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ARTICLES

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Immediate and long-term impact of the COVID-19 pandemic on South African higher education

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Abstract: The COVID-19 pandemic has impacted the higher education sector significantly. It forced the stakeholders to do new things and brought many innovations to educational activities. As the pandemic hit the shores of many countries, among other things and sectors, education activities were disrupted. Many, not well-advanced universities in terms of technology and learning management systems (LMS) embarked on a forced recess, using the period to put online education platforms in place. The advanced universities immediately migrated contact teaching and learning to online platforms. This paper aimed to investigate the immediate effects that the pandemic has on South Africa's higher education systems in terms of how both lecturers and students were made to use new technologies/tools, how the tools enhanced teaching and learning, how assessments transformed due to the pandemic, and if some of the interventions employed during the pandemic will find usefulness when the pandemic has finally retreated. In this study, universities that are offering engineering degrees in South Africa are used as a case study, and data were obtained from both engineering students and engineering lecturers at these universities through qualitative (survey with open-ended questions) together with quantitative

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(surveys with closed-ended questions) research methods. The study shows that higher education activities cannot go back to the way they were before the pandemic. The study brings to light that some old techniques will be combined with some innovations employed during the pandemic to ensure effectiveness and greater throughputs in the higher education systems going forward.

Keywords: Higher education; COVID-19; teaching and learning; assessment; learning management system; university education.

I. Introduction

In early 2020, unexpectedly, the COVID-19 pandemic distorted the normal way of living for the generality of humanity. Most countries all over the world imposed hard lockdowns which, in turn, imposed unmatched challenges on social-economic activities. This sudden public health crisis occasioned by COVID-19 magnified the important role of digital infrastructure and wireless networks in ensuring that society continues to run and that members of families are connected. The effect of the pandemic did not spare the education sector from primary level to tertiary institution. Most of the sectors and parastatals were caught unprepared. As a result, in the educational sector, most of the educational activities were initially suspended, and residential students were asked to vacate the school premises. This time allowed for re-strategizing by the stakeholders in the educational sectors.

Different interventions were deployed in different sectors to mitigate the effect of the pandemic on the economy and humans. In the education sector, many countries employed diverse measures in their education systems. In China, where the pandemic was first reported, over 180 million children in primary and secondary schools were made to stay at home. Though the schools were temporarily closed for quarantine, schooling continued, however in a different format: the mode of educating the student was moved online with the aid of technology. The mitigation methods in all sectors, and the education sector soon spread to most of the countries in Europe, Central Asia, South America, North America, the Middle East, Oceania, and Africa. At the center of these mitigating interventions is technology. There was spread use and availability of technology through which online teachings were delivered. The smooth running of this deployment was based on the availability of relevant electronic devices and the availability of an internet connection at home. However, from North America to South America, Asia to Africa, different countries have diverse economic strengths and levels of development. Consequently, the equity issue cuts across different countries and strata of society. The students from the well-to-do families can be able to

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afford computers and other electronic devices. However, students from poor families will hardly be able to afford any basic electronic device, and internet access could be out of their reach.

This paper seeks to contribute to the understanding of both the immediate and long-term effects of the COVID-19 pandemic on educational systems, especially at higher institutions. This understanding will assist the stakeholders in the higher education sector and relevant policymakers in planning for the future or evolving higher education system that is beneficial to all.

II. Related works

A recent work presented a short review of some papers that focused on the effect of the COVID-19 pandemic on education. The conclusion from the presented overview was that, though various studies have been carried out in this area, suitable pedagogy and platform must be further explored, especially in developing countries.[1] Most of the works that were reviewed focused on the effect of the pandemic on the pre-university schools' education systems. Another work published in 2020 focused on "the impact of COVID-19 on education in India and the measures taken by the government to provide seamless education in the country". The data employed were obtained from secondary sources. The author concluded that though the pandemic imposed some challenges, various opportunities also evolved.[2] These include the exploration of Open and Distance learning (ODL) with the aid of diverse digital technologies that were not in use before the health crisis descended in India. Still, on the effect of the pandemic on Indian education, another work delved into the impact on education activities in the country. Specifically, the various challenges that attended to teaching and learning in the new normal, such as "learning style and cultural challenges", "pedagogical e-learning challenges", "technological challenges", "technical training challenges", and "time management challenges" were reviewed.[3] The effects of various

[1] Sumitra Pokhrel and Roshan Chhetri, "A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning," *Higher Education for the Future* 8, no.1 (2021): 133-141, https://doi.org/10.1177/2347631120983481.

[2] Pravat K. Jena, "Impact of Pandemic COVID-19 on Education in India," *International Journal of Current Research (IJCR)* 2, no.7 (2020): 12582-12586, http://journalcra.com/article/impact-pandemic- COVID-19 -education-india, available at SSRN: https://ssrn.com/abstract=3691506.

[3] Priyanka P. Koul and Omkar J. Bapat, "Impact of COVID-19 On Education Sector In India," *Journal of Critical Review* 7, no.11 (2020): 3919-3930, doi:10.31838/jcr.07.19.535 535.

COVID-19 restrictions on the students' performance were the focus of another research article published in 2020.[4]

The authors used a field experiment with some students from three different subjects, with a university in Spain as a case study. The authors concluded that due to COVID-19 confinement, students' learning strategies changed to a more continuous habit which in turn improved their efficiency. Implications of the COVID-19 pandemic for international higher education are highlighted in another work. The work also presented some potential opportunities (such as "the development of enabling policies and regulations to promote internationalization, offering of incentives to attract students from a wide range of countries, and ensuring that more of the home students have opportunities for studying and working abroad") for the stakeholders to redesign their methods for the new normal.[5] Another recently published work aimed at presenting a systematic literature review on "the transition, due to the COVID-19 pandemic, from traditional education that involves face-to-face interaction in physical classrooms to online distance education". The study examined how this transition has impacted academia and students and then looked at the potential long-term consequences it may have caused. The authors found out that there is "a range of difficulties in switching from offline to online learning modes" for both the learners and the educators and concluded that "it is necessary to continue investigating online education and that policymakers should take the findings of researches on higher education pedagogy seriously to bridge whatever gaps may be present".[6] The "impact of the COVID-19 crisis on the academic performance of veterinary medical students and researchers during the lockdown" was considered in another work. Since the subjects of these students are practical, it was discovered that it was not easy for them to learn such on an online platform. Hence, students who participated in the survey thought that "it is difficult to fulfill the veterinary competencies only with the online education system". The authors, therefore, concluded that "online education should be improved by making it more interactive, showing medical

[4] Teresa Gonzalez et al., "Influence of COVID-19 confinement on students' performance in higher education," *PLoS ONE* 15, no. 10 (2020): 1-23, doi:10.1371/journal.pone.0239490.

