

Online teaching and learning experience at South African higher educational institution

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Abstract— This Innovate Practice Full Paper presents COVID-19 impacts, online teaching for theories, practices and assessments became mandatory at higher educational institutions. Online teaching and learning methodology include 1) Well prepared teaching materials 2) Technology support 3) Online teaching, learning, practise and assessment methodologies 4) Post learning and assessment strategies and 5) Virtual laboratory concept using simulation tools. This paper addresses challenges in implementing 100% online teaching and learning for practical-based subjects in Engineering disciplines. A case study at South African Higher Education Institution is presented and outcomes include technology-supported teaching aid methods improve pass-rate and learners overall performance level, flexibility in learning facilities among part-time learners and full-time employees, introducing virtual laboratory for engineering education using industrial grade simulation tools enable learners with engineering professional skills and secure employment opportunity. Finally, cost-benefit analysis is done and is reported that 20-30% cost saving from both learners and institution by adopting online teaching and learning in comparison with face-face teaching methodology. Higher educational institutions will have a lot of improvements and developments in Online teaching and learning methodology soon will enable to build of a framework for a smart education system.

Keywords— Smart education, Blended learning, Technology aided teaching tools, Online vs face-face education, engineering education, Online teaching and learning, and Virtual engineering simulation laboratory.

I. INTRODUCTION

The paper reports the challenges in online and teaching methods. These challenges include a) Resources to prepare the teaching materials for online classes, b) Find the methodology to share the teaching resources with the student community c) Identify the available online teaching aid tools supported by the Higher Education Institutions to deliver multi-modal teaching. The paper also addresses online assessment challenges and solutions. It requires huge time management for setting the exam paper, rubrics and deployment of the exam. Most of the academic staff set the exam paper offline and deploy it for online assessments. The assessment challenges include the post-assessment process, how to collect the student scripts after the online assessment and address the security measures to minimize the copy and mal-practice in online assessments. The last part of the paper provides recommendation on how to implement virtual laboratory sessions for Engineering courses at Higher Education Institutions. In virtual lab, the student is exposed to self-learning environment, gain knowledge in computational skills and industrial-grade software's;

however, lack in physical training with the equipment's in the lab. The cost benchmark study indicates that virtual lab provides a low-cost budget in comparison with physical lab by considering CAPEX and maintenance cost.

II. RELATED STUDIES

The literature review is grouped into the criteria such as 1) Higher Educational Framework and Policies [1] to [3], 2) Blended learning concepts in [4] to [7], 4) Online/ E-learning models/methodologies in [8] to [14], 5) Issues and Challenges on Online/ E-learning in [15] to [17], 6) Virtual laboratory for education in Science and Engineering in [18] to [20] 7) Online formative assessment in [21] and [25], 8) Smart and Innovation in Education in [26] and [27] respectively. The review structure is given in Table 1.

TABLE I. ONLINE TEACHING AND LEARNING REVIEW CRITERIA

Review Criteria	References
Higher Educational Framework and Policies	[1] to [3]
The author states that online assessment is a big challenge to deal with most of the academic staff and it requires huge time management for setting the exam paper, rubrics and deployment of the exam. Most of the academic staff set the exam paper offline and deploy it for online assessments.	The author states that online assessment is a big challenge to deal with most of the academic staff and it requires huge time management for setting the exam paper, rubrics and deployment of the exam. Most of the academic staff set the exam paper offline and deploy it for online assessments.
Online/ E-learning models/methodologies	[8] to [14]
Issues and Challenges on Online/ E-learning	[15] to [17]
Virtual laboratory for education in Science and Engineering	[18] to [20]
Online formative assessment	[21] to [25]
Smart and Innovation in Education	[26] and [27]

The detailed review as follows: The research scope includes UK framework and policies in higher education [1], comprehensive and accessible guidance on key issues in higher education teaching practice [2] and dealing with the rapid expansion of the use of technology [3] in higher education and widening student diversity.

