specifically due to the nature of mathematics. The focus is not on the final answer in mathematics. However, MCQs were very useful tools to support students' learning in Accounting and Business modules (Einig, 2013). Regarding mathematics topics, students were comfortable with OAs for both formative and summative assessments. This is more natural to the development of mathematics concepts in lessons and textbooks; if examples posed during the lesson are not objective, in what way can they be so in FEA? That would be superfluous.

The administration of FEAs was not uniform, with some courses still resorting to traditional contact assessment. Frequently, instructors' lack of expertise and experience inhibit the use of new and appropriate assessment tools to facilitate learning (Prieto et al., 2012). FEAs on Blackboard require instructors to design and deploy tests themselves, more especially OTs. The instructor still plays a significant role in teaching, learning and assessment (Charteris et al., 2018).

Mathematics assessment traditionally is closed-book and controlled (Iannone, 2020). However, with remote and full e-learning, this is not bound to be the case. This gave rise to FEA, which is a technology-mediated open-book assessment that inevitably enables students' unfair practice tendencies. However, instead of worrying about cheating, instructors should devise questions that may not be straight-forward which cannot be easily searchable on Google or in texts during time for assessment (ibid.). Thus, if the items are designed well, FEAs can be a cornerstone for enhanced student engagement with content.

This study focused on formative assessment, because it was designed to inform both instructors and students about the progress of the student during a course of study. Students' use of FEA is intended to create awareness of their own weaknesses to formulate plans to address them (Charteris et al., 2018). Moreover, the computational nature of mathematics lends itself well to FEA and the performance was normally distributed as expected. Students had positive perceptions of FEAs and had no problem to continue with them in the post-pandemic era. This resonates with the goal of this study, which was to explore students' e-assessment experiences in mathematics. FEAs have earned themselves a place in higher education since the gloomy days of the COVID-19 pandemic. Students did admit that even though digital technologies have infiltrated every facet of human life (with positive results), effective teaching would always require a teacher in front of the class. Digital technologies will not replace the instruction and grading skills of a teacher, but be complementary (Rapanta et al., 2020).

6. Conclusion and recommendations

The study concluded that trade-offs between cooperative learning and independent learning are inevitable through e-learning. Despite that, the provision of e-resources at the institution under study was not comparable to better-resourced institutions; students appreciated the effort made in 2020 by the institution. The study also concluded that most students prefer long and subjective assessments for mathematics where students can show the steps followed to arrive at a solution. This mode of assessment did not require typesetting and was graded by the course instructor. Moreover, students welcomed online assessment upon realising that it was not just for the sake of COVID-19, but it was something that was here to stay. Future uses of online assessment for both formative and summative assessment in mathematics and other courses are guaranteed. The findings of this study have practical significance for the researchers since they are still teaching the same courses under full online learning in subsequent years. Due to expansion of digital transformation, results from this study are relevant to other instructors if they wish to adopt FEA in their courses. This study served as evidence of what worked in a single course, which can be expanded to similar courses like the science, technology and engineering. This study recommends that more practical and research-based evidence is needed to inform online instructional and assessment decisions for mathematics (Marpa, 2021). This study attempted to document the FEA in mathematics as conducted by the first researcher and reflected by students. According to Caspari-Sadeghi et al. (2021), the goal of this research is to ensure that any adopted involvement is supported by evidence that is gathered and analysed by practitioners themselves. This study was limited to a small sample size. It is recommended that instructors and researchers develop versatile and credible assessment strategies in both formative and summative assessment using large sample sizes. This is imperative because some instructors lack the requisite expertise to design, create, deploy and grade assessment on the LMS. When COVID-19 first struck, the shift to online teaching and learning was not very difficult but there was a steep learning curve for lecturers and students (Rudman, 2021). In addition, investigating South African students' readiness for independent learning and autonomy in learning mathematics using digital resources are issues that future research might investigate.

6. References

Alrabai, F. (2017). Exploring the Unknown: The Autonomy of Saudi EFL Learners. *English Language Teaching, 10*(5), 222-233. https://doi.org/10.5539/elt.v10n5p222

Apricio, M., Bação, F. & Oliveira, T. (2016). An e-Learning Theoretical Framework. *Journal of Educational Technology & Society, 19*(1), 292-307.

Baleni, Z. (2015). Online formative assessment in higher education: Its pros and cons. *The Electronic Journal of e-Learning, 13(4),* 228-236. http://www.ejel.org

Boitshwarelo, B., Reedy, A.K., & Billany, T. (2017). Envisioning the use of online tests in assessing twenty-first century learning: a literature review. *Research and Practice in Technology Enhanced Learning, 12(*16). https://doi.org/10.1186/s41039- 017-0055-7

Bradford, P. & Porciello, M. (2007). The Blackboard Learning System: The Be All and End All in Educational Instruction? *Journal of Educational Technology Systems.* https://doi.org/10.2190/X137-X73L-5261-5656

Buzzetto-More, N.A. & Alade, A.J. (2006). Best Practices in e-Assessment. *Journal of Information Technology Education, 5, 251-269*. https://doi.org/10.28945/246

Camilleri, M.A. (2021). Shifting from traditional and blended learning approaches to a fully virtual and remote course delivery: Implications from COVID-19. *Academia Letters, 481*. https://doi.org/10.20935/AL481