[5] Kanwar Asha, and Carr Alexis, "The Impact of COVID-19 on International Higher Education: New Models for the New Normal," *Journal of Learning for Development* 7, no. 3 (2020): 326-333, https://jl4d.org/index.php/ejl4d/article/view/467.

[6] Manar A. Talib., Anissa M. Bettayeb, and Razan I. Omer, "Analytical study on the impact of technology in higher education during the age of COVID-19: Systematic literature review," *Education and Information Technologies* 26, (2021): 6719-6746, https://doi.org/10.1007/s10639-021-10507-1.

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procedures in real situations, giving concise information, and providing 3D virtual tools to mimic the real situation".[7] Another paper in the literature focused on reviewing the "impact of the COVID-19 pandemic on the education system in developing countries". The authors established that online education is challenging in poor countries because most of the parents are uneducated.[8] Another drawback is the lack of electronic devices and ICT infrastructures in these countries. The authors then concluded that "the poor and digitally illiterate families, with lower educational levels children, with poor learning motivation in the developing countries, are likely to be left behind" and disadvantaged when adopting online education. Evaluation of the effect of school closures, because of the pandemic, "on primary school performance using exceptionally rich data from the Netherlands" was discussed in another work.[9] The authors found that "students made little or no progress while learning from home and these suggested losses, even larger in countries with weaker infrastructure or longer school closures". How the pandemic shook the education activities in South Africa is briefly described by other authors. The work beamed light into how "contact universities faced push-back from students who have argued that universities cannot expect them to continue with online learning without providing the necessary resources".[10] This was because a higher percentage of students rely on government financial assistance for their costs of living. The "negative impact of the COVID-19 pandemic on education financing" was reported by another author in 2020. The report suggests that "in low- and middle-income countries, the pandemic is expected to reduce planned increases in education spending in 2020" and beyond due to the overall negative impact the pandemic exacted on the various countries' economies.[11] The effect of the COVID-19 pandemic on

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[7] Mohamed A A Mahdy, "The Impact of COVID-19 Pandemic on the Academic Performance of Veterinary Medical Students," *Frontiers in Veterinary Science* 7, (2020):1-8, https://doi.org/10.3389/fvets.2020.594261.

[8] Seble T. Mekonnen and Worku Muluye, "The Impact of COVID-19 Pandemic on Education System in Developing Countries: A Review," *Open Journal of Social Sciences* 8, no.10 (2020): 159-170, doi: 10.4236/jss.2020.810011.

[9] Per Engzell, Arun Frey, and Mark D. Verhagen, "Learning loss due to school closures during the COVID-19 pandemic," *Proc Natl Acad Sci U S A* 17, (2021 Apr 27): 118, https://doi.org/10.1073/pnas.2022376118.

[10] David W. Hedding et.al, "COVID-19 and the academe in South Africa: Not business as usual," *South Africa Journal of Science* 116, no. 7/8 (2020): 1-3, http://dx.doi.org/10.17159/sajs.2020/8298.

[11] Samer Al-Samarrai, Maulshree Gangwar, and Priyal Gala, "The Impact of the COVID-19 Pandemic on Education Financing," *Economic Impact of COVID-19*, *World Bank*,

the usage of digital tools in educational institutions in South Africa was the focus of another paper. The authors attempted to monitor the rate at which the 4IR-related technologies were employed in the education sector during the lockdown. The finding of the authors, based on the secondary data obtained from sources such as literature, was that "a variety of fourth industrial revolution related tools were employed from primary education to higher and tertiary education when the pandemic forced all educational sectors to shut their doors and ask the students to leave the campus environment".[12]As it was suggested in one of the above-presented works, there is a need for further investigations on the impact of the pandemic to have a better understanding of the immediate and long-term effects of the COVID-19 pandemic on the education sector. This is necessary since the pandemic seems to be evolving from one variant to the other (Alpha, Beta, Gamma, Delta, Omicron, etc.), including the variant of interest, as indicated by the World Health Organization (WHO)- Eta, Iota, Kappa, and Lambda. The introduction of lockdowns continues to be on and off in many countries. Hence, it is imperative to understand the long-term effect of the pandemic on education to guide the education policymakers in what needs to be changed or incorporated into the education systems to ensure future crises will have little or no negative effect on education systems and to also take advantage of the various mitigating methods to improve the educational activities. Consequently, this paper attempts to answer the research questions detailed as follows:

RQ1: How did the COVID-19 pandemic expose both the students and lecturers to new technologies or make them use new tools that are relevant to education activities?

RQ2: How have the various innovations introduced, and the new technologies used due to the pandemic, enhanced teaching and learning activities?

RQ3: In what ways has the pandemic affected education assessments and students' performances?

RQ4: Is it possible to return to the status quo of teaching and learning, and the types of assessments in existence before the pandemic, once COVID-19 has finally retreated?

Washington, DC. © World Bank, (2020): 1-12, https://openknowledge.worldbank.org/handle/10986/33739 License: CC BY 3.0 IGO.

[12] David Mhlanga and Tankiso Moloi, "COVID-19 and the Digital Transformation of Education: What Are We Learning on 4IR in South Africa?" *Education Sciences Journal* 10, no.7 (2020): 180, https://doi.org/10.3390/educsci10070180.

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III. Methodology

This study was approved by the Engineering Council of South Africa (ECSA)'s Research Ethics Committee (RES_FOR_001) dated 16th July 2020. To answer the above-listed questions, primary data were obtained from students and lecturers who are based in the Engineering Faculties in some universities that are offering engineering degrees in South Africa. This is with the aim that the corresponding findings could be applied in other faculties and be generalized for higher education systems at large. The findings presented in some of the works presented earlier that were based on secondary data motivated the efforts in this paper to employ both qualitative method (open-ended survey questions) and quantitative method (closed-ended survey questions) to gather the views of the targeted stakeholders on the effect of COVID-19 on engineering education and higher education in general. The engineering academics and students focused on were from the universities that are offering BSc Engineering degrees in South Africa. These universities include the University of the Witwatersrand (WITS), the University of Cape Town (UCT), the University of Pretoria (UP), Stellenbosch University (SU), the University of KwaZulu-Natal (UKZN), North West University (NWU), Nelson Mandela University (NMU), and the University of Johannesburg (UJ).

According to U.S. News & World Report,[13] these Universities based on their reputation and research in the field of Engineering in 2022 have the following rankings nationally and globally. The University of Pretoria ranked as number one and number 353 in best Universities for Engineering both nationally and globally respectively, while the University of Johannesburg ranked number two and number 415 in best Universities for Engineering both nationally and globally respectively. The University of KwaZulu-Natal is placed number four and number 597 both nationally and globally respectively, whereas Stellenbosch University ranked number five and number 643 both nationally and globally respectively. For the North West University, the University ranked number six and number 652 both nationally and globally respectively, while the University of the Witwatersrand was ranked number seven and number 763 at both national and global levels respectively. In the same Engineering discipline, the University of Cape Town was ranked number eight and number 798 at both national and global levels respectively, while the last University, Nelson Mandela University was not placed on the ranking

[13] Robert Morse and Sam Wellington, "Top Engineering Universities in South Africa," *US News Best Global Universities*, https://www.usnews.com/education/best-global-universities/south-africa/engineering.

