

Remote Online Education in Undergraduate Mathematics: Students' Perspectives



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ABSTRACT

Full remote online education was introduced in higher education in early 2020 in response to the effects of the COVID-19 pandemic. This study aimed to determine students' experiences in the three pillars of online education: teaching, learning and assessment based on the digital technologies platform. Before the pandemic, implementing online education in some universities was basic. A case study of two undergraduate mathematics classes was considered to determine students' experiences in online education. Data were collected using open-ended questionnaires and semi-structured interviews. The findings revealed that prior to the pandemic, online education was sporadically implemented. The advent of COVID-19 informed higher education institutions on the opportunities to effectively engage digital transformation to provide education remotely. Teaching and learning were successfully conducted on Microsoft Teams. Mathematics assessment is conveniently administered as timed Blackboard assignments, much to the students' satisfaction. Even though academia may return to normal contact classes with the waning of COVID-19, online assessment remains a convenient mode in sync to modern technology trends.

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INTRODUCTION

Most universities in South Africa have operated on blended learning since the 2015-16 Fees-must-fall protests and even before. However, blended learning was unattainable for some rural-based universities with limited resources and stringent budgets. The traditional contact and face-to-face tuition dominated the higher education spaces at these institutions, a relic of the digital divide prevalent in South African institutions. With the advent of the COVID-19 pandemic and the subsequent lockdowns, millions of students in higher education worldwide were pushed out of institutional-based contact education.¹ All higher education institutions took an unprecedented move from traditional contact and blended learning approaches to a fully remote online where all instruction and assessment

¹ Mark Anthony Camilleri, "Shifting from Traditional and Blended Learning Approaches to a Fully Virtual and Remote Course Delivery: Implications from COVID-19," *Academia Letters* 481 (March 10, 2021), <https://doi.org/10.20935/AL481>.

took place on web-based platforms.² Online teaching, learning and assessment are termed online education in this study. The COVID-19 situation has made online education a mandatory requirement, displacing any reservations and hesitation about shifting to electronic resources. Instead of folding arms waiting for COVID-19 to subside, researchers and academics should take the opportunity to propel higher education to another level in light of digital transformations.³ Academics must turn the pandemic's current challenges into grand opportunities for online education in higher education. As a result, much funding has been invested in online education.

The higher education teaching, learning and assessment landscape is under immense pressure to transform, especially after the COVID-19 pandemic. The future is bleak; thus, there are possibilities for pursuing online education beyond the COVID-19 pandemic. With the growing interest in digital technologies in almost every facet of human life, academics need to rethink their teaching and learning support.⁴ Thus, instructors and students have to update, upskill and learn further digital skills in order to manage the unprecedented changes in how people live in pre- and post-pandemic times. This study attempted to answer the research question: "What are students' experiences in online education during and after COVID-19?" The purpose of this study was to ground the three pillars of online education, namely, teaching, learning and assessment, on the digital technologies platform in response to the COVID-19 pandemic and beyond. These are illustrated in Figure 1.

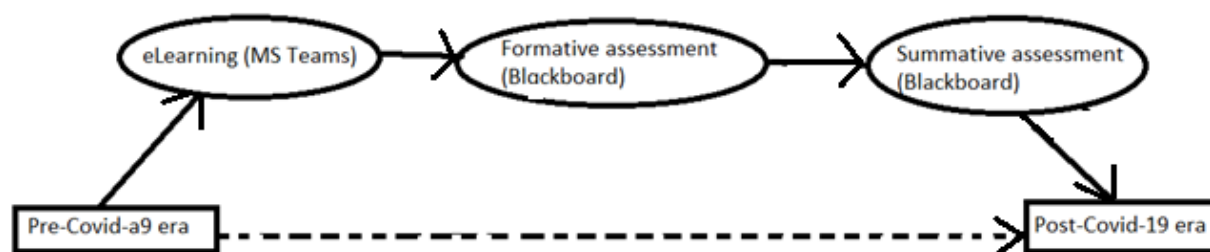


Figure 1: The conceptual framework for online education

Mathematics is of concern to online education because it is composed of special symbols that are not on the keyboard and multi-step solutions that are difficult to do in real-time. Focusing on the final answer only is not appropriate for mathematics. Some topics require proofs and verifications, which necessitates proper teaching and assessment approaches.