References [4] to [7] presents Blended Learning in Higher Education, [4] outlines seven blended learning redesign principles which include professional development issues essential to the implementation of blended learning designs.

In [5], the authors discussed what blended learning is, its pros and cons, and provides some hands-on experience and classroom activities to help instructors integrate blended learning in higher education. In [7] survey and interview are conducted for blended learning among students and faculties and reports that through applying blended learning, a teacher education program improves the quality of teaching preparation, increase trend of online learning, the need to train quality teachers, and the current budget constraints on the development of online technologies to improve the access, efficiency, cost-effectiveness and quality of teacher preparation. The review summarizes that the blended learning technique promotes online/E-learning principles which will be discussed in detail in the next section.

The review investigates Online/E-learning teaching methodologies discussed in [8] to [14]. In [8], shows how learning outcomes and awareness of student characteristics and student feedback such as the perception of classroom environment can be used to enhance the quality of a combined learning online learning environment. Evidence-based research [9] addresses how key aspects of e-learning are internally constituted from a student perspective and how these aspects might be related to university students' learning experiences. Qualitative content analysis for online teaching and learning is reviewed in [10] and authors reported that a) well-designed course content, motivating interaction between the instructor and learners, well-prepared and fully-supported instructors; b) creation of a sense of online learning community; and c) rapid advancement of technology. Reference [11] provides the best practice principles for online instructors, students, and student support and considers how these might apply to intensive online environments. Reference [12] identified five dimensions of online learning self-efficacy, They are (a) self-efficacy to complete an online course, (b) self-efficacy to interact socially with classmates, (c) self-efficacy to handle tools in a Course Management System (CMS), (d) self-efficacy to interact with instructors in an online course, and (e) self-efficacy to interact with classmates for academic purposes. Reference [13] address misconceptions and myths related to the difficulty of online teaching and learning due to increased distance learners, technologies available to support online instruction, the support and compensation needed for high-quality instructors, and the needs of online students. An outbreak of the COVID-19 caused Chinese universities to close their campuses and forced them to initiate online teaching [14], which focuses on a case of Peking University's online education. The review summarizes that online teaching is a supervisor tool to avoid face-face classes due to extremely difficult time and pandemic period. However, there are few challenges in online/E-learning methodologies which are addressed in the next section.

The review investigates issues and challenges on Online/E-learning discussed in [15] to [17]. Three major categories of findings on issues and challenges on Online/ E-learning are reported in [15], they are a) issues related to online learners' issues included learners' expectations, readiness, identity, and participation in online courses b) Instructors' issues included changing faculty roles, transitioning from face-to-face to online, time management, and teaching styles c) Content issues included the role of instructors in content development, integration of multimedia in content, role of instructional strategies in content development, and considerations for content development. In [16], the study was conducted to identify and confirm factors affecting the satisfaction of online faculty at a small research university in the USA. It reports that three factors that affect the satisfaction of faculty in the online environment are student-related, instructor-related, and institution-related factors. Reference [17] provides recommended strategies for improving student retention at early interventions, at-all-times supports for students, effective communication, support for faculty teaching online classes, high-quality instructional feedback and strategies, guidance to foster positive behavioural characteristics, and collaboration among stakeholders to support online students. The review summarizes E-learning issues and challenges from students, faculties, institutions.

The review investigates virtual laboratory for education in Science and Engineering from [18] to [20]. The nature of the subject domain, the teaching of Science, Technology, and Engineering are still relatively behind when using new technological approaches (particularly for online distance learning). The reason for this discrepancy lies in the fact that these fields often require laboratory exercises [18] to provide effective skill acquisition and hands-on experience. Often it is difficult to make these laboratories accessible for online access. Either the real lab needs to be enabled for remote access or it needs to be replicated as a fully software-based virtual lab. The robotics use case study considered in [18] to demonstrate the virtual laboratory principle in an engineering discipline. The virtual laboratory concept for the protective relaying system is replicated as a fully software-based lab to illustrate overcurrent and distance protection scheme in [19] and [20] respectively using industrial grade power factory DigSlient simulation laboratory. These types of simulation laboratory along with their practical experiments provide opportunities for both faculties and students to complete their practical tasks when they are not in a position to access the University campus during the COVID-19 pandemic period and other extremely difficult conditions.