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scale at the time but can be presumed to come behind all the other Universities with rankings.

III.1. Quantitative method: closed-ended questionnaires

The closed-ended survey questions were designed to obtain the stakeholders' perceptions on the impacts or foreseen impacts of the COVID-19 pandemic on the commitment of the students in terms of revisiting online course material, asking questions, getting personal support, and how the deployed technologies were of help or otherwise to the second-language English-speaking students and those with disabilities. Perceptions of the learners were also sought regarding their preferences for the continuation of the new normal mode of teaching and learning as brought about in the education system by the pandemic. The lines of questions posted to the educators range from their teaching and delivery experiences (based on the various interventions suddenly introduced because of the pandemic), and how the various changes had influenced them in using new technologies, to how those changes affected assessment processes.

III.2. Qualitative method: Open-ended questionnaires

To have unrestricted views of the stakeholders, open-ended questionnaire surveys that focused on the impacts or the foreseeable impacts of the COVID-19 pandemic on engineering education, and higher education at large in South Africa were designed. The engineering students' perspectives were sought through the open-ended questions that focused on new tools/technologies applicable to teaching and learning that they have used due to the pandemic and those that will be applicable in the future, how the use of those technologies has impacted teaching and learning, and assessments.

Both types of questionnaires were made available between November 2020 and January 2021. About 280 undergraduate students completed the survey from UP, UKZN, NWU, WITS, and UJ. Out of the 281 student participants, 26 students did not specify their universities. In terms of engineering lecturer participants, only 44 lecturers participated in the survey from WITS, UCT, UKZN, NWU, NMU, and UJ

IV. Results of the survey

All the responses from the targeted groups on the impact of the COVID-19 pandemic on engineering education are presented in this section.

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IV.1. Closed-ended questionnaires' results

For the analysis of the close-ended responses, because of the use of the five-point Likert scale (developed by Likert),[14] the Relative Important Index (RII), a non-parametric technique, widely used for such data[15] is employed. The RII ranks the criteria according to their relative importance. The reasoning behind the Likert item is that attitude (opinion) will change on a bi-polar continuum (the scaled stem), from "negative" (i.e. "strongly disagree"), to "positive" (i.e. "strongly agree"). The RII is expressed as

$$RII = \sum_{a=1}^{A} \frac{P_a U_a}{AN}, \tag{1}$$

where

P_a = Weighting that given to each factor by the respondent, a: 1, 2, … A

U_a = Number of respondents that select P_a

N = Total number of respondents.

For the open-ended questionnaire in this paper, = 5, $P_5 = 5$; $P_4 = 4$, $P_3 = 3$, $P_2 = 2$, $P_1 = 1$. Also, U_a are defined as follows.

U_5 = Number of respondents that opted for the option "strongly agree".

U_4 = Number of respondents that opted for the option "agree".

U_3 = Number of respondents that opted for the option "neither agree nor disagree".

U_2 = Number of respondents that opted for the option "disagree".

U_1 = Number of respondents that opted for the option "strongly disagree".

Thus, (2) can be expressed as

$$RII = \frac{P_5U_5 + P_4U_4 + P_3U_3 + P_2U_2 + P_1U_1}{AN}. \tag{2}$$

Consequently, as an example, the RII for the first row in Table 1 is obtained as:

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[14] Rensis, Likert, "A technique for the measurement of attitudes," Archives of Psychology 22, no. 140 (1932): 55.

[15] Vishal, Sakhare, and Chougule Mahesh, "Construction Equipment Monitoring: By using Relative Important Indices (RII) Analysis," International Journal of Trend in Scientific Research and Development (IJTSRD) 6, no. 4 (2020): 501-503.

$$RII = \frac{P_5U_5 + P_4U_4 + P_3U_3 + P_2U_2 + P_1U_1}{AN} = \frac{5 \times 55 + 4 \times 90 + 3 \times 75 + 2 \times 44 + 1 \times 90}{5 \times 281} = 0.7388. \quad (3)$$

The RII varies from 0 to 1, and has the following levels.[16]

High (H): $0.8 < RII < 1.0$
High-Medium (H-M): $0.6 < RII < 0.8$
Medium (M): $0.4 < RII < 0.6$
Medium-Low (M-L): $0.0 < RII < 0.2$

IV.1.1. Students' perceptions of the closed-ended questionnaires

The first line of the question posed to the students aimed at understanding if they have used some new technologies (automated tools) during the pandemic and if such have enhanced their learning experiences. The results of their responses are shown in Table 1 with a corresponding RII value of 0.7388, which falls within the High-Medium level. Hence, it can be inferred that a relatively higher number of 281 engineering students who participated in the survey across all the universities covered responded that they employed such tools and believed these enhanced their online learning experiences as imposed by the pandemic. The next line of questions attempted to understand how the move to online teaching and learning due to the pandemic influenced individual learning culture and enhanced support systems for the students. The responses obtained result in an RII value of 0.7388, which equally falls within the High-Medium level. This value suggests that a high number of the participating students, out of 281 students who responded, believed that the migration to the online mode of teaching and learning, occasioned by the COVID-19 pandemic, positively steered the students to revisit online course materials, made them ask further questions, and received personal support both within and off teaching hours. These experiences are perceived to be better than what they were used to before the pandemic. Since the English language is not the first language of most of the students in South Africa, and some students have physical disabilities, the next line of the question was posed to see how migration to the online offering of courses due to the pandemic has affected these students. As shown in Table 1, the responses suggest that a slightly high number of the participating students believed that using some of the new technologies, made

[16] K.N. Le, and V.W.Y.Tam, "A survey on effective assessment methods to enhance student learning," Australasian Journal of Engineering Education 13, no. 2 (2007): 13–20.

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available as a means of ameliorating the problems brought by the pandemic to university education, was of great benefit to the students whose first language is not English, including those with some disabilities. The relatively low RII value of 0.6683 in comparison with the first two questions, though still falls within the High-Medium level, could be attributed to the fact that a small number of the students have some disabilities and many students with English as a second language could still manage with the English language.

The experiences of the students in terms of the mode of assessment (open-book assessment) hurriedly introduced to ensure that assessments still took place remotely were sought. The students were asked if they would prefer the new mode of assessments, different from what they were used to before the pandemic, to be adopted after the pandemic has retreated. The responses obtained are shown in Table 1 with an RII value of 0.7388 which falls within the High-Medium level. This suggests that a whole lot of the students would prefer the adoption of open-book assessments after the pandemic. It was understood that most Universities could not wait till the pandemic finally disappears so that the students can be received in the campus environment at full capacity as it was before the pandemic. To this end, the students were asked if they would prefer the status-quo of teaching (face-to-face teaching) to be resumed after the pandemic or if they would prefer this be combined with the new mode of teaching and learning they experienced during the pandemic (the online mode of teaching and learning). The responses obtained, shown in Table 1 with a higher RII value of 0.7794 which falls within the High-Medium level, suggest that most of the students would prefer the adoption of the blended teaching and learning model after the COVID-19 pandemic had disappeared, and normalcy returned to the university environment.