LITERATURE REVIEW

The literature search revealed that among the studies conducted on online learning and mathematics assessment, none has focused on synchronous activities involving long questions on the learning management system (LMS). A study by Caspari-Sadeghi et al. focused on developing mathematics competency through multiple-choice questions (MCQs) formulated by students on a digital platform.⁵ Even though the study enhanced self-regulated strategies in learning mathematics, it did not lead to higher achievement, mainly because of using MCQs solely. MCQs are short and objective, which makes them inappropriate for higher-order questions. Sometimes prompt feedback from computer scoring helps to identify students' misconceptions quickly. This led to the usage of machine-scored

² Nicole A. Buzzetto-More and Ayodele Julius Alade, "Best Practices in E-Assessment," *Journal of Information Technology Education: Research* 5, no. 1 (2006): 251–69.

³ Jace Hargis, "What Is Effective Online Teaching and Learning in Higher Education," *Academia Letters* 13 (November 16, 2020): 1–6, <https://doi.org/10.20935/AL13>.

⁴ Sue Timmis et al., "Rethinking Assessment in a Digital Age: Opportunities, Challenges and Risks," *British Educational Research Journal* 42, no. 3 (June 2016): 454–76, <https://doi.org/10.1002/berj.3215>.

⁵ Sima Caspari-Sadeghi et al., "Student-Generated Questions: Developing Mathematical Competence through Online-Assessment," *International Journal for the Scholarship of Teaching and Learning* 15, no. 1 (May 28, 2021), <https://doi.org/10.20429/ijstl.2021.150108>.

short-answer questions in engineering mathematics in a study by Sikurajapathi et al.⁶ In contrast to this study, the items for the assessment originated from the question bank in Dewis, a home-grown web-based assessment application. In this study, the assessment was based on the LMS, and was created and deployed by the course instructor. With detailed feedback, it was discovered that online assessment tackled misconceptions timeously. Another formative assessment software tool iTest was used in a study by Prieto et al. to study the integration of alternative assessment and online self-assessment tools in mathematics in higher education.⁷ As is common with all test software, the questions were MCQs to enable auto-scoring as part of self-assessment. A survey of students and academics involved in the study revealed positive attitudes towards the tool. Test software tools are much appreciated; however, these are often unavailable in developing countries.

A study by Baleni investigated instructors' and students' experiences in general e-assessment in higher education.⁸ In another study, Elzainy et al. explored students' experiences in eLearning and e-assessment and established that there were benefits to implementing online courses in the medical faculty.⁹ Many more studies investigated online assessment practices before and during COVID-19. For example, Stack et al. reported that MCQs online tests in higher education are growing but in the context of commerce students.¹⁰ Wibowo and Novitasari identified many advantages that come with online assessment relative to paper-based assessment in an English course.¹¹ Despite that, all the studies above used objective online tests, which proved useful tools¹² for those disciplines, an analysis by Senel and Senel revealed that online tests were used less in higher education.¹³ Limited use of online tests resulted from concerns about test security and the test-creation skills of those responsible for creating them. Indeed online tests are easy to grade but command advanced IT skills to create and deploy. Consequently, take-home tools like assignments, portfolios and projects were common. Take-home can do for formative assessment but cannot be relied on for summative assessment. Synchronous and timed LMS-based assignments have not been reported in the literature.

Many scholars have created online learning evaluation scales in online education studies by taking the Technology Acceptance Model (TAM) as a theoretical model.¹⁴ It is a theoretical model

⁶ Indunil Sikurajapathi, Karen Henderson, and Rhys Gwynllwy, "Using E-Assessment to Address Mathematical Misconceptions in Engineering Students," *International Journal of Information and Education Technology* 10, no. 5 (2020): 356–61, <https://doi.org/10.18178/ijiet.2020.10.5.1389>.

⁷ Nuria Joglar et al., "iTest: Online Assessment and Self-assessment in Mathematics," *Interactive Technology and Smart Education* 7, no. 3 (September 7, 2010): 154–67, <https://doi.org/10.1108/17415651011071622>.

⁸ Zwelijongile Gaylard Baleni, "Online Formative Assessment in Higher Education: Its Pros and Cons.," *Electronic Journal of E-Learning* 13, no. 4 (2015): 228–36, www.ejel.org.

⁹ Ahmed Elzainy, Abir El Sadik, and Waleed Al Abdulmonem, "Experience of E-Learning and Online Assessment during the COVID-19 Pandemic at the College of Medicine, Qassim University," *Journal of Taibah University Medical Sciences* 15, no. 6 (December 2020): 456–62, <https://doi.org/10.1016/j.jtumed.2020.09.005>.

¹⁰ Anna Stack et al., "Investigating Online Tests Practices of University Staff Using Data from a Learning Management System," *Australasian Journal of Educational Technology* 36, no. 4 (December 20, 2019): 72–81, <https://doi.org/10.14742/ajet.4975>.

¹¹ Furqon Edi Wibowo and Umi Novitasari, "An Analysis of Online Assessment in Teaching English," *PROJECT (Professional Journal of English Education)* 4, no. 3 (May 11, 2021): 521, <https://doi.org/10.22460/project.v4i3.p521-529>.

