Carnegie African
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A Vision for the Future

Online Education/ Virtual Collaboration/ Mitigating the Digital Divide

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Mitigating the Digital Divide

Improving Academic Resource Capacity at African Universities Through the Development of an Integrated Africa Diaspora MOOCs Project

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ABSTRACT

Africa has faced several political and economic problems that have hindered its growth. Notable among them is the migration of Africa's greatest assets of human capital to the West. Today, Africa universities and colleges struggle with adequate and experienced faculties to train students to solve Africans' problems. The persisting lack of well-trained and experienced faculty produces graduates not qualified for employment nor capable of setting up on their own, resulting in massive unemployment among university graduates. While a physical return is impractical for most trained Africans in the diaspora, remote engagement through video lectures/online sessions provides enormous potential for Africa's educational transformation. Through a project called SankofaLearn, African diaspora teaching and research faculties are recruited to support teaching at African universities. The professor develops and delivers video courses online, both synchronously and asynchronously, which are made accessible to students across universities in Africa. An initial survey conducted in selected institutions in Africa suggests that students are ready to adopt Massive Open Online Courses (MOOCs) as an alternative to the traditional mode of training, known as the brick-and-mortar system. The findings of the study also show that students are willing to spend money on a MOOC with a diaspora focus. The paper discusses initial work done on a proposed MOOCs platform to support higher education in Africa.

Introduction and Background

Institutions of higher learning are charged to train skilled professionals to support the development of their nations. Due to challenges in Africa, many students travel to such countries as China, India, the U.K., and the United States to get higher education, especially in fields that are not in Africa. Online education, since its limited acceptance in Africa, has been filling part of this gap. While the acceptance of online education has been slow in most African countries, recent events have shown the world, especially Africa, that online education cannot be ignored. The need to have a robust and all-inclusive education system, especially at Higher Education Institutions (HEIs), has become apparent.

Previous studies have identified factors such as poor or no funding and access to higher education (Teferra & Altbachl, 2004), inadequate facilities and staffing issues (Mushemeza, 2016), poor internet connectivity, and unstable electricity and poor internet bandwidth (Bervell & Umar, 2018; Oyo & Kalema, 2014) have been widely documented. In the midst of all these challenges, some countries in sub-Saharan Africa are making the necessary move on online education. According to Oyo & Kalema (2014), countries like South Africa, Tanzania, Kenya, and Uganda are embracing online education as a viable option to support the traditional brick-and-mortar system.

With the increasing population in Africa, coupled with the enormous education resource challenges such as lack of trained teachers, accommodation (classroom and hostels), and textbooks, e learning in the form of MOOCs has the potential to change the educational landscape of Africa's HEIs. According to the IEEE CS 2022 Report, MOOCs are one of the 10 technologies that could revolutionize the world by 2022 (Alkhatib et al., 2014). MOOCs provide the platform to provide highly structured, quality open educational resources to students anywhere at all times. MOOCs have become common and popular in institutions of higher learning. Even institutions that were initially reluctant to provide open educational resources (OER) have joined the MOOC phenomenon (Liyanagunawardena et al., 2013). With the increasing youth population of Africa, the challenge of staffing, and the gradual increase of internet connectivity on the continent, MOOCs have the potential to change the education landscape of Africa.

For MOOCs to work in Africa, however, key challenges have to be addressed, including the shortage of quality instructors and the use of modern technologies to deliver course materials to the students. This is the area where the African professional in the diaspora can play a huge role in the transformation process. A significant number of African skilled people live abroad. In the past, countries saw emigration of skilled people from their countries to other countries as a loss. There has been a shift in this discussion, as more countries now see this as a potent force for development for their countries in such areas as remittance, trade, investments, research, innovation, and knowledge and technology (Plaza & Ratha, 2011). For instance, while the actual figure may be significantly larger, remittance flows to sub-Saharan Africa were recorded to be $48 billion in 2019 (Brookings Institute, 2021).

Many developing countries have taken advantage of their diaspora resources to help boost their country's development. China, India, Israel, Japan, the Republic of Korea, and Taiwan are key examples of countries that have tapped into their diasporas as a source of knowledge (Plaza & Ratha, 2011). Countries have used several return initiatives to get skilled diaspora to return to their home countries. Examples of such successful initiatives include: the Chinese government's Hsinchu Industrial Park initiative, which attracted over 5,000 returning scientists in 2000 (Saxenian, 2002), and Thailand's monetary research funding initiative for returnees (Pang et al., 2002). Most of these returnee initiatives are in Asia. Information on Africa's returnee policies is scant, and the little information in the literature does not paint a positive picture. For example, Black et al. (2006) examined return policies on migrants in Côte d'Ivoire and Ghana. The author found that such policies that favor returnees above those who never left the country are likely to be counterproductive and cause resentment.

Experience from many of the government initiatives implemented by developing countries in Africa, Asia, and Latin America (for example, Mexico, Pakistan, Peru, and Turkey) has demonstrated that it is difficult to promote return, and particularly permanent return. Some returnees were not able to reenter local labor markets at a level appropriate for their skills and knowledge. For example, a lack of laboratories and equipment makes it difficult for scientists and researchers to keep up to date on the latest scientific developments worldwide. Some members of the diaspora may return with unrealistic expectations or may find it hard to readjust to local norms (African Development Bank, 2011; Plaza & Ratha, 2011). Physically returning permanently to support the development of home economies becomes a huge obstacle for most people.

The overarching question then is: While permanent return may not be an option for most of Africans' untapped skilled personnel in the diaspora perhaps until retirement, can the use of modern technologies like videoconferencing, such as Zoom, be the catalyst to open up MOOCs developed and managed by African professors/professionals in the diaspora to support education in Africa?

This paper presents the results of a project to support the education system of Africa through MOOCs. The process used to develop the MOOC, the perception of the current system through data collection and analysis processes are discussed in this paper.

The MOOCs Landscape

According to Shah (2020), there are over 16,000 MOOCs in the MOOCs marketplace. These MOOCs are provided by several MOOCs platforms. Table 1 provides some basic data of the top MOOCs providers.

In 2020, the modern MOOC movement globally (excluding China) included 180 million learners and provided over 2,800 courses, 19 online degrees, and 360 micro credentials (Shah, 2020). Coursera (Coursera, 2021), the number one MOOC-providing company, claims 77 million students, 4,600 courses, 200 partner institutions, 600,000 certificates awarded, 3,700 schools using Coursera for campus, and 6,000 using Coursera for business. Figure 1 shows a breakdown of Coursera's students by continent.

A proposed MOOCs framework for Africa

After critical review of the various MOOCs frameworks, Swayam, which is the government of India's national MOOC

FIGURE 1

Breakdown of Learners by Continent

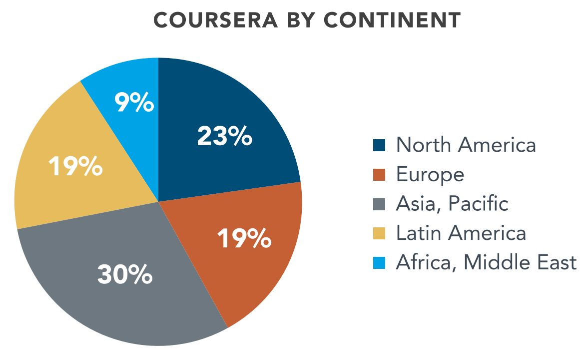


TABLE 1

Top MOOCs Providers

MOOCs PLATFORM	WEBSITE	COURSES	LEARNERS (2020)	LOCATION	PARTNERS
Coursera	coursera.org	5,540	76 million	U.S.	200
EdX	edx.org	3,500	35 million	U.S.	160
FutureLearn	futurelearn.com	1,158	15 million	UK	16
Swayam	swayam.gov.in	2,150	16 million	India	135

platform, appears to be a better model to support the development of a continent-wide MOOC platform to support education at HEIs in Africa. As reported by Swayam (2021), it currently offers over 2,150 courses to over 16 million learners, taught by close to 1,300 instructors from over 135 Indian universities, and allows students in India to earn academic credit online.

A review of the current MOOCs landscape and the current trend to overhaul the education system in Africa makes it clear that the support of the Africa diaspora professionals, especially university faculty, is critical. A MOOC that leverages both the professional and technological experience of the diaspora African will provide the needed technical and local skill requirement to develop a robust academic infrastructure to support the education systems in Africa.

Methodology

The project, which is still in its infant stage, has one basic research question:

> *While most African professionals in the diaspora (professors, medical doctors, etc.) will not relocate back to Africa, can Massive Open Online Courses (MOOCs) developed and managed by these African professionals provide the needed educational support to advance the development of the continent?*

The study had two key objectives:

1. to develop a test MOOC to test learner perceptions, and
2. to collect data from potential users in Africa to help answer the research question.

Developing the Test MOOCs (SankofaLearn)

This section details the methodology of the study. Sankofa in the Akan language of Ghana means go back to your roots. Using SankofaLearn as the test MOOC platform, a MOOC shell has been created (sankofalearn.org). Several test courses have also been created. The courses with respect to the SankofaLearn project have six course categories depicted in Table 2. The categorization approach is intended to help both students and facilitators easily identify and distinguish their areas of need or expertise.