Table 1

Students' Responses to the Close-ended Questionnaires (281 students)

Questions	Strongly Agree (5)	Agree (4)	Neither agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)	RII	Importance Level
"I used some automated tools for online teaching/ learning, due to COVID-19, which allowed me to achieve more than I did in the past"	55	90	75	44	90	0.7388	H-M

Questions	Strongly Agree (5)	Agree (4)	Neither agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)	RII	Importance Level
"The COVID-19 effect of driving the education system in general to online mode of teaching, using some of the new technologies, allowed students to revisit online course material, ask questions and get personal support, in and out-of-normal teaching hours"	68	127	38	28	20	0.7388	H-M
"The COVID-19's effect of driving the education system in general to online mode, using some of the new technologies, was especially helpful to students who are second-language English speakers or who have a disability"	40	81	117	23	18	0.6683	H-M
"Based on my assessment's experience during COVID-19, Open-book mode of assessments should be adopted for students going forward"	95	75	63	26	22	0.7388	H-M
"After the COVID-19 pandemic, as a student, I would prefer that my lecturers adopt blended teaching and learning model (combination of face-to-face and online models) as against face-to-face mode of teaching and learning that was being used before the pandemic disrupted academic activities"	118	89	25	26	22	0.7794	H-M

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IV.1.2. Lecturers' perceptions of closed-ended questionnaires

The lecturers were first asked if the use of evolving technologies deployed for online education as a means of intervention when the pandemic struck various shores was of any benefit. A total of 44 lecturers responded to the posed question with an RII value of 0.6727, which is slightly high and falls within the High-Medium level. The responses, as shown in Table 2, suggest that most of the lecturers believed that the various technologies made available for online education in their various universities assisted them to design good teaching and delivery experiences and reconsider methods of assessment that were best suited for their various subjects without compromising the academic standard. A not-too-high number of the lecturers, as shown in Table 2 with an RII value of 0.6500 which still falls within the High-Medium level, also believed the use of new technologies/tools, consequent upon the COVID-19 pandemic, in teaching activities allowed them to achieve more than they used to before the pandemic. Still in Table 2, with an RII value of 0.6318 that equally falls within the High-Medium level, slightly above the cut-off value for the positive perception level of H-M, a slightly high number of the lecturers believed that they could determine both the location of teaching and learning, as well as their pace of learning using the various introduced technologies and interventions to keep education activities ongoing on the online platform due to the disruption in education activities by the pandemic.

There have been many talks about overworking remotely during the pandemic due to the inability to make a balance between administrative obligations, teaching duties, and community services. However, a relatively high percentage of the lecturers as shown in Table 2 with an RII value of 0.6727, within the High-Medium level, indicated that they were able to balance time allocation between logistics and subject contents during the online lecture delivery than they could do during the face-to-face interactions they had before the pandemic. The inability to assess students' assimilations and emotions is associated with the online delivery of course content. In line with this, as shown in Table 2 with a very high value of RII = 0.8000 which falls at the beginning of the High level, most of the lecturers believed that the online mode of learning presents the challenges of accurately evaluating the students' emotions when compared with the physical mode of teaching and learning. In terms of the mode of assessment for online education, according to the experiences had as the pandemic was ravaging the nation, the majority of the lecturers, as shown in Table 2 with also a very high RII value of 0.8000, agreed that the new mode of assessment or "what it means to be successful in an academic environment" must be designed with the aid of the evolving technologies available for use in an education program.

Table 2

Lecturers' Responses to the Close-ended Questionnaires (44 lecturers)

Questions	Strongly Agree (5)	Agree (4)	Neither agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)	RII	Importance Level
"The COVID-19's effect of driving the education system to the online mode of teaching using some of the evolving technologies due to COVID-19 helped me as a lecturer to design good teaching and delivery experiences and reconsider methods of assessment"	6	17	11	7	3	0.6727	H-M
"The use of new technologies/tools consequent upon the COVID-19 pandemic in engineering education teaching activities allows lecturers to achieve more than they did in the past"	7	16	6	11	4	0.6500	H-M
"Based on the use of new technologies (tools), I can determine my own pace and location of teaching and learning"	6	13	10	12	3	0.6318	H-M
"I am more conscious of the importance of balancing time allocation between logistics and subject content during online lecture delivery than face-to-face interactions"	4	18	14	6	2	0.6727	H-M

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Questions	Strongly Agree (5)	Agree (4)	Neither agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)	RII	Importance Level
"Online teaching and learning presents limitations to accurately evaluate students' emotions compared to face-to-face interactions in class"	15	19	6	3	1	0.8000	H
"New mode of assessments or what it means to be successful in an academic environment must be formulated while deploying the use of evolving technologies for Engineering Education"	14	22	5	2	1	0.8091	H

IV.2. Open-ended questionnaires' results

The open-ended questions were designed to obtain broad views of both students and lecturers from the targeted universities on the effect of the COVID-19 together with various solutions deployed in higher education. Word clustering analysis is applied to all the responses of both the students and lecturers to categorize the most common responses from these stakeholders in tertiary education.

IV.2.1. Students' responses to the open-ended questionnaires

The first question directed to students was to establish the specific technologies/tools employed by them as the pandemic forced teaching and learning to the online platform. The responses from all the students that answered this question are illustrated in Fig. 1, where about 62 students indicated that they did not use any, and about 24 students indicated that they used Blackboard. 20, 13, and 10 students mentioned Zoom, Microsoft Teams, and Google Meet as the tools they used respectively. Microsoft Excel Spreadsheet and Discord are mentioned by nine and seven students to have been used respectively. Six students each indicated that they used programming and Python. Four students each suggested they used cloud computing, Solidworks, Tinkercad, and Microsoft Word. Between one student and three

students indicated that they used some other tools such as Autocad, Internet of Things (IoT), ITspice, MATLAB, and Moodle among others. The responses of the students to this question suggest that the available technologies in different Universities considered for the survey differ. While some of the Universities have made available to their students relatively more advanced technologies and tools, some of these Universities were not so lucky, and the students had to use relatively common or open-source resources.