¹² Sandra Einig, "Supporting Students' Learning: The Use of Formative Online Assessments," *Accounting Education* 22, no. 5 (October 2013): 425–44, <https://doi.org/10.1080/09639284.2013.803868>.

¹³ Selma Şenel and Hüseyin Can Şenel, "Remote Assessment in Higher Education during COVID-19 Pandemic," *International Journal of Assessment Tools in Education*, February 5, 2021, 181–99, <https://doi.org/10.21449/ijate.820140>.

¹⁴ Chunling Shao, "An Empirical Study on the Identification of Driving Factors of Satisfaction with Online Learning Based on TAM*," in *Proceedings of the 5th International Conference on Economics, Management, Law and Education (EMLE 2019)* (Paris, France: Atlantis Press, 2019), <https://doi.org/10.2991/aebmr.k.191225.205>.

formulated by Davis¹⁵ to understand a person's intention in accepting and utilising technology.¹⁶ The original TAM theory explains that perceived usefulness and perceived ease-of-use are determinants of attitude toward participants' usage and behavioural intention.¹⁷ This means that the user's intention to accept and use technology will be influenced by the person's attitude and views on the usefulness of technology and the perception of convenience. This study investigated students' use of online education by using the original TAM model.

METHODOLOGY

The researcher conducted a detailed investigation on undergraduate students' experiences in mathematics during full online education in 2021. As a case study, the researcher intended to investigate the subjects in their natural settings. This was made possible by analysing students' narratives on their experiences in online education for the course they were registered. Data on students' online education experiences were collected through open-ended questionnaires and semi-structured interviews. The participants initially completed individual questionnaires. After that, the researcher conducted one-on-one interviews to delve deeper into students' experiences by asking probing questions where applicable. The questionnaires and interviews were online and telephonic, respectively, in harmony with remote learning during that time. Data were collected towards the end of 2021 since both courses were year-long each. This gave a balanced platform to students' experiences in teaching, learning and assessment. The use of two instruments was meant to add credibility to the data.

Two mathematics classes instructed by the researcher took part in the study. The sizes of the classes were 37 level 2 and 180 level 3, respectively. Out of both groups, a sample of 23 participants was selected through volunteering and convenience for answering the questionnaire and interviews, respectively. The distribution of the participants is shown in Table 1. The participants were all given pseudonyms in this study, which were T1, T2 and up to T23. The ordering of the participants carried no significance. Participants T1-T10 took part in the interview, while T11-T23 responded to the questionnaire.

Table 1: Distribution of the participants for the study

Level/Gender	Female	Male	Total
Level 2	2	4	6
Level 3	6	11	17
Total	8	15	23

All the participants were engaged in eLearning and e-assessment for the first time; hence, the interpretation of their experiences would assist with the sustainability of the online education engagements in 2021 and in the coming years.

The researcher conducted synchronous lectures on Microsoft Teams to two mathematics classes twice per week. He presented the lecture notes as Microsoft Word slides. That way, mathematics symbols and formulae were presented quite well using the Equation editor. The Blackboard LMS was used for timed and synchronous formal and informal formative and summative assessments. The assessments were objective and auto-scored initially. Later, subjective questions were posed, which were handwritten, scanned, uploaded to the LMS and graded by a human assisted by digital tools. A narrative analysis of the participants' written responses and verbal transcriptions was conducted in order to characterise the five categories identified in the conceptual framework.

¹⁵ Fred D. Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," *MIS Quarterly* 13, no. 3 (September 1989): 319, <https://doi.org/10.2307/249008>.

¹⁶ Ngabiyanto et al., "Teacher's Intention to Use Online Learning; an Extended Technology Acceptance Model (TAM) Investigation," *Journal of Physics: Conference Series* 1783, no. 1 (February 1, 2021): 012123, <https://doi.org/10.1088/1742-6596/1783/1/012123>.

¹⁷ Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology."

RESULTS

In line with the conceptual framework, the results were organised in the following sub-categories, namely, pre-COVID-19 era, Microsoft Teams-based eLearning, Blackboard-based formative assessment, Blackboard-based summative assessment and the post-COVID-19 era.