This section of the review investigates online formative assessment [21] to [25]. Reference [21] provides a systematic qualitative review of the research literature on online formative assessment in higher education using online tools such as self-test quiz tools, discussion forums and e-portfolios. The authors [21] key findings are that effective online formative assessment can foster a learner and assessment centred focus through formative feedback and enhanced learner engagement with valuable learning experiences. Reference [22] and [23] presented how online formative assessment provides teaching and learning as well as how lecturers and students benefit from it. A mixed-method questionnaire on formative assessment with the main focus on how formative assessment within online contexts operates was used to collect data from courses using Blackboard. Various techniques for formative assessment linked with

online tools [22] and [23] such as discussion forums and objective tests were used. The famous benefits comprise improvement of student commitment, faster feedback, enhanced flexibility around time and place of taking the assessment task and importance in the procedure for students and lecturers also benefited with less marking time and saved on administrative costs. Reference [24] guides the form of principled design frameworks that can assist the design practitioner in the development of online assessment strategies. The authors identified six design principles that represent the collective experience of design practitioners in creating assessment strategies for online teaching and learning environments; (a) technology affordances, (b) alignment of objectives with assessment, (c) discipline-specific practices and approaches, (d) meaningful and timely feedback, (e) authenticity and transferability and (f) transparency of assessment criteria. Research work on E-assessment practices [25] is often conducted as small-scale studies in which the e-assessment task comprises closed questions such as multiple-choice questions. This part of the review summarizes that online assessment still a crucial task at higher educational institutions for both students and instructors, however technology support tools will partially avoid mal-practice and enhance virtual supervision using video-conferencing facilities for online assessments.

The last section of the review investigates smart and innovation in education [26] to [27]. In [26] outlines the classification of innovations discusses the hurdles to innovation and offers ways to increase the scale and rate of innovation-based transformations in the education system. The author findings state that US education badly needs effective innovations of scale that can help produce the needed high-quality learning outcomes across the system. The primary focus of educational innovations should be on teaching and learning theory and practice, as well as on the learner, parents, community, society, and its culture. The papers outline critical areas of research and innovation that can be cost and time efficiency of the learning. Smart education [27] a concept that describes learning in the digital

age, has gained increased attention due to technology development enables learners to learn more effectively, efficiently, flexibly and comfortably [27]. Learners utilize smart devices [27] to access digital resources through a wireless network and to immerse in both personalized and seamless learning. This section of the review summarizes that there is a need to enhance smartness and innovation in the higher education system across the globe.

III. CHALLENGES AND SOLUTIONS IN ONLINE TEACHING AND LEARNING

This section describes challenges and solutions to implement online teaching in higher education institutions which include details on resources needed for academic staff to prepare teaching materials and how to share the teaching materials with the student community using the available online teaching application software's, digital technology and other tools. The next section discusses details on resources needed to prepare online teaching materials.

A. Resources needed to prepare online teaching material's

It is best to practise to identify a subject expert and a team with internal and external moderator and assign a task to prepare a teaching material well advanced before the start of the course. The technical content of the preparation material covers basic foundation knowledge, industrial applications and research scope. The subject expert should be in the knowledge field domain and his/her teaching, research and industrial experience play a vital role to deliver high-quality teaching materials. The teaching materials may use references from standard textbooks, publications (journal and conference papers), national and international standard documents from Utility/IEEE/IEC professional bodies. The next section discusses details about how to share the prepared teaching materials with the student community. Table 2 below provide requirements for academic staff to prepare quality online teaching materials.