The next questions posed to the students aimed at understanding the impacts of using these technologies/tools (some of which were newly used by the students) on teaching and learning in tertiary education due to the COVID-19 pandemic. The responses of the students who answered the question are shown in Fig.2. Most of the respondents use the term "lectures". Examples of such responses include the following:

- *A student can access live **lectures** recorded and access it at any time.*
- *It makes it easier to revisit **lectures** and catch up when you missed **lectures** for some reason.*
- *Online learning is more helpful in the sense that I can rewatch and learn the material until I understand and it's easier to keep up with the work than in a traditional **lecture**.*
- *The ability to re-watch **lectures**' videos where the lecturer may have been progressing too quickly for notetaking, greatly aids in the understanding of concepts on, or close to the day they were presented.*
- *Personally, the online mode of education is much better and more effective and wastes less time. Also, if you miss something a lecturer said you can watch the **lectures** again.*
- *Good impact since students had more time to recap or listen to the **lectures** again even after the lecture had ended.*

The next most used keyword is "**Concepts**", while the impact phrases include the following:

- *Allows a deeper understanding of **concepts** and gives you ample time for research. Being in control of the pace of the lectures allows me to grasp **concepts** once off and spend more time practicing the **concepts** in calculations.*
- *The ability for students to revise work helps solidify concepts.*

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The other uses of the term are in the same line of articulation. The next most used keyword is "**skills**", with statements such as follows made by the students:

- *For me the technologies employed allow a lot more time for exploring and developing own **skills** to be used in engineering applications.*
- *I would say it has been a positive experience thus far, as I have learned to teach myself, which is one of the most valuable **skill**s.*

Another most used keyword is "**solving**" with an example of statements in which it was used given as:

- *I have also been able to use far more tools and online technologies available to me now and having full access to a computer and books when learning and doing assessments makes me a lot lazier, but also better at problem-**solving**.*

From the responses of the students, it is very clear that the migration to online teaching and learning mode gives some flexibility for most of the students because of the ease of accessing online materials, and pre-recorded lectures at any time. The opportunity to repeatedly listen to the pre-recorded lectures accompanied by the lecture notes/slides also enhanced their understanding of various concepts. Some of these students also applied themselves to the usage of tools they would not ordinarily have used should the teaching and learning not move online.

The last question posed to the students focused on understanding what the effects of taking tertiary education to the online platform with the aid of the available technologies will have on the assessments in tertiary education. Fig. 3 illustrates the responses from the students. The most used keyword which also appears in the question asked is "**assessment(s)**", with the following being examples of statements from the students.

- ***Assessments** are harder to regulate as it becomes much easier to **cheat**.*
- *The criteria of **assessments** should be changed. Instead of being **traditionally** knowledge-based, they should assess the student's **ability** to complete tasks.*
- *(Even though the integrity of online **assessments** is highly questionable depending on the type of LMS a university uses, and the skill sets of individual lecturers on how to create smart and intuitive online*

***assessments**, Online **assessments** can open a wide variety of testing students, **test** scenarios can be very practical, and students may be able to provide tangible solutions.*

- ***Assessments** are made more efficient).*
- *This will greatly increase efficiency for engineering students, more knowledge about the online tools, in general, is needed and **assessments** will be more applicable in real-world situations.*
- *It makes **assessments** more focused on the technical concepts and understanding the content.*
- *Engineering education would develop into a much more automated environment with auto-graded **assessments** and a virtual classroom/ learning platform.*
- *The old paper and pen mode of **assessment** is still the best in my opinion as it minimizes the possibility of cheating and fully **tests** if the student is capable of answering the questions without any external help.*
- *I still believe that some kind of in-person **assessment** is required, probably semester tests but definitely exams.*
- ***Assessment** will have to involve a critical thinking approach rather than a **memory** exercise.*
- *The online tools and technology employed simplify the **assessment** and speed up the process of getting feedback in a faster and more intuitive way.*

The next most used keyword is "**changing**", with the following statements being examples of where it appears.

- *Preparing students for a rapidly **changing** world.*
- *Online tools and technologies are **changing** how **assessments** can be completed by showing that it is possible to move away from traditional paper-based **assessments** to online formats.*
- ***Changing** of mindsets to engineering education.*

Some other keywords are used within the statements used for the earlier presented keywords, and some other used words include "**faster**", and "**results**", etc. as illustrated in Fig.3. From the feedback of the students, it is obvious that the online technologies deployed brought about automated

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marking which increased the rate at which feedbacks were provided to students, but it widened the massive gate of exam malpractices. Some students also complained of being stressed out which could be attributed to not being used to those tools which might affect such students in an online timed-out assessment.

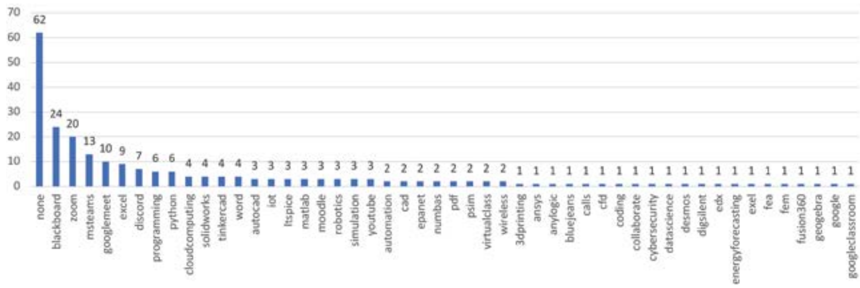

Figure 1

Students' responses to "Name some of the new technologies/ tools you have learned to use for online teaching/learning due to COVID-19"

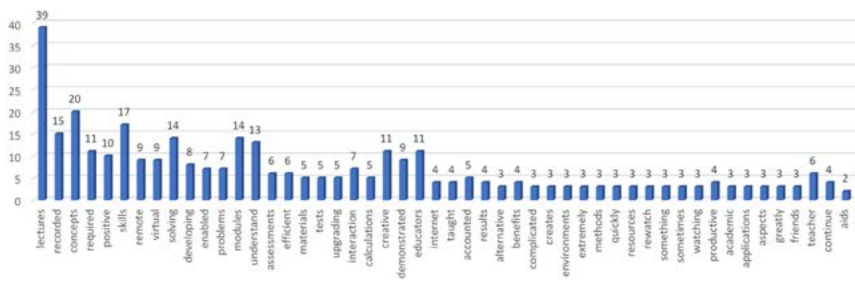

Figure 2

Students' responses to "According to you kindly state the main impacts of new technologies/ tools that have been used due to the COVID-19 pandemic on teaching and learning in tertiary education (mode of teaching deliveries)"

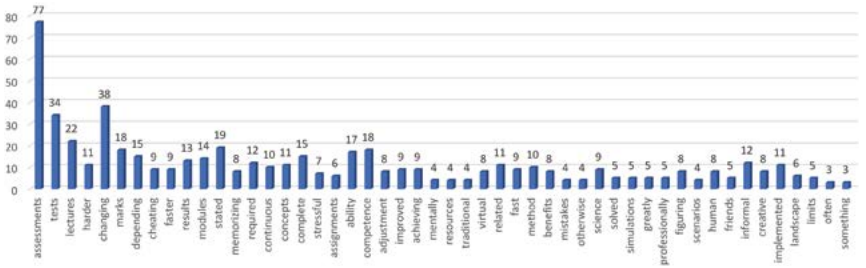

Figure 3

Students' responses to "According to you kindly state the main impacts of new technologies/ tools that have been used due to the COVID-19 pandemic on assessments in tertiary education"