Pre-COVID-19 period

Like most residential institutions in South Africa, the institution (TI) where this study took place operated on blended learning in the pre-COVID-19 period. However, as TI was classified as a historically disadvantaged institution, the use of digital resources was limited thereat. If not for COVID-19, contact classes were to continue as usual. This was confirmed by T5, *“As it is, it’s all because of COVID-19. Remember, in 2019, we were all attending contact classes, not this online thing. After the COVID-19 pandemic, everything changed to online.”* Thus, students encountered full online education in 2020 when the lockdowns were introduced. To this effect, T15 concurred and said, *“If that was not the case [COVID-19] we would be having contact classes.”* T21 also emphatically said, *“Online learning was never used before at our institution”*. This was the case despite the existence of the LMS and other digital tools at the institution. T16 and T17 hinted that resources like the Blackboard LMS were available at TI but were not fully used for teaching, learning and assessment. *“TI is a varsity and for that matter, online learning is the thing which was in motion but not in an advanced way. For example, we were using Blackboard to get notes, assignments and tests sometimes but we were not writing them over there”*, said T17. Thus, instructors used Blackboard as a repository for notes and take-home tasks. This represents some basic attempts at online education in the pre-COVID-19 era. Maybe online education would slowly creep into undergraduate studies more actively had it not been COVID-19 which abruptly brought contact classes to a standstill.

Microsoft Teams-based e-Learning

With the cessation of contact classes in 2020, all students engaged in eLearning for the first time. T23 found lectures on Teams quite convenient. *“We can also record the lecture while lecturing whenever we do not understand something. We can refer to the recording,”* said T23. In fact, Teams lectures can always be accessed any time later via the recordings and students like T123 were aware of this.

Participant T11 indicated some challenges specific to mathematics during Teams lectures: *“Mathematics needs more time to discuss with the lecture and write problems on board or calculate; it’s hard to do that online.”* Indeed, discussion and student participation were unobtrusive. In addition, writing equations and formulae on Teams was not easy, as posited by T11; the researcher resorted to using the Equation Editor in MS Word to show all steps in the solution processes. However, he could not draw graphs and diagrams. Teams can draw using an active pen, but gadgets like active pens were not available to instructors due to a lack of resources. This was supported by T8, who said, *“Euclidean geometry is better when taught in contact classes because it has lots of drawings and constructions to be done. If it is taught online, it needs someone who is familiar with graphical packages. I believe it’s not easy to make drawings.”* With the active pen and whiteboard, it is possible to make drawings on Teams without special knowledge of graphical packages.

In addition, T14 said, *“Some of the modules like Mathematics are not for online learning because they deal with proofs and calculations. They should be taught manually.”* However, the researcher was able to present steps in calculations to the class with basic tools in the Equation Editor, as illustrated in Figure 2. The slides were shared on MS Teams.

Workout the following problems:

- Find the following limits:
 - algebraically, and then again by
 - using L'Hospital's Rule

a) By factorization, $\lim_{x \rightarrow 4^+} \frac{(\sqrt{x})^2 - 4}{\sqrt{x} - 2} = \lim_{x \rightarrow 4^+} \frac{(\sqrt{x}-2)(\sqrt{x}+2)}{\sqrt{x}-2} = \lim_{x \rightarrow 4^+} (\sqrt{x} + 2) = 4$

b) By LHR: $\lim_{x \rightarrow 4^+} \frac{x-4}{\sqrt{x}-2} = \lim_{x \rightarrow 4^+} \frac{1}{\frac{1}{2}x^{-\frac{1}{2}}} = \frac{1}{\frac{1}{2} \times \frac{1}{2}} = 4$

2. $\lim_{x \rightarrow +\infty} \frac{x^2-9}{x^2-4x+3} = \frac{2x}{2x-4} = \frac{2}{2} = \lim 1 = 1$ (homework)

Figure 2: Use of MS Word as a platform to teach mathematics and shared on Teams

T20 had inclinations toward face-to-face learning when he suggested getting a few knowledgeable students to help others in groups. Cooperative learning works best in face-to-face settings. E-Learning is poised to promote autonomous learning in remote learning. Nevertheless, T17 did not perceive much autonomous learning in synchronous lectures. She said, “*The fact that we still have lectures means it is not quite independent there.*” Some students still desired cooperative learning. Even though online learning was predominantly remote, students like T3 congregated at the campus and worked as a group. “*I am already in it right now because there are some of my classmates with whom we study as a group,*” said T3. This represented the trade-off between independent learning and cooperative learning.

It was not all participants who preferred learning on Teams. The pandemic, to some extent, dictated the genesis of eLearning. According to T22, “*It is not easy to adjust to the current situation; some of us need a physical lesson; being taught face-to-face makes us master the content.*” In this regard, T7 also said, “*Some students believe in seeing a lecturer in front of them for them to understand a lecture.*” Thus, students perceive online lectures on Teams as a stop-gap measure in response to the pandemic rather than a permanent solution. T10 also said,

I prefer manual. Online is just a temporal thing. It's not going to help us in the future because we are doing it for the sake of COVID-19. It's easy to remember something that has been explained face-to-face even after a year. As for these online classes, we are doing it just to pass.