TABLE 2

SankofaLearn Course Categories

COURSE CATEGORY	DESCRIPTION	SUBCATEGORIES
SL for Professionals	SankofaLearn for Professionals: Features professional development courses—certificate courses to enhance knowledge and skills for working-class people.	• Business certificate courses • IT certificate courses • Postgraduate certificate courses
SL for Campus	SankofaLearn for Campus: Courses are developed for students at the college level. They include subjects in taught in various disciplines in colleges and universities with practice exercises and solutions.	• Business • Computer science and IT • Arts and humanities • Engineering sciences • Health and wellness • Examination solutions
SL for High School	SankofaLearn for High School: These courses are intend-ed to help students at the junior and senior high school levels.	• Business • General arts • General science • English • Mathematics • Languages (electives) • Information technology
TURN	Technical University Education: Courses developed are intended to cover the technical university curriculum in Africa.	• Business • Computer science and IT • Engineering sciences • Build environment
Micro Courses	Micro Courses covers spe-cific topics in various subjects in all categories. This is to give detailed and better clarity of topics students have challenges.	• All categories
Degree Programs	Provides a platform to accredited universities to run and upload their courses online and access their students.	• All categories

Data Collection and Analysis

To test the viability of a continent-wide MOOCs project, an 18-point questionnaire on a 1-to-5 Likert scale was developed. The survey, developed in Google Forms, was sent to two universities in Ghana as a test survey. The survey focused on issues such as challenges of online education in Africa, the potential advantages of a proposed diaspora MOOC, and some cost issues. Participants completed the survey using the Google Forms link provided to them. While data collection is still ongoing, this paper presents results from the initial responses from 50 participants. Basic descriptive statistics were used to answer the main research question of the study. Mean scores and standard deviation of the scaled questions were calculated. To rank the key factors in order of importance to the survey participants, the Relative Importance Index (RII) was calculated for the 16 factors identified in the questionnaire. The last two questions, which addressed cost-of-usage issues, were analyzed using basic pie charts in Excel. The results are discussed in the Results and Discussions section of this paper.

Results and Discussions

The second objective examined how potential MOOC users will respond to a MOOCs platform developed and managed by African professionals in the diaspora. Table 3 summarizes responses to 16 items on potential MOOCs usage. On a Likert scale of 1 to 5, the mean scores ranged from 3.38 to

TABLE 3

Potential MOOCs Usage Statistics

SCALE QUESTION	N	MEAN	SD	RII	RANK
The Afridemy MOOCs will provide experienced and quality instructors/lecturers.	47	3.91	0.86	0.78	6
The Afridemy MOOCs will expose students to needed modern and current educational concepts.	47	4.09	0.80	0.82	4
The Afridemy MOOCs will expose students to needed modern and current educational technologies and resources.	47	3.98	0.82	0.80	5
If adopted by the universities, the Afridemy MOOCs will eliminate the problem of over-crowding in the classrooms.	47	3.66	1.20	0.73	11
The Afridemy MOOCs will make technical university education affordable by reducing tuition cost	44	3.52	1.11	0.72	15
The Afridemy MOOCs will make technical university education affordable by removing the need for on- or near-campus accommodation	47	3.72	1.10	0.74	10
The Afridemy MOOCs will make technical university education accessible by providing reliable and state-of-the-practice learning platforms	45	3.57	1.08	0.73	11
The Afridemy MOOCs will make technical university education accessible by providing more programs that are generally not available at the local universities	46	3.66	1.13	0.73	11
The Afridemy MOOCs will make technical university education accessible by making self-paced, anytime and anywhere learning possible	46	3.91	0.83	0.78	6
Lack of reliable internet and connectivity	48	4.36	1.03	0.86	2
High cost of internet data bundles	47	4.40	1.08	0.88	1
Low internet speeds	47	4.37	1.02	0.86	2
Lack of locally created course content	48	3.83	1.07	0.75	9
Lack of training and support to use the systems	47	3.79	1.25	0.76	8
Lack of computer hardware to access online material (phones, computers, tablets, etc.)	47	3.70	1.23	0.74	10
I would like to take courses from here to supplement the courses I am taking in my local university, even for a fee	45	3.38	0.90	0.68	16

4.40. Fifteen of the items were rated above 3.5, while only one item was rated below 3.5. No item was rated below 3.38. The highest rating (RII) related to one of the key challenges of online education in Africa: high cost of internet data bundles, with mean = 4.40 and RII = 0.88. The lowest-rated issue was on using MOOCs as a supplementary course material; here the mean was 3.38 with an RII = 0.68. The results suggest that while internet penetration is improving in Africa, the cost to get on the internet is still a major concern.

On the question of how much potential learners are willing to pay to use diaspora MOOCs to supplement their local courses (question 17), about 36 respondents out of 44, representing 82%, say they are willing to pay between $10 and $25. Considering the economics of Africa, that is significant.

Most MOOCs tailored to the academic community are free, with students opting to pay for a certificate. That is how Coursera (Coursera, 2021) and Swayam (Swayam, 2021) generate revenue to sustain their progress. On the question of how much learners are willing to pay for a course certificate, of the 45 respondents, 64% are willing to pay up to $20 and 11% are willing to pay $30. Only a small fraction of 7% said they are willing to pay over $50 for a course certificate. Similar course certificates cost $50 in Coursera (Coursera, 2021), and an in-person proctored exam to get a certificate costs $14 by Swayam (Swayam, 2021). This response makes a preliminary business case for the establishment of a MOOC to support education delivery in Africa.

FIGURE 2

Payment for a MOOC as a Course Supplement

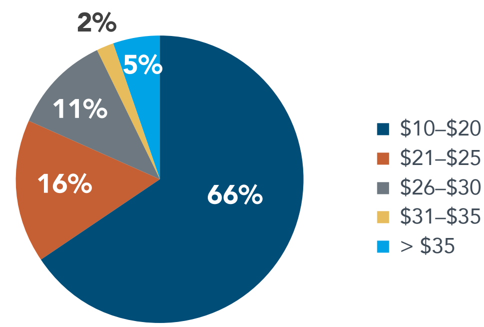
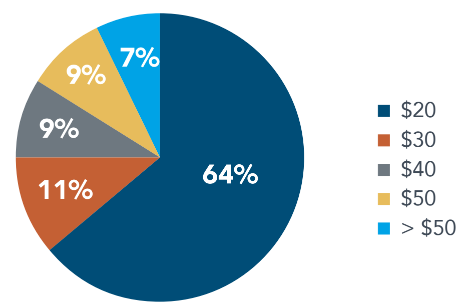


FIGURE 3

Payment for MOOC Certificate



Conclusion

The purpose of this study was to investigate the viability of a continent-wide MOOC project to support education in Africa. While the project is in its infancy, the initial data coming from one country is encouraging. With the enormous challenges of e-learning still a major issue in the delivery of online education in Africa, there appears to be some enthusiasm among current students. The initial data suggest that not only do students in Africa support the reinforcement of their academic work with resources in the diaspora, they are willing to spend money to supplement what they get from their current instructors. This makes the overall picture of the establishment of an integrated MOOC using African diaspora resource personnel very positive. Sixty-four percent of students willing to pay $20 to get a certificate is very encouraging. As a new project, new data will be collected across different African counties and in different languages.

Acknowledgement

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Online Education/Virtual Collaboration/
Mitigating the Digital Divide

Promoting Digital Learning in Africa's Public Universities During and After the COVID-19 Pandemic

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ABSTRACT

In the African context, it is difficult to imagine public universities facing a more intense set of challenges than what we are experiencing because of the COVID-19 pandemic. When the COVID-19 pandemic broke out in spring 2020, public universities in Africa closed while some private universities—like many universities globally—switched to online learning. The "digital divide" has been examined as a social and/or political issue referring to the socio-economic gap between communities that have access to computers and the internet infrastructure and those that do not have such access. The term also refers to gaps between groups regarding their ability to use these technologies due to differing levels of literacy and technical skills and access to high-quality and useful digital content. This paper seeks to accomplish three objectives. The first is to examine the need for online learning in Africa's universities. The second is to discuss the policy, institutional, pedagogical, and quality assurance issues of such learning. The third is to provide a practical collaboration model for design and successful delivery of online learning programs in African universities.

Introduction

The onset of the global COVID-19 pandemic in spring 2020 not only threatened the well-being of individuals and communities, but also the very survival of business operations and higher education institutions that provide discovery and innovation services essential to the innovation ecosystem (Lanahan, 2020). In short, the COVID-19 pandemic disrupted every aspect of people's lives (ILO, 2020). In a joint statement, the International Labor Organization (ILO), Food and Agricultural Organization (FAO), International Fund for Agricultural Development (IFAD), and World Health Organization (WHO) noted that the pandemic led to a dramatic loss of human life worldwide and presented an unprecedented challenge to public health, food systems, and the world of work (WHO, 2020). In the case of higher education, the crisis hit universities (both public and private) particularly hard. As COVIDEA (2020, p.11) noted, "The COVID-19 pandemic is far more than a health crisis—it is affecting societies and economies at their core and will have long-lasting consequences." Given the difficult pandemic situation, one major tool for supporting and sustaining the learning process is the internet. Advances in technology have enabled students and professors to continue working and learning despite the challenges posed by COVID-19. Technology platforms such as Zoom, Skype, Google Meet, and WebEx, among others, have made it possible for universities and organizations to not only reduce the costs associated with delivery of training, but also to increase the effectiveness of the learning environment and help improve learning and teaching functions, especially for adult learners in colleges and universities. Thus, various virtual platforms have become more sophisticated in recent years and now provide a videoconferencing environment with high-quality eye contact, voice, and body language contexts. For many public universities in Africa, obtaining financial resources to invest in digital learning infrastructure such as high-speed internet, learning management systems (LMSs), wi-fi, and computer hardware remains extremely difficult (Wangange-Ouma & Kupe, 2020). In addition, many universities in Africa suffer from limited digital infrastructure, capacity, and connectivity, which made the transition to online learning even more difficult (Zeleza & Okanda, 2021). This is especially true for universities with large contingents of underrepresented groups, such as ethnic minorities, women, learners in urban slums and rural areas, and those from low social and economic statuses in various African countries.

All university employees and students working face-to-face, virtually, or in a hybrid format must make a deliberate effort to understand how the virtual workplace affects work practice and productivity, and the morale of employees and learners. The relative importance of new internet technologies to those working and learning virtually is an open question that deserves to be studied. And, by extension, the question of how the virtual workplace has assisted the development and delivery of optimal teaching and learning also should be addressed post-COVID-19. There is an urgent need to study the lived experiences of employees, leaders, students, teachers, and staff who use virtual work settings. In addition, further research into the well-being of students, faculty, and staff during and after the COVID pandemic is necessary. The lessons learned would improve future face-to-face, remote, and virtual workplace learning environments. To that end, this paper has three main objectives. The first is to examine the need for online learning in Africa's universities. The second is to discuss the policy, institutional, pedagogical, and quality assurance issues of such learning. The third is to provide a practical collaboration model for the design and successful delivery of online learning programs in African universities.