IV.2.2. Lecturers' responses to the open-ended questionnaires

To confirm the responses of the students to the above three questions, the engineering lecturers were also asked similar questions. Some of the responses of the engineering lecturer to the questions asked to know the types of specific technologies/tools employed when teaching and learning were migrated to the online mode are illustrated in Fig. 4. The most used tools stated by them include the "Moodle", "Microsoft Streams" "Zoom", "Sakai", a type of Canva, "Katura" (within Moodle), "BBB-BigBlueButton", *"*OBS" Studio Bash scripting, "SPICE", "Proteus" Design Suite for Microcontroller-based Simulation, "Droid" cam, "Vula" -a type of Canva, "Discord", "Jupyter", "Scorm" among others. Though a few numbers of engineering lecturers participated in the survey, significant numbers of them tend to use the most recent Learning Management Systems (LMS), and other technologies and tools.

Most of the keywords in the responses of the engineering lecturers to the second question that seek to establish the impacts on the migration of tertiary education to the online platform with the aid of the available technologies on Teaching and Learning are included in Fig. 5. The most prominent keywords from the list include "**educator**", "**knowledge**", "**students**", "**processing**", "**learning**", "**incorporating**", "**quality**", "**structured**", and "**assessment**", where the statements in which some of these keywords were used include the following.

- *The **assessment** of a student's **knowledge** is almost impossible because of the dishonesty of the students.*

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- *Both the teacher and the students will have enhanced **skill** sets and **knowledge**.*
- ***Educators** are not Trained fast enough to train **students**.*
- *Online **educators** are overburdened with **student** mental health wellness aspects that could be solved by more qualified people.*
- ***Promotes** individual **learning**.*
- *Develop student **learning abilities**.*
- *Online education and related **technologies** are now allowing for more effective asynchronous teaching and **learning** which improves the flexibility of engineering education and **students'** access to it.*
- *Much greater flexibility, e.g., flipped classroom and blended **learning**.*
- *Due to the lack of **computer** literacy, **students** are **forced** to learn **computer skills**.*
- *Teaching and **learning** must be **structured**, concise, and well-planned to ensure a balanced approach with technology.*
- ***Students** have greater access to their lecturers.*

The last question posed to the engineering lecturers similarly seeks to understand the effects of taking tertiary education to the online platform with the aid of the available technologies on the assessments in tertiary education. The keywords from the lecturers' responses are illustrated in Fig. 6, and some of these include "**assessments**", "**students**", "**testing**", "**application**", "**cheating**", "**marking**", "**book**", "**good**", "**internet**", "**staff**", "**academic**", "**benefits**", "**evaluated**", "**problems**", "**assignments**", etc. The following are some statements in which some of the keywords were used by the engineering lecturers.

- ***Assessments** must be re-engineered to reflect the new needs.*
- ***Assessments** have to be very specific. **Marking assignments** easily becomes automated.*
- *The main **benefits** from my perspective are that learning platforms such as Moodle, enable often more personalized self-paced content delivery.*

- ***Randomized** questions, with **randomized** numbers for calculations, enable a large range of **questions** to be made available for evaluation which can partly assist in preventing copying from other **students**.*
- *Rethinking your **assessments** is key to success while still allowing learning to take place.*
- *Assess them with an open **book**, and open **internet** and make them solve real-life **problems** with time constraints. Just like they will do it when they are in the workplace. Online **marking** is automated.*
- *Attempting to do a high-stakes **assessment** (e.g., writing exams remotely) has been fraught with problems, particularly **cheating**, and **plagiarism**.*
- *This has added a burden to the teaching staff, in addition to having to perform re-**testing** due to concerns of too many **students** who have cheated, etc.*
- *Transfer to open book **assessments**, very similar to professional practice at the workplace where design is off manual.*
- *New types of **assessment** open up. Lecturers can use the technologies to give quality feedback while spending less time on **assessment**.*
- *Move towards **open-book** evaluations. Closer to real-world practice.*
- *There is no way to assess a large class online in a manner that is fair and free of **cheating**).*
- *No monitoring of **students** whether they are **cheating** or sharing knowledge during assessments.*
- *Requires a greater **application** of knowledge approach when setting **assessments**. Allows for **application** of case study and **application assessments**.*
- ***Marking assignments** easily becomes automated.*
- *The main **benefits** from my perspective are that **learning** platforms such as Moodle, enable often more personalized self-paced content delivery.*

In all the responses of the lecturers, it could be inferred that most of them believe that the new technologies/tools employed for online teaching and learning will have positive impacts on assessments-these range from easy to reshuffling questions used in online assessments, automated marking (less work for lecturers), higher rate of releasing assessments' feedbacks to

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students, and the possibility of re-engineering of assessment to meet the evolving needs of our generation. However, some of the lecturers were concerned that the online assessment would open floodgates of cheating and examination malpractices to students.

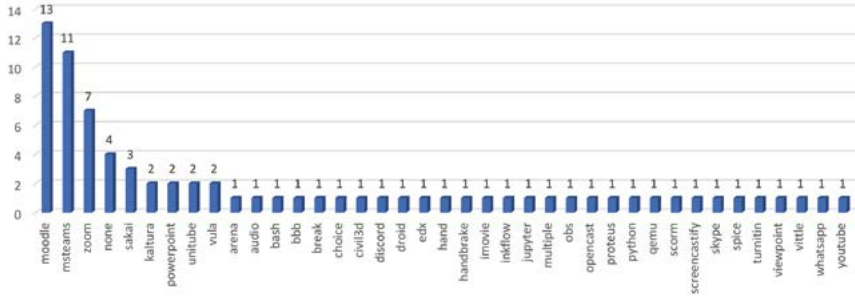

Figure 4

Lecturers' responses to "Name some of the new technologies/tools or/and platforms you have learned to teach your class due to the COVID-19 pandemic"

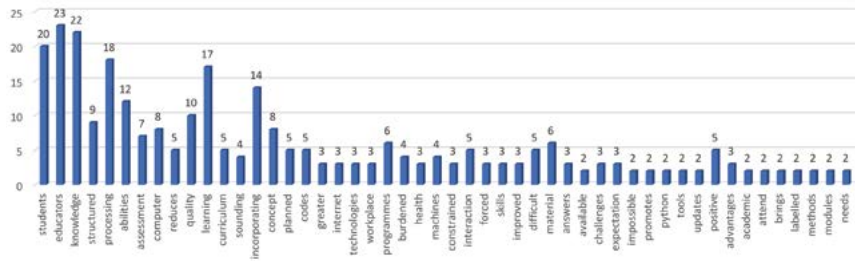

Figure 5

Lecturers' responses to "In your opinion, kindly state the main impacts of new technologies/ tools that have been used due to the COVID-19 pandemic on Teaching and Learning"