T3 indicated that e-assessment is for passing examinations as if it is easy to pass. If students find it easy to pass formal tasks, they may not take eLearning seriously. This may lead to a drop in attendance. Students think they can “*copy and paste*” as indicated by T5, “*I sometimes do not attend but I pass with at least 60%. Online learning is not effective.*” Non-attendance of online classes takes another turn when students start using the supposedly free time for non-academic businesses instead of attending classes. For example, T5 frankly said,

In 2019, I attended full-time classes. But with online, I don't feel that way, so I have plenty of time to do other businesses. Right now, you are speaking to a businessman. I am dealing in business and also studying. I am tired of staying at home.”

Since T5 sounded as if he was against digital transformations, the researcher had to probe this idea, as shown in the dialogue below:

Researcher (R): But are you aware that computers are taking a leading role in people's daily lives?

T5: When it comes to teaching, everything has to be ... not electronic.

R: You mean it has to be face-to-face?

T5: Yes. Remember, we are dealing with students who don't understand so easily.

The connotation is that digital technologies will not take the place of a human teacher in the classroom. Teachers shall continue to stand in front of classrooms at all levels of education. Teachers' jobs are safe as of now from digitisation. In higher education, an instructor is needed to direct the Teams and Blackboard activities. Online assessment conducted on Blackboard is the subject of the next sub-heading.

Blackboard-based formative assessment

All assessments at TI took place on Blackboard as the official platform. E-assessment was introduced in the mathematics courses as a sequel to eLearning. T11 commented that they must also write tests online since they were taught online. This was confirmed by T13, who said, *"These should be partners. We cannot learn online and write manual assessments."* Having successfully conducted remote classes on Teams, students felt that it should be complemented by an e-assessment on Blackboard. *"I believe online teaching/learning using MS Teams should go hand-in-hand with online assessment."*

The greatest concern with e-assessment is quality, which would be at stake if rampant cheating and other unfair practices exist. Students were frank about this issue. T6 regarded cheating in e-assessment as natural; *"We like cheating. We can't run away from that. Cheating is natural. We cheat and pass but we do know what is going on."* Some students perceived indulging in unfair assessment practices as an advantage. For the examination, T11 said, *"You have advantages of searching the question you don't know."* Consequently, T11 concluded that e-assessments are easy to pass. In contrast to students who said e-assessment is easy to pass, the scores from the formative e-assessment were not bloated but followed the bell-shaped normal distribution curve.

To some students, e-assessment was conducted out of necessity, just like eLearning. T13 said, *"We couldn't have contact classes; online assessment and teaching is the only option"*. Moreover, T22 said, *"Online assessment is the last and only option for pursuing studies during this pandemic."* These perceptions indicate that online education is directly connected to the COVID-19 pandemic.

To induct students into the intricacies of e-assessment they were undertaking for the first time, the researcher also created informal pre-tests before each formal task. This was meant to familiarise students with the technical aspects of e-assessment, which is, accessing the tests and submitting the answers. T22 commented that he was grateful *"to be given the pre-test to adapt to being assessed online and the style of setting"* so that *"students will get familiar with the system before they write the real test"* (T16). Assessing students beforehand and giving them feedback motivates them to study and learn more, as they strive to perform better in the subsequent formal assessment. With the necessary technical know-how, lecturers can successfully create informal assessment tools on the LMS, which students can take individually in a non-intimidating environment as they learn mathematics.

When e-assessment was introduced, the initial mode of assessment was quizzes. These consisted of objective questions, making MCQs and other short questions with pre-determined responses popular in e-assessment.¹⁸ However, students were dissatisfied with these kinds of questions for mathematics, where all steps carry credits. According to the students, the advantages of objective tests were outweighed by the disadvantages for mathematics. Instead of auto-grading with instant feedback, they opted for human scoring with a slightly protracted feedback delay. At that point, the assessment was switched to timed Blackboard assignments. The change was based on practice after students had experienced both modes. Students' greatest concerns were the inability to show steps in the solution (mentioned by T14, T16, T21 and T22) and the uncertainty in representing expected answers in fill-in questions. T10 elaborated on the challenges of getting the expected responses to objective tests:

Maybe the lecturer only put one answer or one option on the system. There was a question that I wrote $x = 3$ and when I checked the answer, it was 3. So I got it wrong because I put $x = 3$ while I was

¹⁸ Einig, "Supporting Students' Learning: The Use of Formative Online Assessments," 425-444.

supposed to put 3. But what I wrote was worthy of all the full marks. Therefore, I suggest that you put two options because some students will not put the exact answer you want.