The Need for Online Learning in Africa's Universities

It has been observed that the terms e-learning, online learning, web-based learning, and virtual learning have been used interchangeably to refer to the same method of instruction using information and communication technologies (Nafukho & Park, 2004). Given recent advancements in technologies, especially the availability of many digital learning applications (apps) and mobile phones and easily accessible social media platforms such as WhatsApp learning groups, Twitter, LinkedIn Learning, Instagram, Facebook, and video animations, various digital and mobile learning modes for formal and informal learning are now prevalent (Bella-Bravo & Lutomia, 2019). The multitude of social media platforms can be used creatively and innovatively to augment or open up accessibility to remote learning, hybrid learning, and HyFlex learning modes. Therefore, the terms e-learning, online learning, web-based learning, mobile learning, and digital learning are used interchangeably in this paper.

Prior to the COVID-19 pandemic, there were educators who questioned the benefits of digital learning in higher education (Dhawan, 2020). Now, however, in large part due to the pandemic, the impact and benefits of digital learning are crystal clear. The first step for universities considering digital learning is to conduct a needs analysis involving key stakeholders such as students, faculty, curriculum developers, instructional designers, educational leaders, policy makers, teachers, and employers, among many other constituents.

Mungania and Nafukho (2005) found that a systematic needs assessment is the first step to ensure high-quality, successful design and delivery of online e-learning programs. The needs analysis "… helps clarify and define the institutional needs, strategic plans, target population, competition, technology, [and] human and fiscal capital issues, among others. … The results emerging from a needs analysis will aid in the policy formulation and policy changes" (p. 3). Universities in Africa and elsewhere, therefore, should not necessarily rush to implement a digital learning mode in response to COVID-19 or any crisis, as was the case with remote learning. Instead, institutions should develop e-learning strategic plans based on students' learning needs determined in a systematic needs analysis. As Cyrs and Conway (1997, p. 385) correctly noted, "Distance learning programs that are not given top priority in the mission statement will eventually falter." Nafukho, Thompson and Brooks (2004) established that employer support was critical to the success of working employees enrolled in online learning degree completion programs.

From the author's practical experience, one major way to prioritize and support online learning is to have a mission statement focusing on the importance of harnessing modern technology to support learning and teaching processes. The goals and objectives derived from the institution's overall strategic plan should be consistent and assist with the development of digital learning policies and practices. In order to realize the potential benefits of digital learning, some existing policies will need to be revised or replaced. University leaders will need to think—and rethink—policy shifts as a strategy for creating digital learning environments aimed at offering quality continuing education programs grounded in lifelong learning (Nafukho & Muyia, 2021).

Policy Considerations and Quality Assurance in E-Learning

As universities consider digital learning modes, they must address several issues: faculty and student readiness, strategic enrollment management, health, and safety; academic quality; budgets; peer competition; effective marketing; qualified faculty and staff; technology infrastructure; and the current digital divide. Identifying these issues is the first step toward quality assurance for any e-learning platforms that are implemented. Quality assurance refers to the need for a set of procedures and standards regarding the design, delivery, measurement, monitoring, evaluation, guaranteeing, maintenance, or enhancement regarding the quality of education provided through e-learning (Nafukho, 2007; Rwamasirabo & Beebe, 2005). After all, the likelihood of success in all learning endeavors, especially in higher education, depends largely on modern pedagogy. In the case of e-learning as a form of distance education in Africa, successful implementation has to be guided by a clear teaching and learning philosophy (Nafukho, 2007). Mishra (2002) and Villalba and Romiszowski (2001) noted that three schools of thought have been widely used in the use of technology for learning purposes: behaviorism, cognitive psychology, and constructivism. Of the three, constructivism has been identified as the most suitable for online learning (Hung, 2001; Kitainge, 2008; Mishra, 2002). The constructivist school of thought claims that teaching is more efficient and effective when students engage in activities within a supportive learning environment and when they get proper guidance mediated by learning tools. Constructivism is a philosophy of learning based on the premise that learners who reflect on their learning experiences are able to construct their own understanding of their learning environments and the world (Nafukho, 2007). To ensure successful design and delivery of courses using digital learning, universities in Africa must pay attention to macro, meso, and micro policy issues, followed by policy formulation, policy implementation, and support (Gordon, 2003; Mungania & Nafukho, 2005). They must be willing to go beyond the so-called benchmarks or best practices, which too often are blind spots that make institutions complacent. Universities should instead seek better practices aimed at ensuring they are continuously improving their digital learning endeavors (Grant, 2021). They should at the same time seek to encourage learners to be committed to learning for a lifetime also referred to as lifelong learning – a key requirement for learning for success in life and work (Nafukho & Muyia, 2021).

Burke (2002) noted that universities, as institutions of higher learning, are open systems and thus are affected by the internal and external environments in which they operate. This means that e-learning policies may be influenced by macro forces beyond the institution, and in this case, these include health and safety issues resulting from the COVID-19 pandemic. Meso policy issues refer to national or regional issues, while micro policy issues relate to internal, institutional issues that must be addressed in order to have a functional and optimal digital learning environment. At the micro level, each university will need to pay attention to talent acquisition and development and compensation or financial aid support for students, as well as policies for evaluation, intellectual property, technological infrastructure, support services, and collaboration. Given that universities are made up of people (students, faculty, and staff), this paper focuses on the people component of digital learning.

People-Centered Policies and Practices

Talent Acquisition Policy

Universities in Africa that plan to adopt digital learning will have to strategically think about talent management and development policies. As Nafukho et al. (2017, p. 2) stated, "Talent has been identified as the only differentiator for an organization, nation or region's success in this uncertain, complex, competitive and global environment." Ulrich (2008) defined talent as the equation of 3 C's: Talent = Competence × Commitment × Contribution. This will require further thinking about the faculty and staff competencies necessary for e-learning programs. As noted earlier, a systematic needs analysis should uncover any new or additional skills, knowledge, attitudes, and competencies required to design and deliver quality e-learning programs. In United States in the early 2000s, for instance, it was predicted that as e-learning programs became popular, the market for adjunct faculty or clinical faculty with heavier teaching workloads would explode (Bonk, 2001). This prediction is now a reality and universities in Africa have some useful lessons to learn from the north.

Talent Development Policy

Given the ever-changing landscape of the technological infrastructure, faculty and staff who work with students will require continuous training and development to equip them with the skills, competencies, and confidence needed to utilize technology and social media tools in digital learning settings. In the United States for example, the early adopters of the World Wide Web for teaching were suspicious of the motives of administrators who promoted web-based education without appropriate technical and pedagogical support (Bonk, 2001). This may also be the case for faculty at African universities, despite the subsequent advances in technology. Institutional strategic plans will need to address faculty training and development in the optimal use of internet infrastructure and social media devices and platforms for learning purposes. To cite one example, "faculty teaching online are faced with new instructional design and curriculum development challenges" (Mungania & Nafukho, 2005, p. 5). In addition, faculty are faced with challenges regarding the selection, management, and optimal implementation of e-learning technology (given the digital divide), social media, instructional design, LMSs, learner support, and high-tech classrooms. Non-tangible factors to be addressed include becoming comfortable with new technologies, adapting traditional courseware for digital learning, providing sufficient time for course preparation and design, ensuring student engagement through meaningful immediate feedback and social presence, and providing avenues to address policy and other general management issues (Chakraborty & Nafukho, 2015).

Remuneration Policy

Faculty who had to switch to remote learning immediately due to COVID-19, or teach via face-to-face, hybrid, and HyFlex modes experienced additional workload, burnout and in some cases mental health issues (Chirikov et al., 2020). This added workload justifies incentives such as course releases or financial compensation based on good performance—what are referred to as merit raises elsewhere. While working in Africa the author found that faculty at most universities there do not receive performance-based merit raises. The economic situation has even been made worse by the negative impact of the pandemic on business and industry, especially with the lockdowns (Zeleza & Okanda, 2021). In Europe and the United States, the preferred modes of compensation for faculty teaching online include additional salary, non-discretionary stipends for course design, course royalties, release time, and awards and recognition of exemplary teaching (Bonk, 2001). Thus, every university offering online learning courses should clearly stipulate their compensation policy aimed at motivating faculty, recruiting talented faculty, supporting online courses, and generally ensuring the overall high quality of e-learning programs.

Evaluation Policy

The design, development, and implementation of online programs should be supported by a formal evaluation policy to ensure that digital learning programs meet set goals, including access and quality imperatives. This helps determine the efficiency and effectiveness of the university's administrative, instructional, and technical and/or learner support services related to the program. Every institution should have a policy in place that directs when, how, and who will carry out program evaluation activities, who gets access to the results, and how the results are announced and disseminated.

Copyright and Intellectual Property Policy

In the African higher education setting, the issue of copyright and intellectual property as it relates to digital and mobile learning needs immediate attention. According to Cyrs and Conway (1997), policies that protect intellectual property rights and delineate the sharing of royalties derived from intellectual property need to be clearly stated before the project begins. Therefore, it is essential for universities considering offering e-learning programs to explore ways to protect intellectual rights (Broskoske & Harvey, 2000). Mungania and Nafukho (2005) noted that as e-learning programs surged through the African market, more faculty could end up teaching in more than one institution, hence the need for universities to develop clear guidelines and policies regarding the ownership of online course materials.