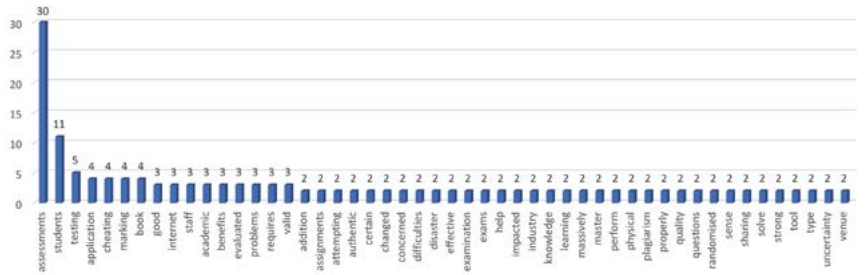

Figure 6

Lecturers' responses to "In your opinion, kindly state the main impacts of new technologies/ tools that have been used due to the COVID-19 pandemic on assessments in tertiary education"

V. General discussion of the survey results

With an in-depth look at all the survey results, it could be inferred that most of the changes and interventions deployed to rescue the academic sessions in most universities due to the COVID-19 pandemic will outlive the pandemic. As the pandemic hit different shores, many universities deployed their existing Learning Management Systems (LMS) in a way that had never been used before, and they used them as a means of intervention to ensure that teaching and learning continued remotely. Some universities had to upgrade these platforms with the incorporation of new technologies, while others had to delay the resumption of online education activities to install the LMS where they were not in existence. Though the various technologies associated with the LMS enhanced the teaching and learning experiences of students and aided content delivery by the lecturers, however, some of the tools were new to both students and lecturers where the LMS had never been actively used as a means of distance learning platforms. In some of the universities targeted in South Africa, the universities had to set some weeks aside to train both the students and lecturers on how to use some of the features that were both old and new on the LMS employed by these universities. It was after the students and the lecturers were trained that the remote lectures commenced. Another country-wide challenge that emerged with deploying the remote teaching and learning platforms as a means of intervention to the disruption in the tertiary education system by the pandemic was that a large number of students from poor families were without devices that could be used for this purpose. Most of these universities had to place an

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order for large quantities of the needed devices (laptops and tablets). These were mailed to these students after some essential software had been installed in them. The devices were made available to these groups of students as loans (with the condition that if they were returned in good form the students will not incur any financial debt, however, if it is returned with defects, the cost will be debited to the individual student's account). The government also re-purposed some funding to make these devices available to the students who were under government funding. Another challenge that propped up with most of the students was the cost of accessing internet facilities to be connected to the various LMSs of the universities. This forced all universities under the umbrella of the "Universities South Africa (USAf)" to negotiate with two major network service providers in South Africa to make some educational websites zero-rated when their networks were used to access these websites. Most of these universities also planned with some of the network service providers to make monthly "network data" available for both the students and lecturers to be used to access the non-zero-rated websites for educational purposes. As indicated in the responses by the students, the migration of educational activities to online platforms made teaching and learning flexible, allowing students to work and learn at their own pace, most of these students preferred attending to their work after working hours, some worked until midnight. Hence, special network data were provided for the period after midnight through which some of these students who could not join synchronous sessions accessed the uploaded recorded online lectures. The flexibility provided by the remote teaching approach worked well for some of the students who reside in rural areas where there are weak networks or no network coverage at all. This also benefited some lecturers who provided pre-recorded lectures audio/video, some of these were prepared during the late hours of the day and uploaded, while day times were used to attend to some other academic obligations. Some of these students had to go to nearby community facilities, such as community libraries where such networks are available.

Another obvious advantage of the migration of higher education activities to online platforms because of the pandemic was associated with some students who speak English as a second language and those with disabilities (especially partial earing challenges). Some of the educators, based on their different backgrounds, exhibit different accents/intonations which the students found difficult to follow during face-to-face teaching and learning. The opportunities to go over the pre-recorded lectures and recorded synchronous sessions took care of these challenges for both students with English as a second language and those with disabilities. The problems of

large lecture halls with poor audio systems whereby the students at the back of the lecture room hardly gained much in the lecture were also solved by the deployment of online platforms for higher education during the pandemic. Further, some students have "anxiety" problems with public speaking in a large class. Such are afraid of speaking wrongly; hence they keep quiet in class during face-to-face sessions. However, as teaching and learning moved online such students could easily express themselves using the "live chat", "Forum", and "Discussion" features in LMSs such as Moodle, Canvass, and others. Another advantage derived from the migration of the higher education programs to online mode was the prompt provision of feedback on assessments to students by the lecturers. This was made possible because some or most of the assessments were graded using automation systems incorporated into the LMS employed by the universities.

In terms of assessments of the students using the LMS for remote teaching and learning, some of the students and lecturers believed that the integrity of these online assessments is highly questionable. These became evident in the volume of plagiarism cases attended to by the university's committees responsible for these tasks. Collusion, impersonation, and contract cheating became the order of the day. It was found that some online websites provided solutions to some of the exam/test questions in exchange for money. Some other students were also found to copy from each other or pass answers through some social platforms' groups for their classes since these assessments were not invigilated. However, it must be emphasized that cheating is a common problem in the invigilated examination as well. Based on the responses received from both the students and lecturers, it is evident that the mode of assessment should change from the traditional closed-book examination to an open-book assessment. This made some lecturers to employ other modes of examination, such as boot camps, continuous assessment, and projects-based exams. It is worth stating that there is some online technology with software configurations that can be used to reduce cheating to the barest minimum. Examples of these include the reshuffling of questions, the reshuffling of multiple-choice answers, timed-out questions, and the detection of IP addresses. Some platforms also have an "Honor Pledge", where students are required to digitally confirm that they "will neither give nor receive aid on the assessment". However, all these still depend on the students' integrity and honesty. By employing open book assessment, examinations that focus on a novel application of course contents to arrive at a correct solution will be created. Such assessment will encourage skills of critical thinking rather than the types of questions that seek to assess mere memorization of information and as against understanding of these.