Even though both quizzes and assignments had the same duration, tests were very sensitive to internet connection instabilities. The rather mandatory forced completion feature meant the computer submits a student's partially completed work should there be a break in the network. Some students were negatively affected by network issues; for instance, T14 said, *"I have failed both of the tests not because I didn't know what the question wanted, but because of network connections and Wi-Fi problems."* On the other hand, assignments only require an internet connection to download the question paper and submit the solutions. In between, students can write their responses offline. After sitting pre-tests and the main formal tasks, students were persuaded that they could scale year-end online examinations, as explained in the next subsection.

Blackboard-based Summative Assessment

Formative assessment prepared students for summative assessment scheduled at the end of the course. It would be awkward for students to sit for online examinations without due preparation. With regard to that, T13 said, *"I am much aware of what online assessment is all about therefore, I can proudly say I'll find writing online examinations easy."* T1 and T2 also agreed that the formative tasks they wrote during the year were enough to prepare them for the final examination. *"It will be easy because I know how to access and submit,"* said T11. The experiences also informed the format of the final examination in the formative assessment which was the Blackboard assignment. In this study, the e-assessment was treated as an open-book test. Open-book tests are designed to assess students' abilities to analyse, evaluate or synthesise knowledge rather than their ability to recall facts. Furthermore, open-book examinations require students to really understand mathematical concepts and be able to apply them. This was achieved by administering subjective questions in timed Blackboard assignments without proctoring. Nevertheless, T16 had feelings of going back to contact assessment should the COVID-19 pandemic ease off: *"If COVID-19 were to loosen up now, I wouldn't mind going to the Great hall and writing my exam though I was taught using MS Teams."* Hence, some still did not appreciate the significance of online examinations. To them, controlled venue-based was the ultimate in mathematics.

Post-COVID-19 Era

After attending classes on Teams and writing assessment tasks on Blackboard, students were drawn closer to online education and perceived valuable rewards. T17 supported this by saying, *"I've learnt and written assessments online and switching back to manual will be a problem for me since I'm used to doing everything in the comfort zone of my home."* Online education opened new dimensions to teaching, learning and assessment. T23's mind opened. Some students felt that in the future, higher education institutions might proceed with online education because of the huge capital investments that have been put in place for it. The capital outlay includes data plans, digital devices for all students and academic staff, and the licences paid for Blackboard and Teams. These investments were promptly scrambled in response to the pandemic but have not been withdrawn after the easing of the pandemic. The dialogue with T4 below captures this idea clearly:

R: If we wake up and find that Covid-19 is gone, should we proceed with online education?

T4: Maybe we can continue. We can continue because we have Teams and Blackboard.

R: Explain.

T4: Because information will still be there on the Internet; but in manual, if lost my book I have lost everything.

R: What are the advantages of using digital technologies in education?

T4: On Blackboard, we get our marks sooner. It takes so long for the manual. Blackboard already contains our information.

T4 also mentioned two advantages of digital technologies in higher education: robust record-keeping and immediate feedback to assessments. Even though the human-scored Blackboard assignments were

not instant, the system permits feedback to be delivered after each script is graded. Moreover, T3 spoke of online education as convenient to students: *“Online education is very much easier than going to a venue. I prefer online because you can do it anywhere, even if you are at home.”* Some students’ reservations about online education were due to internet data and Wi-Fi challenges. Being true as it may be at a disadvantaged institution such as TI, participants like T16 attempted to overcome connectivity issues. She said, *“I make sure I am in a better environment before I start writing.”* The campus was then open to students in 2021; hence some students chose to operate from there to access an unlimited and robust network. Even with all this, T17 mentioned having extra backup data plans for synchronous engagements. Maybe this meant purchasing one’s internet data.

Furthermore, some students felt that COVID-19 fast-tracked the introduction of online education, but it was something that was eventually going to be realised. T6 confirmed this by saying, *“We were going to use eLearning but not now. Maybe sometime later. The process was not going to be as fast as it is now”*. Some students were cautious concerning the future. This was supported by the T6, who responded, *“I think let us continue with Teams and Blackboard because we will never know what will happen tomorrow.”* These students suggest proceeding with online education based on the uncertainties of the future of humanity. Natural disasters, wars and diseases may be lurking around the next bend.

Students also appreciated that online education exposed them to digital and online technologies in learning disciplines like mathematics. The majority of students attending TI come from disadvantaged backgrounds. Thus, they stand to benefit enormously from digital transformations. T6 explained it this way:

We can be familiarised with computers. Some of us are from rural backgrounds; we don’t have prior experience in using computers. Also as a new generation, we can embrace technology in the classroom. Some old teachers do not know how to use a computer.