TABLE II. BENCHMARK STRUCTURE PROVIDE ACADEMIC STAFF REQUIREMENTS TO PREPARE ONLINE TEACHING MATERIALS

Academic staff qualification and knowledge	Teaching and industrial Experience	Resources to prepare teaching materials	Industry engagement and Professional society activities
<ul style="list-style-type: none"> • Staff Qualified with minimum Masters or maximum Doctoral Degree in relevant field. • Demonstrate excellent knowledge and expertise in the subject field. 	<ul style="list-style-type: none"> • Academic experience after Post-graduate qualification. • Research experience in relevant field. • Industry experience with Post-graduate qualification. 	<ul style="list-style-type: none"> • Relevant textbooks in the subject domain. • Publications include journal, conference and IEEE and IEC standard documents. • Industrial equipment manuals. • Knowledge of relevant software and hardware tools. 	<ul style="list-style-type: none"> • Involvement, participation and knowledge in industrial engagement and professional bodies such as IEEE, IEC and national utility standards.

B. Methodology to share teaching material's with the student community

Due to the recently increased trend on online teaching, higher education institutions need to plan a smarter way of delivering the teaching materials to the student community. Most of the developed institutions use teaching aid technology

tools such as BlackBoard which provide access to the university Learning Management Systems (LMS) for the registered students. The university spends part of the budget to build and maintain their own IT infrastructure for cloud storage and purchase the license for active learning

management systems from LMS companies and it is a cost-effective benchmark model.

However, underdeveloped institutions do not have sufficient financial model to build either IT infrastructure or to purchase learning management license. In these cases, institutions advise the teaching staff to use open source platforms such as Email, Gdrive, Whatsapp, etc., to share the digital content of the teaching materials. It is a zero-cost model approach to sharing the teaching aids to the student

community and however risk involved in the protection and security of the teaching materials.

Some student community do not have IT infrastructure which includes computers and data bundles, in those cases students willing to use either printed copies of the teaching materials (cost-effective model) or prefer to loan textbook from institution library resources. Table 3 summarize the available open/non-open-source platforms to share teaching materials with the student community

TABLE III. BENCHMARK STRUCTURE TO SHARE TEACHING MATERIALS TO THE STUDENT COMMUNITY

Methods to share teaching materials to the student community	Teaching applications and communication tools	Cost analysis		Reliability
		Student	Institution	
University Learning Management System	BlackBoard, SUNlearn, etc.,	Zero cost (Include in their tuition fees)	Moderate cost for the institution to purchase LM license and host IT infrastructure	Highly reliable and available 24X7
Library resources	Textbook hard copy or e-copy library loan	Zero cost (Include in their tuition fees)	Moderate cost for the institution to purchase license with publishers and host IT infrastructure	<ul style="list-style-type: none"> Moderate reliability due to the limited number of hard copies of the textbook available. Highly reliable on e-books
Open Source platform	Email, GDrive, Whatsapp, etc.,	The moderate cost which includes data bundle, smart devices and laptops	Zero	<ul style="list-style-type: none"> Highly reliable and available 24X7 High risk on protection and security
Printed hard copies	Teaching material content or Chapters from textbooks	High	Moderate cost for the institution to purchase hard copies of the textbook from publishers.	Moderate reliable

C. Online teaching application software support features

Previously face-face teaching plays a vital role and a small percentage involves in online teaching mostly for distance education courses. Nowadays online teaching became familiar among the student and academic staff community due to the COVID-19 pandemic. This section describes the online teaching section in details and highlights online teaching application software support for both staff and student during their participation in online teaching sessions.

Technology plays a vital role in online teaching which includes the support of application software in online teaching which includes Blackboard collaborate, ZOOM, WebEx, etc. The online teaching application software supports 1) Setup and share meeting links to student community well advanced 2) The application software support online teaching sessions using multiple devices which include a smartphone, Tablets, PC's or laptops 3) Allow a maximum number of users 1000+ to be connected to the online teaching sessions 4) Sharing option supports both application window or file-sharing 5) Recording options to stream online teaching sessions and these streaming videos will be available to student community post online teaching sessions 6) Real-time interaction between students and staff using voice over communication, live chat

messages, audio and video conference enable/disable options and 7) Whiteboard option with a stylus pen to interact with student queries on written mode during online teaching sessions.