Learning Management System (LMS) Policy

Currently there exist many learning support systems, such as Blackboard, Canvas, eCampus, Blackboard, Moodle, and eLearnAfrica. Some LMSs are offered for sale commercially, others are provided for free, and some are designed by the institutions themselves. Prior to selecting an LMS, the needs of the learners and faculty must be considered. The technology adopted for instruction must be student centered and meet the institution's quality standards. The process to select the LMS should be inclusive, involving the entire campus, and should consider the advantages and disadvantages of the LMS eventually selected. Considerations include student access to computers, Wi-Fi, high-speed internet, mobile learning tools, and the learning apps implemented, as well as the specific institution's ability to sustain the related operational costs and manage time differences and geographic accessibility (Belanger & Jordan, 2000). In the case of faculty and staff in Africa, the particular challenges often include the cost of quality LMS, the digital divide (in terms of access to, or ownership of, computers), and access to wi-fi and internet bundles (Odebero, 2015). In courses that involve inter-institutional collaboration, time differences could limit students' ability to interact or participate in synchronous activities, for example, leading to isolation. Students for whom communication is limited because they lack access to digital infrastructure or social media would find it very difficult to receive meaningful feedback from faculty, which is critical to success in digital learning courses (Galusha, 1998).

Diversity, Equity, and Inclusion Policy

Universities must create a policy aimed at creating a potentially successful learning environment for all students, regardless of students' age, race, disability/ability, ethnicity, and economic background (King, 1999). Acknowledging and recognizing students' diversity of background and of thought is important in higher education learning settings (Morris, 2018). Equity refers to the need for universities to provide access and distribute resources that allow everyone the opportunity to meaningfully participate in digital learning programs, while inclusion refers to the need to facilitate opportunities for learners to fully participate in, and contribute to, a digital learning environment that is welcoming, respectful, and supportive for all learners, staff, and faculty (Morris, 2018). Given that the needs of learners are diverse, and that the population of learners changes regularly, then it is important for student affairs experts to regularly evaluate (and re-evaluate) the support services needed for students' success (King, 1999). Examples of support services for students enrolled in digital learning programs include online admissions and registration, academic advising, virtual tutoring and mentoring, library services, financial aid services, financial counseling, mental health services, and career counseling, among others. As Mungania and Nafukho (2005, p. 7) noted, "There is definitely need to create an institutional culture and environment that is supportive of online learners and faculty teaching online."

Collaboration Policy

To successfully and positively impact the world, universities cannot work in silos and must cultivate and nurture collaborations within Africa and beyond. African scholars and educators need to collaborate with educators engaged in digital learning from within and without Africa. Faculty working in African universities must continuously be encouraged to work with their peers and colleagues in the diaspora. To have meaningful collaborations, every African university should implement a clear collaboration policy to guide faculty. Faculty actually deliver e-learning courses, so they should have a voice in the establishment of e-learning programs to be offered within their institutions and in collaboration with other institutions. For instance, Broskoske and Harvey (2000) observed that partnerships are one way to function efficiently and effectively in the increasingly expensive and competitive e-learning environment. This still holds true twenty years later. This was reiterated by Mungania and Nafukho (2005, p. 8): "Since such collaboration could increase access to subject matter experts and to resources, there should be a policy in place on how to deal with such new partnerships. It is important to point out that given the complex nature of higher education, a comprehensive assessment of all the policies that impact e-learning programs is impractical. Given that, this section of the paper focused on people-centered (students, faculty, and staff) policies. People-centered policies deserve special attention before any institution designs, develops, and implements a digital learning program.

A Holistic Digital Learning Program

Empirical studies show that when designing learning programs for college students, the professors involved must first seek to understand the learners: their learning needs, the experiences they bring to the learning setting, their psychological needs, and their socio-economic needs (Caffarella, 2001; Fasokun et al., 2005; Indabawa & Mpofu, 2005; Knowles, 1980; Merriam & Brockett, 1996; Nafukho et al., 2005).

To facilitate this process, the diversity of adult learning needs can be explained in terms of a learner's socio-economic background, work and educational experiences, professional background, personality type, and learning style (Nafukho et al., 2011). Lieb (1991) argued that effective design and delivery of virtual learning programs requires an understanding of how college students learn best. Likewise, Bruner (1966) noted that the success of adult learners will depend on how the courses and curriculum are structured. He suggested a learning model that focuses on how to learn and not what to learn (a concept also known as metacognition).

Empirical studies show that each individual learner learns differently according to the various learning styles (Belenky et al., 1986; Dunn, 1990; Kolb, 1984). This means that while designing a digital learning curriculum for adult learners, designers must seek to accommodate the various learning styles represented. Keefe (1979) refers to the term learning style as the cognitive, affective, and physiological factors that affect how learners perceive, interact with, and respond to the learning environment, in this case, the e-learning environment. Examples of learning styles include visual, auditory, tactual/kinesthetic, and mixed modalities (Gardner, 1993). Reiff's (1992) study further noted that the learners in any classroom will fall into these major categories in the following percentages: 25–30% visual, 25–30% auditory, 15% tactual/kinesthetic, and 25–30% mixed modalities. These categories are critical when it comes to the design and successful delivery of virtual learning programs.

Closely related to learning styles are the different intelligences that learners possess. According to the multiple intelligences theory proposed by Gardner (2006), all learners possess one or more of eight modes of intelligence: (1) visual/spatial intelligence, or the ability to visualize objects and create mental images of the objects; (2) verbal/linguistic intelligence, or the ability to read, write, and listen to and remember information, and narrate stories; (3) logical/mathematical intelligence, or the ability to learn best through the use of reason, logic, and numbers; (4) bodily/kinesthetic intelligence, or the ability to learn best through hands-on tasks, games, and movement, and to create, build, and express emotions through the body; (5) musical/rhythmic intelligence, or ability to learn best through songs, patterns, rhythms, and musical instruments; (6) interpersonal intelligence, or the ability to learn best by relating to other people or learners; (7) intrapersonal intelligence, or the ability to learn best by self-examination and seeking to remain independent; and (8) naturalistic intelligence, or the ability to learn best through seeking to understand, comprehend, and explain things in terms of nature.

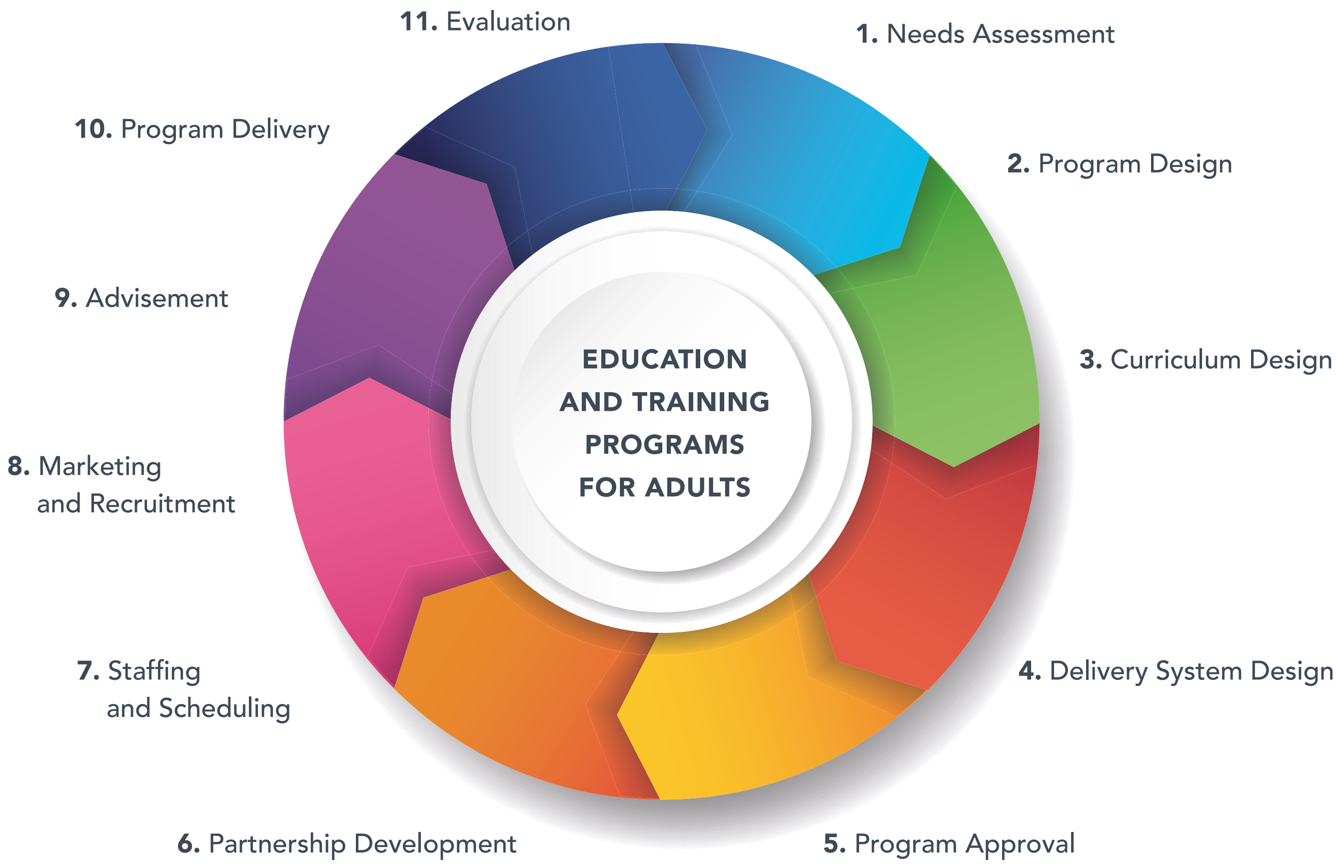
For the purpose of this paper, the eight intelligences are distilled into the concepts of cognitive intelligence, emotional intelligence, behavioral intelligence, and spiritual intelligence—what is referred to as body, mind, heart, and soul. Furthermore, those designing digital learning programs should pay special attention to the three domains of learning: cognitive domain, affective domain, and behavioral domain. The cognitive domain of learning aims to develop the mental skills and the acquisition of knowledge. The affective domain of learning includes the feelings, emotions, and attitudes of the learners. According to Anderson et al. (2001), the categories of affective domain include receiving phenomena, responding to phenomena; valuing; organization; and characterization. The psychomotor (behavioral) domain of learning includes the learners' ability motor skills and the ability to coordinate them. The sub domains of psychomotor include perception set; guided response; mechanism; complex overt response; adaptation; and origination (London School of Management, 2019). Digital learning curricula should be diversified, with the main focus on developing the learners' varied intelligences. In addition, the curriculum should be holistic in its design in that it develops synergy in the content that "engages fully all aspects of the whole person through the use of body, mind and spirit" (Fasokun et al., 2005, p. 134).