Caspari-Sadeghi, S., Forster-Heinlein, B., Maegdefrau, J. & Bachl, L. (2021). Student-generated Questions: Developing Mathematical Competence through Online-Assessment. *International Journal for the Scholarship of Teaching and Learning, 15*(1). https://doi.org/10.20429/ijsotl.2021.150108

Charteris, J., Quinn, F., Parkes, M., Fletcher, P. & Reyes, A. (2018). e-Assessment for learning and performativity in higher education: A case for existential learning. *Australasian Journal of Educational Technology, 32*(3). https://doi.org/10.14742/ajet.2595

Chen, Z., Jiao, J., & Hu, K. (2021). Formative Assessment as an Online Instruction Intervention: Student Engagement, Outcomes, and Perceptions. *International Journal of Distance Education Technologies, 19*(1). https://doi.org/10.4018/IJDET.20210101.oa1

Creswell, J. W., & Creswell, J. D. (2018). *Research Design Qualitative, Quantitative, and Mixed Methods Approaches 5th Ed*. Sage.

Dann, R. (2014). Assessment as learning: Blurring the boundaries of assessment and learning for theory, policy and practice. *Assess. Educ. Princ. Policy Pract.* https://doi.org/10.1080/0969594X.2014.898128

Einig, S. (2013). Supporting students' learning: The use of formative online assessments. *Accounting Education: An International Journal, 22*(5), 425-444. https://doi.org/10.1080/09639284.2013.803868

Elzainy, A., El Sadik, A., & Al Abdulmonem, W. (2020). Experience of e-learning and online assessment during the COVID-19 pandemic at the College of Medicine, Qassim University. *J Taibah Univ Med Sc, 15*(6), 456-462. https://doi.org/10.1016/j.jtumed.2020.09.005

Fontanillas, R., Carbonell, M.R., & Catasús, M.G. (2016). E-assessment process: giving a voice to online learners. *International Journal of Educational Technology in Higher Education, 13*(20). https://doi.org/10.1186/s41239-016-0019-9

Iannone, P. (2020). Assessing mathematics at university: Covid-19 and beyond. *Newsletter of the London Mathematical Society, 490,* 34-40. https://doi.org/10.1112/NLMS

Koneru, I. (2017). Exploring Moodle functionality for managing open distance learning e-assessments. *Turkish Online Journal of Distance Education-TOJDE, 18*(4). https://doi.org/10.17718/tojde.340402

Kundu, A., & Bej, T. (2021). Experiencing e-assessment during COVID-19: an analysis of Indian students' perception. *Higher Education Evaluation and Development, Emerald Publishing Limited.* https://doi.org/10.1108/HEED-03-2021-0032

Marpa, E. P. (2021). Technology in the teaching of mathematics: An analysis of teachers' attitudes during the COVID-19 pandemic. *International Journal on Studies in Education, 3*(2), 92-102. https://doi.org/10.46328/ijonse.36

Merriam, S. B. (2009) *Qualitative Research: A Guide to Design and Implementation*. John Wiley and Sons.

Oliver, E. (2018). Change agency and higher education in South Africa. *HTS Theological Studies, 74*(3). https://doi.org/10.4102/hts.v74i3.5133

Prieto, N.J., Martin, K.J., Colmenar, J.M., Martinez-ortiz, I. & Hidalgo, J.I. (2012). iTest: Online assessment and self-assessment in mathematics. *Interactive Technology and Smart Education*. https://doi.org/10.1108/17415651011071622

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L. & Koole, M. (2020). Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity. *Postdigit Sci Educ* 2, 923–945. https://doi.org/10.1007/s42438-020-00155-y

Rudman, R. J. (2021). Understanding the unintended consequences of online teaching. *South African Journal of Higher Education, 35*(4), 1-12. https://dx.doi.org/10.20853/35-4-4717

Sangwin, C. (2013). *Computer- Aided Assessment of Mathematics.* Oxford University Press. https://www.researchgate.net/publication/262933216_Computer-aided_assessment_in_mathematical_sciences

Sikurajapathi, I., Henderson, K., & Gwynllyw, R. (2020). Using e-Assessment to Address Mathematical Misconceptions in Engineering Students. *International Journal of Information and Education Technology, 10*(5). https://doi.org/10.18178/ijiet.2020.10.5.1389

Sosibo, Z.C. (2019). Self-assessment: A learner-centred approach towards transforming traditional practices and building self-directed learners. *South African Journal of Higher Education, 33*(5), 76-97. http://dx.doi.org/10.20853/33-5-3586

Stone, D. E., & Zheng, G. (2014). Learning management systems in a changing environment. In V. C. X. Wang (Ed.), *Handbook of research on education and technology in a changing society* (pp. 756–767). IGI Global.

Timmis, S., Broadfoot, P., Sutherland, R. & Oldfield, A. (2016). Rethinking assessment in a digital age: opportunities, challenges and risks. *British Educational Research Journal, 42*(3), 454-476. https://doi.org/10.1002/berj.3215

Xu, H., & Mahenthiran, S. (2016). Factors that Influence Online Learning Assessment and Satisfaction: Using Moodle as a Learning Management System. *International Business Research, 9*(2). https://doi.org/10.5539/ibr.v9n2p1