D. Discussion on challenges and solutions on online teaching and learning

Some challenges in online teaching sessions include 1) Provide adequate infrastructure and technology support from institutional management for online teaching 2) Provide adequate human capacity, well experienced and knowledgeable academic staff for preplanning and preparing quality teaching materials 3) Provide adequate knowledge on online teaching application software through pre-planned training and workshops to both student and staff community 4) Provide technical software support to plan and arrange for virtual laboratory sessions 5) Larger class size will affect synchronous online teaching 2) Lack of device and data support to participate in online teaching sessions 6) face-face interactions is restricted in online teaching sessions and 7) Load shedding issues on during remote online teaching sessions.

Huge support from the government, education department and academic institutions to face those challenges and the success rate was gradually improved over online teaching particularly in the COVID-19 pandemic period. However, there is still a big challenge and issues in online assessments and is discussed in detail in the next section.

IV. ONLINE ASSESSMENT CHALLENGES AND SOLUTIONS

The online teaching application software's support online assessment with different options, however, there are still need a lot of improvements and technology support to minimize the malpractice and is discussed in details in this section.

The author states that online assessment is a big challenge to deal with most of the academic staff and it requires huge time management for setting the exam paper, rubrics and deployment of the exam. Most of the academic staff set the exam paper offline and deploy it for online assessments.

Setting the exam paper and rubrics with different question types which include 1) Multiple choice 2) Fill in the blank 3) Descriptive type and 4) File response, etc. Type of question should cover blooms taxonomy structure which includes a) Recall of subject knowledge, b) Application of familiar and unfamiliar questions, c) Critical and synthesis analysis of the subject knowledge.

Most of the online teaching application software support recall of subject knowledge type questions through multiple choice and fill in the blank and the malpractice is minimum in this case. Challenge is to assess student knowledge on the application on familiar/unfamiliar and Critical/synthesis analysis of the subject knowledge through descriptive and file response type questions. It is a big concern on academic staff, how to deal with malpractice on those type of questions in online assessments. There are third party applications software such as proctor used to monitor the online assessments and usually have a collaboration with institution learning management systems. However, there is a cost

involved in the management side to engage with proctor application software companies to avoid student cheating during online exams. It is observed that not all academic institutions have sufficient fund to support this proctor facility for their online exams.

From the management point of view, there will be a huge cost reduction in online virtual exams in comparison with face-face exams. Management saves cost on invigilator payment, rent for booking exam venue and saving stationary cost on exam scripts due to paperless exam. The author suggests that management utilize that saved fund and purchase a proctor software which helps the academic community to ensure minimize student cheating in online assessments.

The online assessment deployment has different options which include randomizing the questions, presenting the questions one at a time, back trapping, excluding a certain group of students, forced to complete the assessment in one sitting and time-based setting for the assessments. The above-mentioned assessment deployment options provide control to academic staff and minimize student cheating in online assessments.

There are few challenges in post-assessment which include a collection of student exam scripts for familiar/unfamiliar, critical/synthesis types of questions through either file submission or descriptive answer method by student community during online assessments. There are options available in Blackboard, for example, the student can scan and upload a memo for descriptive type questions using the file response option. However, there will be a huge risk or a bigger amount of malpractice may happen in the file submission method in virtual assessments. However, besides the challenges, there is continued support from the government, higher education institutions, education departments, academia, online teaching application software companies and IT experts continuously working to adapt best online assessment practice.