Digital Collaboration Learning Model

In this section, we discuss a holistic and practical digital/e-learning program development model developed by Barbara Hinton and a team of faculty at the University of Arkansas. The holistic virtual learning model (Hinton, 1998) was developed based on practical experience of developing e-learning programs in the state of Arkansas. The model has been translated from theory into research, policy, and

FIGURE 1

E-Learning Program Developmental Model



Source: Hinton, H. E. (1998). Paper presented at the Academy of Human Resource Development Annual Research Conference.

practice (Chun & Hinton, 2001; Chakraborty & Nafukho, 2015; Hinton, 1998; Nafukho, 2007; Nafukho et al., 2002). To successfully navigate the COVID-19 pandemic environment, all educators, and especially those at African universities, must engage in interdisciplinary, multidisciplinary, and transdisciplinary education and research enterprises. This means that educators and researchers in Africa need to collaborate with colleagues and peers in Africa and beyond, especially their colleagues in the diaspora – thus the need for the digital collaboration model advanced in this paper. Figure 1 illustrates the optimal development cycle for an e-learning model (Hinton, 1998).

As discussed, **Step 1, Needs Assessment**, should involve all relevant parties: educators who are subject matter experts in the institutions and countries involved in the partnerships, as well as vice chancellors, deputy vice chancellors, deans, department heads, program directors, program chairs, faculty, and staff. In this step, subject matter experts identify any infrastructural, human, time, educational, and financial resources required for the design and successful delivery of digital learning programs.

In addition, a survey of faculty professionals in the program content areas fields should be conducted. **Step 2, Program Design**, should involve a task force of faculty and instructional designers to be involved in the partnership The partnership degree programs should not benefit one institution at the expense of another. The role of this task force should be to use the needs analysis results to design a digital learning degree program that aims at ensuring academic quality while accommodating the needs of the learners, faculty, departments, and institutions involved, and external stakeholders such as parents and others.

Step 3, Curriculum Design, likewise should be conducted based on the needs analysis findings. The curriculum should be designed to reflect the core competencies and skills identified by subject matter experts, current students, former students, employers, prospective employers, and key community stakeholders.

Step 4, Delivery System Design, involves building the technology and internet infrastructure necessary to deliver the courses through platforms such as AAU-eLearnAfricaLMS, Blackboard, Canvas, Moodle, and others. In this step, the issues include identifying faculty qualified to successfully deliver the courses, securing the technical resources required to support the delivery of online courses, and recruiting and training (or untraining and retraining) staff. Resources needed are software and platforms such as high-speed internet, internet bundles, Wi-Fi, Learning Support Systems, and email capabilities, and hardware such as relevant educational videos, computers, printers, servers, and copiers.

Step 5, Program Approval, involves approval of the e-learning program at the program, department, college, and the university levels, continuing up through the university boards of trustees in the case of the United States universities, or university councils in the case of African universities. The approval process should be guided by a well-articulated information and communication technologies (ICT) and distance learning policies. In addition, the respective ministries of education in the countries concerned should be involved.

Step 6, Partnership Development, ensures that program delivery does not benefit one institution at the expense of the other. For example, African universities should not be used solely to provide a market for their partners in the north. They should not be used only to collect fees for their foreign partners. It is also important that partnerships between well-established universities in digital learning with less-established universities should aim at developing the less-established universities (Nafukho, 2007). A win–win relationship between the international universities in the north and the host institutions in the south must be established at this stage. Important items to be considered may include training faculty and staff in African universities to teach using ICT. Finally, this step involves the negotiation and formal signing of Memoranda of Understanding (MOUs) between the institutions involved. The MOU serves as a legal and guiding document, outlining the details of the collaboration and the responsibilities of each institution.

Step 7, Staffing and Scheduling, involves the selection of faculty with the academic expertise (credentials) to teach online. Credentialing includes a demonstration that the faculty have the appropriate academic expertise, training, and experience in delivering e-learning courses, as well as training faculty who have no skills or experience in this area. Furthermore, technical staff must be recruited, trained, or retrained. Thus, reskilling and upskilling will be needed as technology changes.

Step 8, Marketing and Recruitment, involves communicating to relevant audiences through several venues, particularly those that are the most powerful for recruitment in Africa: faculty members speaking at professional organizational meetings; social media such as LinkedIn, Twitter, and Facebook; newspaper articles, op-eds, and advertisements; and flyers. Enrollment packets containing guidelines for admission to the programs and program requirements, and application forms, have to be disseminated to prospective students (Nafukho & Burnett, 2002). The websites of the partner institutions similarly should promote the program's clearly defined vision, mission, and priority goals.

Step 9, Academic Advising, involves all the e-mentoring services that must be provided. Student advising is especially critical in African universities, where faculty workload does not include this task. With the complexity associated with the use of ICT for learning purposes, student academic advisors, faculty advisors and e-mentoring as a form of advising must be made available to all certificate, undergraduate, graduate, and professional students. To assist students as they navigate the complex world of higher education, professional academic advisors must be recruited, trained, and deployed.

Step 10, Program Delivery, pertains to coordination, class scheduling, and student registration. Technology staff should assist with the mechanics of delivering instruction via technology. Information on courses and the sequence in which they must be taken should be available on the institution's website.

Step 11, Evaluation, is as critically important as the needs analysis conducted before program design and delivery. Both internal and external evaluators should be involved in the formative and summative evaluations of the e-learning programs. Evaluation should focus on traditional output measures such as how many collaborating institutions were involved, how many courses were offered, how many students enrolled in the courses, who taught the courses, how the students performed, what problems the students encountered, and how these problems were addressed. Evaluation should also seek to establish the relevance of the course content and to compare the performance of this cohort of students to those enrolled in hybrid or face-to-face learning programs. The summative evaluation should use longitudinal studies to provide key quantitative data and should assess periodically every aspect of the learning programs. Some of the most important questions include the following: What aspects of the e-learning programs were most beneficial? Should the programs be revised, expanded, or recreated? What barriers, if any, do the students and faculty face, and how can they be resolved to ensure optimal learning? What are the short-, medium-, or long-term impacts, if any, of the programs offered? How many current professors created and taught new courses? The evaluation findings should be analyzed and shared with key stakeholders. To popularize e-learning, the evaluation stage may also require a monthly online newsletter, updates on the websites of the institutions involved, and informational communications to employers, funders, students, and other key stakeholders (Nafukho, 2007).

Conclusion

For e-learning to benefit Africa, universities there should collaborate directly with well-established universities in the areas of digital learning and mobile learning within Africa and outside Africa. The COVID-19 pandemic underscored the positive impact of technology in ensuring the continued operation of universities around the world. As educators, we must use technology and computers as tools to build better learning processes aimed at improving the learning and teaching processes. African universities, as centers of excellence in teaching, research, and outreach, should take up the challenge of promoting distance education while keeping in mind the cardinal principle of education: quality assurance. The provision of higher education through ICT should not be left to economic entrepreneurs alone, however; instead, higher education professions should respond to the urgent need to collaboratively work with business and industry peers to harness technology for the purpose of advancing learning aimed at improving the human condition. As professional educators and researchers, faculty should take the lead in digital and mobile learning innovations in education, training, and development. After all, technology can only support the teaching and learning process if the teacher facilities the process. Even with the advancement of artificial intelligence, there is no way that technology will replace the human teacher, at least for many years to come.

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Online Education/Virtual Collaboration/
Mitigating the Digital Divide

Integrating Technology Despite Its Absence: Lessons Learned in Tanzania

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Introduction

This paper is about my experiences integrating technology in an institution with very limited access to technology in Tanzania. While there is an abundance of support and justification of the role of technology in the classroom as a teaching and learning tool, there is a global digital divide within and between countries (Gureshi, 2012). Despite the narrowing of this divide, there are still countries and communities that are being left behind (ndunda & Malecela, 2018). Prior to the coronavirus pandemic, many institutions in Africa had incorporated little technology in teaching and learning. The pandemic intensified the digital divide between countries, which had been narrowing (Steele, 2019).

This paper will focus on the lessons learned about integrating technology with my colleagues in my host institution from 2012 to 2018 as a Fulbright Scholar and as a Carnegie African Diaspora Fellow. The paper will present how the process began and ended, emphasizing the importance of using any available technology, such as mobile devices/ smartphones, as teaching and learning tools. This journey progressed in phases.

Theoretical Framework

Several bodies of knowledge, including literature on co-teaching, technology integration, Technology Acceptance Models (TAMs), and Theory of Planned Behavior (TPB) concepts relating to organizational change and learning, inform this experience of integrating technology despite the odds. The literature on co-teaching shows that students and instructors benefit from co-teaching experiences (ndunda & Malecela, 2018; Mofield, 2020). In a co-teaching context, the students have more support and a more meaningful connection with their instructors (Graziano & Navarrete, 2012; Harris & Watson, 1997; Mofield, 2020). Literature on TAM (Davis, 1985), the Unified Theory of Acceptance and Use of Technology (UTAUT), and TPB models are important lenses for understanding the experiences discussed in this paper. The Perceived Usefulness (PU) of the technology and Perceived Ease of Use (PEOU) are perceptions of beliefs that users hold about the system (Dillon & Morris, 1996, as cited in Koul & Eydgahi, 2017), provide an important framework for understanding technology adaptation.