The compatibility of the web-based applications on multiple devices meant that students could easily use the commonly available smartphones for lectures and assessments. Online resources have permeated almost every facet of human existence, and education is no exception.¹⁹ T6 supported this by saying, *“Most things nowadays use technology, so everyone must be familiar with online education.”*

DISCUSSION

Higher education has undergone a digital transformation that has seen the emergence of education facilitated by web-based technologies.²⁰ The LMS and video conferencing applications play a key role in delivering instruction and assessment in higher education institutions. LMSs have been a permanent feature of higher education institutions but were not put to full use prior to COVID-19.²¹ However, video conferencing software is recent, having gained popularity during the COVID-19 pandemic as a measure to adhere to calls for physical and social distancing. Prior to COVID-19, higher education purportedly operated on hybrid education, but the use of digital technologies was discretionary to individual instructors based on their abilities and interests. Even now and going forward, instructors’ expertise is highly called for, a lack of which hampers efforts to online education.²² For instance, MCQs design demand rich IT skills that the older generation of academics may not possess. Gordon

¹⁹ Timmis et al., “Rethinking Assessment in a Digital Age: Opportunities, Challenges and Risks.”

²⁰ Buzzetto-More and Alade, “Best Practices in E-Assessment,” 251-269.

²¹ David E. Stone and Guangzhi Zheng, “Learning Management Systems in a Changing Environment,” in *Handbook of Research on Education and Technology in a Changing Society*. (Hershey: IGI Global, 2014), 756–67, <https://doi.org/10.4018/978-1-4666-6046-5.ch056>.

²² Fernando Ferri, Patrizia Grifoni, and Tiziana Guzzo, “Online Learning and Emergency Remote Teaching: Opportunities and Challenges in Emergency Situations,” *Societies* 10, no. 4 (November 13, 2020): 86, <https://doi.org/10.3390/soc10040086>.

posited that challenges for online education centre on developing new skills and managing new technologies.²³

Assessment is the heart of the learning process, which translates to encapsulation of an institution's goals for teaching learning.²⁴ Assessment acts as a barometer for learning and for reporting assessment of learning. E-assessment can be delivered in two ways. The first is web-based delivery, where students use the Internet to access the assessment tasks in real time. This works best in objective items where the scoring is based on only one correct answer, thereby making automatic marking appropriate. Hence, the instructor must make some decisions regarding unforeseen responses that may be deemed acceptable. In this case, computer software might mark most students' responses as incorrect.²⁵ Secondly, there are subjective questions where different long answers might be acceptable. Herein, human marking is necessary but done within the confines of the LMS. Mathematics assessment falls in the latter category, whereby solutions are handwritten and credit is given for all steps in the solution.

The proliferation of digital technologies as a mode of learning and teaching necessitates their growth in assessment too.²⁶ Instruction and assessment complement each other in both contact and online forms of learning. As a sequel to eLearning, e-assessment is a good strategy to promote student-centred learning in a non-intimidating environment.²⁷ Going forward, e-assessment has the potential to become a preferred form of assessment since it has come to become an integral element of eLearning.²⁸ Because of automated handling, feedback and record-keeping, e-assessment is regarded as relatively efficient, fast and useful for large class sizes.

Technology has increasingly transformed how people communicate, do business and live their daily lives.²⁹ However, universities have slowly adapted to digital transformations, particularly in assessment modes and practices.³⁰ To some, the introduction of eLearning and e-assessment was conceived out of necessity so that the normal functions of universities could proceed. Furthermore, students are not always assumed to have equitable distribution of resources like laptops and internet data. Lack of access to devices acts as a dissuasive element to online education for financially disadvantaged students, which in turn engenders some kind of resistance to a shift to full online education.³¹ As leverage, there is the widespread use of smartphones by students to attend classes and write tests. In fact, online education should be compatible with multiple devices like tablets, smartphones, laptops and desktops. The small screen size may distort item appearance in objective tests, but in subjective, it does not matter.

Miniature tests called online pre-tests were administered to align students to the expectations of test questions and e-assessment. Through the pre-tests, students gained confidence in the concepts

²³ Neil Gordon, "A Permanent Pivot to Online Learning, or Will Universities Bounce Back to Normal?," *Academia Letters*, July 27, 2021, <https://doi.org/10.20935/AL2394>.

²⁴ Timmis et al., "Rethinking Assessment in a Digital Age: Opportunities, Challenges and Risks," 454-476.

²⁵ Martin Appiah and Fanus van Tonder, "E-Assessment in Higher Education: A Review," *International Journal of Business Management and Economic Research* 9, no. 6 (2018): 1454-60, www.ijbmer.com.