TABLE IV. ONLINE ASSESSMENT STRATEGY

Assessment question paper setting as per blooms Taxonomy	Question Types	Malpractice	Cost
<ul style="list-style-type: none"> Recall subject knowledge. Application on familiar/unfamiliar questions. Critical and Synthesis analysis. 	<ul style="list-style-type: none"> Multiple choice Fill in the blank Descriptive type File response 	<ul style="list-style-type: none"> Relatively low - In Multiple choice and Fill in blank type of questions. Moderately high - In descriptive and file response types. Recommend to use Proctor software to minimize student cheating. 	<ul style="list-style-type: none"> Saving on human capacity - No invigilator payment. Saving on stationery items due to paperless electronic exams. High capital cost by purchasing third party proctor software and license to avoid student cheating. Save cost on digital marking of exam scripts, however, risk in auditing those exam scripts.

V. IMPLEMENTING VIRTUAL REMOTE LABORATORY SESSIONS FOR ENGINEERING COURSE

Online teaching plays a vital role in engineering education, however, implementing virtual remote laboratory for engineering courses are below 100% due to lack of technical and infrastructure support. In this section, the author shares his own experience of how he successfully implemented a virtual laboratory for one of his power engineering protective relaying course at CPUT, Higher education institution in South Africa.

Traditional universities offering protective relaying courses use either computer simulation with virtual laboratory concept or physical protective relaying laboratory set up to teach the undergraduate programme and post-graduate research. Virtual laboratory setup can be performed by recording computer simulation of the protective relaying system using available recording application software (Active Presenter) and then provide recorded videos to the student community using an online tool such as YouTube or BlackBoard. Computer simulation laboratory setup for protective relaying education need only limited resources such as computer lab and license cost to purchase the simulation software DigSilent power factory. Physical protective relaying laboratory setup requires numerical relays from any vendors such as ABB, SEL, GE, Siemens, Schinder, etc., and test injection device from Omicron and relay configuration software tools. Therefore, setting up the physical protective relaying laboratory needed more financial constraints in comparison with computer simulations. Traditional universities offering protective relaying courses do not have sufficient fund to set up the physical laboratory for protective relay testing, in this case, computer laboratory simulations with E-learning concept is a viable solution. The author implemented a virtual laboratory for overcurrent, distance and differential protection practical tasks in his power engineering course at CPUT.

A. Discussion on laboratory sessions

This section discusses challenges and solutions for implementing virtual and physical laboratory. For bigger class size academic staff have to plan time slot for practical sessions based on available lab infrastructure and maximum student capacity that each lab could accommodate. The best practice is to break down the bigger class into smaller groups for practical lab experiments, however, in the virtual lab these challenges are easily managed and most of the student complete their practical task during their self-study hours. In virtual lab, the student is exposed to self-learning environment, gain knowledge in computational skills and industrial-grade software's; however, lack in physical training with the equipment's in the lab. The cost benchmark study indicates that virtual lab provides a low-cost budget in comparison with physical lab by considering CAPEX and maintenance cost. In summary, it is the academic duty and responsibility to provide the best laboratory practice sessions to the student community by providing combined training and knowledge on soft computing skills through virtual lab and physical training with the equipment in the lab.

VI. CONCLUSION

The paper presents challenges and solution in implementing online teaching, learning and assessments in Higher Educational institutions. Academic staff faced a new Era in 2020 teaching, learning and assessments. Therefore, they are forced to introduce an online teaching environment due to the COVID-19 pandemic and lockdown levels. The university learning management application software example Blackboard played a vital role in Higher Educational institution to support online teaching and learning. The paper discussed staff and student readiness for online teaching, how to handle post-teaching activities which include formative and summative online assessments. The paper highlighted student cheating issues in online assessments and mitigation plans to minimize the mal-practise. Finally, the author shared his own experience on a successful implementation story on a virtual laboratory for one of his power engineering courses. Skill transfer, employment opportunity and job security are important criteria that will contribute to the growth of the economy. Therefore, the author believes that skill transfer play important role in both online and face-face teaching and learning. Higher educational institutions will have a lot of improvements and developments in Online teaching and learning methodology soon to build a smart education system.

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