In addition, theories of organizational change, leadership, and learning provide important perspectives for interrogating how change is experienced (Fullan et al, 2021). Knowledge of the processes of educational change provides a critical lens through which to understand educational innovation and reforms, including the adoption of technology. The attitude one holds toward adoption determines the adopter's positive or negative behavior concerning the adoption. The Diffusion of Innovation (DoI) model developed by Rogers in 1962 is helpful in explaining why some people are more apt to adopt an innovation than others (cited in ndunda & Malecela, 2018).

Researchers have found that people who adopt an innovation early have different characteristics than people who adopt an innovation later. When promoting an innovation to a target population, it is important to understand the characteristics of the target population that will help or hinder the adoption of the innovation (LaMorte, 2019, paragraph 2). These frameworks serve as lenses for understanding the factors that affect the use of mobile devices and, in particular, the adoption of smartphones as teaching and learning tools (Dong-Hee et al., 2011; Darko-Adjei, 2019).

Literature Review

Technology integration entails using resources, such as computers, mobile devices (e.g., smartphones and tablets), digital cameras, social media platforms and networks, software applications, and the internet, in daily classroom practices and school management (Edutopia, 2007). Successful technology integration is achieved when the use of technology (a) is routine and transparent, (b) is accessible and readily available for the task at hand, (c) supports the curricular goals, and, (d) helps the students effectively reach their goals (Edutopia, 2007).

Mobile learning devices and apps have been used to transform other sectors and have become increasingly affordable and powerful. In research published about the use of smartphones, there is evidence that they are powerful tools that can be used for teaching and learning (Darko-Adjei, 2019). However, they have remained underutilized in education (GettingSmart, 2020). Although educators and students use mobile technologies for personal communications, these devices have not been considered legitimate teaching and learning tools despite their obvious prevalence and capacity to be used as an efficient learning platform. Darko-Adjei (2019) notes that "smartphone usage ensures flexible course delivery, makes it possible for learners to access online learning platforms, access course resources, and interact digitally" (paragraph 1).

Africa's population is one of the fastest growing in the world, and access to educational opportunities continues to be a challenge. Despite African countries devoting significant resources to education, the region has the worst education spending efficiency (Gandhi, 2020). There are huge disparities along gender and regional lines (UNESCO, 2021). Lack of teachers and print material is a challenge many schools face. For example, in Tanzania, especially in rural areas, classes can have as many as 200 students, most of whom sit on the floor (Mtahabwa & Rao, 2010).

E-learning has the potential to address lack of access to education, as it would make education available to more children anytime and anywhere (Ischebeck, 2020). However, there are still barriers to adoption of mobile learning. These include lack of electrical power, internet connectivity, training and professional development, value of teachers, and affordability of these devices, especially in rural communities (Wright, 2014). There is also a dire need for proper digital infrastructure. These challenges are compounded by the fact that the majority of the population lives on less than $2 per day (Ischebeck, 2020), especially in the rural areas. Access to a decent education has become something that only a minority of the population can truly afford. E-learning offers an opportunity to provide access to high-quality learning materials that can be used to abate the existing discrepancies in quality and access to learning at all levels of education.

According to Elliott (2019 a), 75% of sub-Saharan Africans possessed a mobile device in 2017, and by 2025, 84% of the population (1 billion people) will have access to a Subscriber Identity Module (SIM) connection, a 3.7% increase from 2017. A survey by Silver and Johnson (2018b) showed that a majority in sub-Saharan Africa own mobile phones, but smartphone adoption is modest. Ownership and usage gaps were particularly pronounced in smartphones.

Globally, in 2018, the world had over 253 million children and youth out of school, and the majority of those were in Africa (UNESCO UIS, 2021). In 2020, the COVID-19 pandemic caused a majority of countries to temporarily close schools, and by April 2020, close to 1.6 billion children and youth were out of school (UNESCO, 2021). Currently most countries are behind in Sustainable Development Goal 4 (SDG4), which aims to provide free access to primary and secondary education for all children and youth by 2030 (UNESCO UIS, 2021). These statistics have certainly been exacerbated by the pandemic. However, due to the vast numbers of people owning or having access to mobile devices, it makes sense to use these tools for teaching and learning. In most African countries, there has been a major delay in implementing technology in the classrooms, largely due to lack of resources and support for the use of mobile devices in the classroom by educators, schools, and politicians (Mayega, 2019). Despite the resistance, there is still a proliferation of new technologies being introduced in classrooms in lower-income countries. For example, Twitter Lite was introduced in 2017 to allow use of the social platform while using less data (Workman, 2017).

Background

This paper discusses the experiences I had in Tanzania as a Fulbright Scholar and Carnegie African Diaspora Fellow. I received the Fulbright Scholar award in 2012 to go to Muslim University of Morogoro (MUM). My goal was to share my expertise as a technology and math educator with an institution in Africa, in a culture that was different from mine. I chose MUM because it is an Islamic university and, as a non-Muslim, I would have a unique experience teaching and living in this context. There were other differences between MUM and the College of Charleston. For example, the College of Charleston has a Teaching and Learning Team whose main goal is to support faculty members' integration of technology. At MUM, there is one technician and a computer lab with 20 broken-down computers for over 3,000 students. Internet connectivity was very limited. College of Charleston was started in 1770, and MUM was established in 2004. Therefore, at MUM, I would have plenty of opportunities to share my experiences, learn how to adapt to such conditions, and develop and enhance my intercultural competencies. MUM is a private university founded on Islamic values to which all Muslim students and faculty members are required to adhere. Everyone has to follow the conservative Islamic dress code. I was not exempted.

I was assigned to teach math methods and educational resources media courses. The media course had 1,200 students. I was to teach half of the students, while the other half was assigned to my colleague, who had been teaching at MUM for four years. Each one of us was assigned to teach at different times during the same day. We decided to co-teach each section at the assigned times.

The decision to co-teach was the result of (a) teaching experiences in different contexts; (b) the opportunity to share ideas to enhance the quality of learning for a large class, (c) the opportunity to use co-teaching as a model, and (d) the opportunity for professional development for both instructors. The co-teaching experience was mutually beneficial. The guidelines for collaboration included acknowledgment of each instructor's knowledge and contributions to the overall teaching and learning experience, and the freedom for each instructor to play multiple roles during the lectures. For example, if one instructor was leading the lecture, the other was free to elaborate ideas without the other instructor feeling disrespected (ndunda & Malecela, 2018).

Co-Teaching and Introduction of Technology as a Teaching and Learning Tool

The wireless network was installed in MUM at the beginning of 2012 with a goal of enabling students and faculty members to access electronic resources. However, there was one computer lab that had about 20 computers for 3,000 students. Most of the computers were not working. Very few students had personal computers and modems, and rarely used them to access online resources because this was not modeled to them.

At the College of Charleston, we had been using the WEBCT learning management system, and I was also using PBworks' free Educational Hub. My colleague and I decided to require our students to open an email account and join PBworks as our educational hub. Notes and information were posted in PBworks for our students to retrieve. Normally, we would have had to give a hard copy to the class president to take to the stationery store for students to purchase. We found that many students did not pay to get copies of the notes, and they did not come to class prepared. Out of the 1,200 students, 368 students (31%) registered to use PBworks and 188 (~16%) regularly accessed information through PBworks. Consequently, more students accessed the notes and other course materials in a more timely manner, and more students were better prepared for seminar discussions. Students with laptops did not have to print the notes and shared them with classmates who did not have them. This strategy significantly improved our teaching and learning in this course (ndunda & Malecela, 2018).

Another change that we implemented through our co-teaching was the use of two microphones to increase student-instructor interactions. During our course planning, we divided the topics that each one would lead. We decided who would play the supportive role, ensuring that the students, crowded in the small, climate-uncontrolled hall and others sitting outside, were attentive. I brought an additional microphone and projector with a better resolution that we used instead of the old, portable projectors the university provided. The supporting lecturer would make their way into the hall and give the students the microphone to ask questions or answer them. This made the learning more interactive. A survey given to the students about their experiences with co-teaching showed that the experience was positive. In total, 102 students responded to the online survey. Approximately 89% of respondents noted that the co-teaching approach was either very effective or effective, and 61% of them said they liked the interactive format of the course despite the large number of students (ndunda & Malecela, 2018). Approximately 93% of the students noted that the online component was either very important or important because they were able to access the information and prepare for class without waiting for the class president to take the notes to the stationery store. The students recommended that other lecturers use online collaborative sites like PBworks to share learning materials and other resources with them.

Distance Readiness Training for Instructors

In 2015, I received a Carnegie African Diaspora Fellowship to return to Tanzania to continue what I had started during my Fulbright Fellowship. My colleague and I decided to share our co-teaching experience, especially the impact of technology implementation. We conducted a workshop for instructors on distance education readiness so that they could prepare their course materials for online delivery. The training focused on (a) course development, including how to create effective syllabi; (b) how to build an online classroom; (c) components of an online classroom, including designing student activities in the online environment; (d) training students to access the online materials; (e) copyrights and intellectual property; and (f) open educational resources. This was work I had done in my institutions since 2004, when Dr. Cozart and I received $998,000 from the U.S. Department of Education (ndunda & Malecela, 2018).

The specific goals included (a) revision of dated content, (b) development of assessments and rubrics, and (c) integration of technology, including nontraditional technologies. Only 10 of the 30 instructors participated in the workshop. The low participation was due to lack of resources, including heavy teaching loads; internet accessibility; and over-reliance on adjuncts, who sometimes have to teach in different institutions within the same day. In addition, the university's WiFi was weak and unreliable. The faculty members were forced to purchase expensive internet bundles and use their phones as hotspots. I used some of my subsidy from Carnegie to pay for the internet bundles.

Lessons Learned from Co-Teaching and Introduction of Technology

My work with colleagues at MUM caused me to realize how privileged I was to be teaching in an institution where technology was readily available. The availability of technology in high income countries made me ignorant of the reality of my colleagues. I learned to be flexible, understanding, adaptable, and most of all appreciative of the challenges that my colleagues have to overcome to ensure that their students learn. I also learned to appreciate the dedication of my colleagues to teach in circumstances that were very challenging. In fact, at that time, the lecturers had not been paid for over three months. Available lecturers were extremely burdened with heavy teaching course loads. I learned from them how to use other types of apps (e.g., WhatsApp) that were not familiar to me at that time. I realized that if I wanted the instructors to participate in the workshops, I needed to provide data bundles and small stipends, and involve my colleagues in scheduling workshop dates. I learned that my colleagues would accept change and adopt technology only if they saw it as useful and easy to implement.