²⁶ Bopelo Boitshwarelo, Alison Kay Reedy, and Trevor Billany, "Envisioning the Use of Online Tests in Assessing Twenty-First Century Learning: A Literature Review," *Research and Practice in Technology Enhanced Learning* 12, no. 1 (December 7, 2017): 16, <https://doi.org/10.1186/s41039-017-0055-7>.

²⁷ Teresa Romeu Fontanillas, Marc Romero Carbonell, and Montse Guitert Catasús, "E-Assessment Process: Giving a Voice to Online Learners," *International Journal of Educational Technology in Higher Education* 13, no. 1 (December 26, 2016): 20, <https://doi.org/10.1186/s41239-016-0019-9>.

²⁸ Appiah and van Tonder, "E-Assessment in Higher Education: A Review," 1454-1460.

²⁹ Timmis et al. "Rethinking assessment in a digital age," 454-476.

³⁰ J C M Shute et al., "21st Century Assessment to Promote 21st Century Learning: The Benefits of Blinking.," in *A Report for Digital Media and Learning Network.*, 2008.

³¹ Elzainy, El Sadik, and Al Abdulmonem, "Experience of E-Learning and Online Assessment during the COVID-19 Pandemic at the College of Medicine, Qassim University."

and test-taking. Some authors used sample examinations and carefully designed in-class activities.³² The activities were used to mimic the examination and familiarise online resources under controlled conditions. Some form of formative e-assessment needs to be done in the early stages of the course to ensure that technological obstacles do not prevent students from succeeding.³³

Treating the mathematics e-assessment as a modified form of an open-book test made student cheating and other unfair practices less prominent. This change resulted in the use of questions that were not straightforward and could not be searched on Google or in the lecture notes at the moment of assessment.³⁴ When students can use the Google search engine to source answers, no learning is involved. The questions in this study did not focus on the final answer only but were multi-step solutions and proofs.

At some point, it seemed universities rushed to introduce eLearning in order for normal teaching to proceed. The pandemic taught them to be proactive rather than hold their breath and wait for normal school routine to revert. Instead, most have taken the pandemic as an opportunity to rethink education and make it more accessible to all students. Higher education seemingly emerged from COVID-19 with more understanding that digital tools complement contact teaching and learning.³⁵ Online education is still not a substitute for the traditional classroom, but it endeavours to make learning more effective and efficient.³⁶ Flexibility in teaching and assessment can create more robust systems that can cope with possible future crises. Web-based online education has made strides in this regard in sync with the technological advancements in modern society.³⁷ As such, the gains that higher education has made must not be dumped with the waning of COVID-19.

CONCLUSION

Given that higher education is preparing students for occupations where access to internet resources and digital tools will be ubiquitous, traditional education is “becoming increasingly artificial and unrealistic.”³⁸ Continuing with full-contact education is inconsistent with modern learning theories that seek to make education relevant. Mathematics as a discipline has been accommodated well in the intricacies of online education. Unlike before, students can now learn mathematics using video conferencing packages, where Word processors can be used to display mathematics text in the shared slides. Subjective online tests proved expedient for mathematics assessment for both formative and summative assessments. COVID-19 helped to bring into the spotlight online education, which was there all the time but in small measure. COVID-19 hastened humanity’s ability to deliver online education and readiness for possible future disruptions.

³² Patricia Muñoz-Escalona et al., “Promoting Undergraduate Student Engagement through Self-Generated Exam Activity,” *International Journal of Mechanical Engineering Education* 46, no. 3 (July 10, 2018): 252–73, <https://doi.org/10.1177/0306419017743215>.

³³ Baleni, “Online Formative Assessment in Higher Education: Its Pros and Cons.”

³⁴ Sven Trenholm, “An Investigation of Assessment in Fully Asynchronous Online Math Courses,” *International Journal for Educational Integrity* 3, no. 2 (December 14, 2007): 41–55, <https://doi.org/10.21913/IJEI.v3i2.165>.

³⁵ Chrysi Rapanta et al., “Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity,” *Postdigital Science and Education* 2, no. 3 (October 7, 2020): 923–45, <https://doi.org/10.1007/s42438-020-00155-y>.

³⁶ Arnab Kundu and Tripti Bej, “Experiencing E-Assessment during COVID-19: An Analysis of Indian Students’ Perception,” *Higher Education Evaluation and Development* 15, no. 2 (September 16, 2021): 114–34, <https://doi.org/10.1108/HEED-03-2021-0032>.

³⁷ Hargis, “What Is Effective Online Teaching and Learning in Higher Education?” 1-6

³⁸ Laurent Mocozet et al., “A Versatile and Flexible Framework for E-Assessment in Higher-Education,” in *2018 17th International Conference on Information Technology Based Higher Education and Training (ITHET)* (IEEE, 2018), 1–6, <https://doi.org/10.1109/ITHET.2018.8424764>.

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