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When employed, the open-book mode of assessment exhibits the following characteristics: assessment of the student's ability to digest the information learned, and the evaluation of the ability of the individual student to apply the information learned. Consequently, this mode of assessment will force students to have a good grasp of the course material at a deeper level than they would on an assessment that is based exclusively on the recollection of information. However, the application of closed-book assessment should not be generalized to all subjects and all fields of study. For instance, some areas of study demand that the students should have sufficient knowledge of and be able to memorize a broad area of the subject to perform excellently. In such subjects, close book assessment will still be necessary to evaluate students' skills and comprehension of such subjects. This is because such examines the ability of the student to succinctly remember and fuse information from different modules to come up with an accurate solution. In such instances, understanding the subject matter includes memorization. Specifically, those who are in the Law discipline might find it difficult to use an online platform to assess verbal skills that used to be assessed through physical "moots" or class presentations and discussions. Such assessments might seem strange to be migrated online because giving a presentation online where one lacks a sense of the room is not the same as doing so in person. In the "Law" subject there is no direct "right answer" to most of the posed legal questions. Hence, law students need to have basic knowledge of the "case law", the "terms of the legislation", and the "legal principles". Therefore, it is essential for the students in a field such as Law, to be assessed based on their clear argumentative communication skills, and their understanding of how the law functions the way it does. In such a case, the students might be asked to execute "research essays" and "research memoranda", as it happens in real-time scenarios in a court of law. But when subjects in physical sciences and engineering are considered, in which answers to problems are not easily found in the lecture notes, an open-book assessment evaluates the student's comprehension of concepts. In these fields, applications of students' knowledge, and analytical skills (including "problem-solving" abilities) are evaluated rather than the student's ability to remember details.

The probing question that comes to mind is, can formal assessment be done away with as reassessing the "student's assessment" is considered? There is one main reason why assessment is needed, which is to ensure that students study. This is in line with the "foundational first principle of management theory" that says, "what gets measured gets done". Hence, whichever mode of assessment will be adopted for the different subjects after the pandemic, the integrity of the online assessment could be maintained by

adopting remote proctoring. Hence, tools for monitoring online education assessments must be incorporated into the LMS of each university as it is obvious that online assessments will become more popular and widely adopted going forward, after the COVID-19 pandemic. Though, some people have the feeling that using "proctoring software" or "remote invigilation" will be encroaching on the student's privacy and could affect the student psychologically, however, its use can still be applied to introduce some form of online invigilation to mitigate the issue of cheating.

One notable problem associated with online/remote teaching and learning is the lack of social interactions experienced when teaching and learning are performed face-to-face. These made it impossible for the lecturers to assess both students' emotions and instant comprehension of the course content. To circumvent this to some extent, some features are provided in the LMS that make room for some forms of interaction in terms of chat, discussions, etc. Some of these can be activated to function in a real-time scenario. Another challenge with online teaching is associated with the remote learning environments of some of the students. The environments where some of these students reside are not conducive to learning due to noise, and distractions from family members and neighbors. The immediate solution employed by some of these students was to go to nearby community centers and vacant religious buildings like church buildings (when not in use for religion programs). As previously mentioned, some other students used nighttime to study when family members and neighbors were sleeping.

In terms of the quality of teaching and learning, when the outcomes of the online mode of learning imposed upon the universities by COVID-19 are compared with that of pre-COVID-19, one can be tempted to conclude that the quality of teaching and learning is excellent during COVID-19 than what it used to be in pre-COVID-19 era due to sudden surge of pass rates witnessed in most of the Universities. The students' performances were largely associated with good Wi-Fi access, relative to using mobile internet data as claimed by some other authors.[17] Interestingly, multiple cases of cheating and plagiarism handled by the legal offices in most of these Universities also increased astronomically and widely reported in the media. This led to the belief that the pass rate during the COVID-19 online mode of teaching cannot be used to conclude that the quality of teaching and learning during the period is better than what it used to be in the pre-COVID-19 eras. On this

[17] Carolyn Chisadza et al., "Online and face-to-face learning: Evidence from students' performance during the COVID-19 pandemic," *African Development Review* 33, (2021): S114-S125, https://doi.org/10.1111/1467-8268.12520

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point, it was noted in another paper[18] that it seems some students were indeed more likely to fall behind during the online mode of teaching and learning as compared to face-to-face teaching and learning. The proof that the surge in the pass rate during the online mode of teaching-learning cannot be attributed to the good quality of the mode of teaching and learning employed became obvious in the subsequent year. When most of the COVID-19 lockdown rules were relaxed and the opportunities to conduct face-to-face invigilated assessments were made possible, especially for the students who had been on remote learning/assessment for the past one/two year(s). The failure rate was abysmal. It was such that had never been witnessed in ages. This lends credence to the fact that most of the students indeed did fall behind during the online mode of teaching and learning in accumulating the expected knowledge.

When both the advantages and disadvantages of the online mode of teaching and learning are juxtaposed together, it then goes without saying that the blended teaching and learning model is the optimum method that will magnify the various advantages associated with the two modes of teaching and learning and do away with their shortcomings with the consequential result of bringing about the desired enhancement in the quality of teaching and learning.

VI. Conclusion

The pandemic has certainly had great effects on engineering education, and higher education in general. It made both the lecturers and students do new things. As the pandemic seems to be in retreat with the high level of vaccinations across the globe, the question that is up in the mind of everyone is, should we now revert to the pre-COVID-19 pandemic status quo in higher education institutions? The reality is sinking deep into our minds that the teaching and learning activities in engineering education and the broader higher education systems cannot go back to the way they were before the emergence of the COVID-19 pandemic. This paper has shown that most of the interventions deployed to ensure the continuity of higher education activities in the universities will continue to be relevant after the pandemic has been long forgotten. These interventions will bring some changes to the tertiary education pedagogy. Without a doubt, some subjects may still

[18] Anet Knoetze and Yadah du Toit, "Emergency Remote Teaching and Learning vs Face-to-Face: When are Students More Likely to Fall Behind?" *South African Journal of Higher Education* 36, no. 5 (2022): 157-178, https://hdl.handle.net/10520/ejchigh_v36_n5_a8.

require on-campus sessions, especially those that require practical sessions such as Engineering, Medicine, Law, Dramatic Art, etc. Hence, the blended teaching and learning model (a combination of face-to-face and online models) will most likely be the new normal in most universities. By this, advantages from both modes of teaching and learning will be fully exploited towards robust experiences of the learners, while ameliorating their shortcomings. The lecturers would need to ensure that they keep abreast of the new technologies for content deliveries by undergoing continuing training. Both new and returning students must undergo regular training on the new technologies for teaching and learning that are incorporated into the existing LMS. In terms of assessment, there is no one-way approach that is optimal; both open-book and closed-book modes of assessment will be relevant based on discipline and subject. However, to maintain assessment integrity, electronic devices for invigilation of online education assessment will be needed for tertiary education, while this mode of assessment is gaining wider acceptance. Consequently, remote proctoring that enables students to be assessed at a remote location while maintaining the integrity of the assessment will be critical to be incorporated into the university's LMS. This new normal in higher education programs might reduce spending on physical infrastructures, however, the universities' managements should re-direct funding into new technologies and incorporate such into the LMS. COVID-19 though caused devastating effects on the health sector, and disruption in economic activities did not spare the education programs in the higher institutions of learning but has become the force to accelerate the needed changes that have been overdue for a long time in the higher education sector. New spectrums have been opened for higher education to navigate through for effectiveness and greater throughputs, the onus rests on the stakeholders to strike the iron when it is hot.

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