Workshop on Use of G-Suites for Education

My last opportunity to work with my colleagues at MUM was in 2017, when I was awarded another Carnegie African Diaspora Fellowship Program Award to go back to MUM to work with the instructors. The two main goals of the award were (a) to interview and observe instructors' integration of technology (computers, laptops, and handheld devices, including tablets and smartphones) in their teaching, and (b) develop and conduct workshops for lecturers to learn how to design courses that integrate technology to enhance instruction using portable devices—in particular, smartphones. We focused on how to use G Suite's free productivity tools to help students and faculty interact seamlessly and securely across devices..

Before the workshop, I had the opportunity to observe one instructor teaching. What I saw happening in the classroom reinforced the need for use of mobile technological devices in teaching. Classroom observation showed very limited use of technology. I observed a measurement and evaluation course that was taught by an adjunct faculty member. He was explaining how the coefficient correlation formula is derived on the whiteboard. He had over 200 students in a crowded hall at midday just before the midday prayers during Ramadan. This was a particularly hot day. The content and the conditions made it extremely difficult for the students and the instructor. He did not set up the computer to use the projector. Many students were completely lost, and he had no way of interacting with them to gauge their understanding. Students made a great effort to understand what was being taught. I could appreciate their anxiety given that I have a math degree and was struggling to follow his explanations. As I walked around, I saw students holding their smartphones, reading messages on WhatsApp.

The instructor did not set up the projector on this day. The process of setting up the projector was always a challenge for many lecturers, especially adjuncts who come in to teach one or two courses, then leave to teach elsewhere on the same day. The use of smartphones to search for information, such as the formula (in this case, the correlation coefficient formula) and its meaning, would have been helpful to the students. As I walked among the students, some asked me how to interpret the correlation data; they wanted to know what positive, negative, and zero correlations meant. I asked one student to make a guess, then look up the meaning on his smartphone. He made a guess that gave him an idea of what the best choice was. When he checked the answer using his smartphone, he found that his interpretation of the data was correct, and he was very satisfied to receive this feedback. He would not have had a chance to ask his instructor this question because the lecturer left immediately after delivering the lecture, most likely to head to another institution.

To support more instructors to use technology in their teaching, we developed a three-day workshop focusing on the integration of educational technologies in teaching and learning. We specifically focused on Google suites for education. Initially, the workshop was supposed to be for two days. However, the Deputy Vice Chancellor of Academics requested that we add a third day to the workshop. The workshop was attended by 30 lecturers.

A post-workshop survey given to the participants was completed by 18 out of the 30 participants. The results showed that almost all lecturers (94%) own a smartphone and use it mostly for personal communication or money transfer, but not for educational purposes. As Matinde (2016) observes, there is an increase in global smartphone proliferation, especially in Africa. Unfortunately, the instructors did not use theirs as teaching or learning tools. There was an over-reliance on the laptop and projector when it worked. In the workshops we showed instructors how to use Google apps, such as Google Docs, Google Slides, and Google Drive.

The lecturers noted that they need regular professional development opportunities as well as reliable interconnections. Their comments about the workshop included "I myself got eger [sic] to open it and learn more than before"; "technology integration is very important to facilitate teaching, but in order to get its fruits fully there should be time for workshops for teachers and a thorough training for students so as to ensure a good product in teaching and learning process"; and " we need to cope with changes in academic arena—today technology is everything in education." The instructors noted that such workshops should be provided quarterly or every six months (Survey, 2017, as cited in Ndunda & Malecela, 2018).

Discussions

I learned many valuable lessons from working with instructors at MUM. The co-teaching experience provided a rich environment for my colleague and I to learn from and with each other. My colleague served as a language and cultural interpreter/

mediator/broker for me. There were many times when I could have reacted/responded to students or things that happened in the classroom, such as a female student fainting, in ways that could have been very offensive in an Islamic context. The instructors who attended the workshop also had the opportunity to review their syllabi and learn some new strategies of integrating technology in their content. We updated the educational media course and aligned the goals with 21st-century skills for students.

I do not know how many instructors continued to integrate technology in their teaching between 2017 and 2019. However, we can deduce that these instructors had a head start and were better equipped to use smartphones during the pandemic. We did not explore the extent to which technology was accepted as per the Unified Theory of Acceptance and Use of Technology (UTAUT). The online survey completed at the end of the workshops indicated that the instructors thought that technology integration is important. However, they needed more frequent professional development opportunities and resources to fully prepare to integrate technology.

Overall, the instructors were very positive about integrating technology in their content areas and using Moodle as the learning management system. They agreed that technology can make a difference in teaching and learning in a country where there are limited resources. Smartphones and other mobile technologies can be used to deliver instruction. How much change then took place? As Fullan (2001) noted, change should be understood as a journey, not a blueprint; problems should be accepted as inevitable and should be embraced as friends; and the individual should not be lost in the collective.

The biggest lesson learned is the importance of using any technology that is available—improvise it and be creative, adaptable, and flexible. Also, train students about safety and how to use smartphones to access information online. Teach them about selecting the most relevant choice, sources of information, and copyright issues.

i) Teach students to be responsible and independent learners and allow them to use their smartphones in class to look up information.

ii) In class, ask the students to look up words—teach them to use Google and select the meaning that is most appropriate for the context.

iii) Have students use smartphones for collaborative brainstorming, using simple collaboration and polling tools, such as Google Docs, Jamboard, Poll Everywhere.

Conclusion

I learned many lessons from my experiences working with my MUM colleagues. It became clear that smartphones are readily available and have great potential for providing educational opportunities. It is important to harness this technology as a teaching and learning tool. To do so, it is important to train educators how to use tools and access online resources for teaching and learning. Over-reliance on dated textbooks is restrictive and contrary to a teaching and learning approach that values creativity and innovation, and promotes critical thinking skills.

The use of technology like smartphones as teaching and learning tools can address some educational access gaps that exist in many African communities. The significant growth in the number of students going to school in East African countries, such as Tanzania, is not matched with resources/textbooks for these children. It is common for a classroom of 100 students to have only one textbook. In addition, there is still a large population of children who do not attend formal education or drop out of elementary or secondary school.

Distance education is not a new phenomenon in Africa. Providing access to technology and online learning resources is the first step. The end goal is to efficiently use these tools to ensure that students' levels of competence are maintained even when in-person learning is not an option. There are existing challenges that need to be overcome. Such hurdles include the lack of broadband internet connectivity, especially in rural areas and among the urban poor. Other challenges are unavailability of locally created courses, language barriers, lack of training and professional development opportunities, and the production of mobile-friendly course materials (Ischebeck, 2020).

University of South Africa (Unisa), a long-distance-dedicated university, provides a great example of sustained long-distance education and e-learning. Unisa currently offers educational opportunities to over 400,000 students from across South Africa, Africa, and other parts of the world, and enrolls almost one-third of all South African students. Founded in 1873 as the College of the Cape of Good Hope, the institution became the first public higher learning institution in the world to teach exclusively by way of distance education in 1946. Throughout the years, Unisa was possibly the only university in South Africa to have provided all people with entry to education, irrespective of race, color, or creed, and has recently adopted e-learning as one of its main platforms. The importance of this lies in Unisa's conviction to overcome the socioeconomic, political, race, and gender issues prevalent in South Africa and Africa today (Facts & Figures, 2020).

Given what Unisa has achieved, as well as the lessons learned from the pandemic, it is safe to conclude that e-learning in Africa is a necessity. It can serve as an essential part of breaking down the barriers to higher education in Africa. E-learning can potentially create the desired impact of efficiently widening access to higher education, as it is a much cheaper alternative to the traditional in-person setting (Department of Higher Education and Training, 2021). Well-prepared e-learning content can enable institutions to provide education to a larger population and differentiate course materials pedagogically, where different learning styles can be more readily accommodated. (Ischebeck, 2020). For example, Coursera provides high-quality education to a multitude of students across the world.

However, the existing hurdles that widen Africa's education gap, such as internet and connectivity issues, especially in rural areas, have to be addressed. When I am in the village, I spend over $2 per day for data only. This is too expensive for someone who lives on $2 per day. However, rural communities do not have broadband internet connectivity.

Partnerships with large internet companies and edtech providers are steps to building teacher skills. For example, in South Africa, Microsoft has trained thousands of instructors on distance learning using information and communication technologies. This will impact thousands of learners. These types of initiatives need to be rolled out across other parts of Africa for e-learning to succeed (Ischebeck, 2020).

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Online Education/Virtual Collaboration/
Mitigating the Digital Divide

A Model for Transforming Traditional Instruction to Online Learning Environments in Africa

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ABSTRACT

Effective teaching and learning online pose several institutional challenges worldwide. The philosophy of teaching at any institution should influence teaching online. Should courses be taught entirely online, or in a hybrid of the traditional classroom and online? What kinds of hardware, networks, and software are available for online course delivery? How should courses be developed or converted for effective online teaching and learning? What alternative platforms and tools are available for use in an effective online classroom? This paper examines current theory and practices of online teaching, in efforts to promote the best practices of effective online teaching and learning at African institutions. A comprehensive model is presented for exploring alternative resources and techniques that can be used to set up courses, teach and assess learning in an online classroom. The paper features examples of effective online course design, syllabus, discussion forums, student activities and assessment for use at African institutions. The paper details free and commercial online web resources for incorporating best online teaching practices into existing traditional classroom instruction, to help more African faculty members to engage in effective online teaching and learning.

Introduction

Online teaching and learning principles are important depictions of hypotheses for predicting and explaining current and emerging best practices. All advocators of online teaching, particularly in Africa, ought to investigate the goals, environments, supporting tools that are essential to online learning in individual academic disciplines (Barab & Duffy, 2000; Dick & Carey, 1990; Jonassen, 1999). Certainly, online learning involves the use of tools and procedures to manage activities in learning environments.

Today, there is a variety of online courses and degree programs via the internet. But what are the crucial components of real-time online instruction? Creators of online courses are faced with the challenge of knowing the subtleties of discovering and partaking in asynchronous mediums (Xin & Feenberg, 2005). Online instruction should stimulate crucial learning and engage learners in computer-supported collaborative learning (Xin & Feenberg, 2005). Online learning is also called E-Learning with some well-defined theoretical foundations (Anderson, 2008; Xin & Feenberg, 2005). Based on the existing theories of effective online teaching and learning, this paper presents practical strategies for creating new and converting existing traditional courses for delivery in online modes at African universities. The paper discusses the current and ongoing online activities at Bugema University in Africa, and the continued challenges of implementing real-time online courses.

Models for Online Teaching and Learning in Africa

Online course contents at African institutions can be effectively delivered in technology enhanced learning environments that are amenable to foster telecommunications and assessments of learning among learners with synchronous and asynchronous communication tools for collaboration. African universities that require personal individual student interaction, authorship, peer mediation and reviews should consider these alternative tools for communication in online courses. Fortunately however, African educators can become facilitators in alternative environments such as knowledge building via critical inquiry; collaborative learning and problem solving that includes online discussions, clarifications, and debates on tasks that facilitate personal constructive engagement in which the locus of control is in the hands of the students. We need online African learners to become more inherently ambitious, autonomous, and serious intellectuals.

Online teaching and learning principles include: distributed and embodied cognition (group assignments, involvement in questions about ideas and practices); promotion of areas of study with communities of practice; use of discussions and posts to encourage social interactions; exploration of questions, individual reflections with discovery learning, tolerance, adaptation and steadiness processes (Scardamalia & Bereiter, 1994); and wholistic interactions with materials and individuals with the principle of connectivism (Siemens, 2004).

Course Management Systems with Software and Hardware in Africa

At African institutions, course management systems (CMSs) or learning management systems (LMSs) such as Blackboard, Moodle, Desire2Learn, Angel Learning Management, Scholar 360, and coVis will provide tools for instantaneous chatting, discussion forums and administration, and file and folder exchanges among students and teachers; they are valuable for promoting collaborative learning among students and teachers in Africa. There is a variety of software for supporting synchronous and asynchronous communication beyond the CMS or LMS because the available shell tools in a LMS might not be appropriate for voice- or video-enabled chat. There are web-based (w), client-based © for installation on a local machine, server-side (s) software, or hardware (h) or a combination of tools for supporting communication in LMS. At African institutions, here are tools that can facilitate communications in applications such as (1) text and audio/video chat, for example Web Messenger (w), iChat (c, s), and Skype (c); (2) whiteboard applications and hardware, for example Mimio (h, s) and Smartboard (h, s); (3) sharing computer desktop platforms such as Windows Remote Desktop Connection (c), Apple Remote Desktop (c), and Virtual Networking Client (c); and (4) collaboration and meeting platforms, such as Elluminate (w), MediaWiki (w, s), WetPaint Free Wikis (w).

Practical Samples of Online Course Creation Strategies and Online Self-Learning Tools

Questions natural arise on how African teachers should be creating courses to promote effective teaching and learning online. Online instructors should be capable of designing a course backward template that details the course description, learning objectives, short module objectives, learning activities, assessments and resources as outlined in Appendix A for a course module of an Advanced Cryptography course. A generic model for presenting effective online courses in a uniform format is outlined in Appendix B. The comprehensive details for crafting effective online course contents are illustrated in Appendix C.

Self-paced online learning tools are valuable for students to learn difficult course materials such as quantitative security risk assessments and elements of number theory in Cryptography. In fact, we have implemented a tool called MySecurityLab to facilitate security risk assessments by faculty and students in Cybersecurity, Information Technology, and Information Security degree programs, and by security practitioners in industry. The online tool contains a variety of learning and practice modules of security risk assessment scenarios, comprehensive case-based and scenario-based quantitative security risk assessment learning, and practice modules. The generic online tool allows students, faculty members, and industry personnel to define their own security risk scenarios and to perform quantitative risk assessments. We have implemented another self-paced learning tool called Another MySecurityLab for use by information technology students and employees in organizations to learn the administration of technical security controls in stand-alone and network systems.

Challenges and Opportunities for Online Teaching and Learning in Africa

Without a doubt, African institutions will continue to be restricted in implementing effective online teaching and learning strategies in classrooms due to the lack of available modernized hardware, software, and technology. According to Ruth Wilson (2003), there is a fear that "increasing the quantity of course material delivered electronically may actually inhibit access: students' technical skills vary, and less competent computer users could be disadvantaged." The lack of time, skills, and support for implementing electronic learning ideas will remain a challenge at African institutions.

Online learning arises mainly in asynchronous environments (Anderson, 2008; Garrison et al., 2000) with the risks of timely available visual and verbal communications required for clarifications in e-learning (Xin & Feenberg, 2005). Consequently, African teachers will continue to face the barriers of understanding and collecting data about student engagements for learning. Students in online learning environments often sieve and select pertinent information for use in navigating through problem solving of real-world task with exemplar application materials and knowledge building, augment existing cognitive processes. However, there are alternative avenues for African teachers to use for providing access to process, interact and retain the information of students (Driscoll, 2005; Schunk, 2008).

The worldwide debate on less teacher-centered to become more focus on student-centered learning is alive. Constructivist strategies and principles have been advocated for moving the roles of teachers worldwide to become arbiters of acquiring knowledge, rather than the facilitator sources of information for online learning (Reigeluth, 1999; Xin & Feenberg, 2005). Rapidly changing course information are often conveyed to students via site links and hyperlinks that change with times. African teachers ought to level up with the dynamically changing information on the Internet and be capable of providing examples of switching into current course materials and websites of information.

Remarks

There are several interwoven constraints that may hinder the implementation of the models and strategies for delivering effective teaching and learning presented in this paper. Clearly, at many African institutions, there is no release time for faculty members to develop online course. Moreover, there might be the lack of training, support, and incentives for faculty members in Africa to engage in cumbersome developments on online training tools, courses, and environments for students. Learning management systems are expensive to acquire and maintain. How will African institutions sustain the need to maintain their hardware and software given the limited budget constrains?

With our current Carnegie African Diaspora Fellowship Program (CADFP) funding, the design and implementation of effective online courses for graduate programs in the areas of data science and cybersecurity will be phased in at Bugema University beginning in January 2022.

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APPENDIX A

Backward Course Design Template for Advanced Cryptography

Cyber Module Description

This module covers cryptographic properties, mathematical ideas, complexity theoretic principles, privacy, and digital signature algorithms for complete understanding of advanced cryptographic methods.

Cyber Module Learning Objectives

After completing this module students will be able to:

1. Appraise the security of advanced cryptographic properties
2. Identify the mathematical principles underneath advanced cryptographic algorithms
3. Describe the complexity-theoretic foundations of cryptography
4. Implement advanced cryptographic algorithms to provide privacy and verification
5. Implement advanced two-party and multi-party protocols in cryptographic systems

SHORT MODULE LEARNING OBJECTIVES *(List the Module Learning Objective(s) that align with the corresponding Course Learning Objective)*	**ASSESSMENTS** *(List the Assessment(s) that align with the corresponding Module Learning Objective(s))*	**ACTIVITIES** *(List the Activities that align with the corresponding Assessment(s))*	**RESOURCES** *(List the Learning Materials/Resources necessary to complete corresponding Activities)*
1. Cryptographic Properties 2. Mathematical Principles 3. Complexity-Theoretic Principles 4. Privacy and Verification Algorithms 5. Two-Party and Multi-Party Protocols	1. Assessment for students to demonstrate mastery of Course/Module Learning Objective 1 2. Assessment for students to demonstrate mastery of Course/Module Learning Objective 2 3. Assessment for students to demonstrate mastery of Course/Module Learning Objective 3	1. Activities to help students practice for Assessment 1 2. Activities to help students practice for Assessment 2 3. Activities to help students practice for Assessment 3	1. Resources needed for students to complete Activities/Assessments for Course/Module Learning Objective 1 2. Resources needed for students to complete Activities/Assessments for Course/Module Learning Objective 2 3. Resources needed for students to complete Activities/Assessments for Course/Module Learning Objective 3

APPENDIX B

A Template for Designing Uniformly Formatted Courses for Online Instruction

Module Name	
# Module Description and Learning Objectives	
# Learning Objectives	
# Quizzes	
# Assignments	
# Discussions	
Faculty Name/s	
Email Addresses	
Pre-Req Knowledge or Courses – What should students know prior to taking this module?	No prior knowledge expected.

Module Description and Learning Objectives
Description (1-3 sentences)

This module covers/introduces…

Learning Objectives
(List of the 3–5 Learning Objectives that will be covered in this module) After completing this module students will be able to:
1.
2.
3.

Module Introduction—Module Name

APPENDIX B (CONTINUED)

LEARNING OBJECTIVE 1—LO SHORT TITLE

Introduction

Knowledge

Key Points to Remember

Practice

Reflection [Topic Title] {Forum Title will be LO Title} {Discussion Topic Title and Description}

Assessment—Assignment 1

Assessment—Quiz 1

LEARNING OBJECTIVE 2—LO SHORT TITLE

Introduction

Knowledge

Key Points to Remember

Reflection [Topic Title] {Forum Title will be LO Title} {Discussion Topic Title and Description}

Assessment—Assignment 2

Assessment—Quiz 2

LEARNING OBJECTIVE 3—LO SHORT TITLE

Introduction

Knowledge

Key Points to Remember

Reflection [Topic Title] {Forum Title will be LO Title} {Discussion Topic Title and Description}

Assessment—Assignment

Assessment—Quiz 3

Test Your Knowledge
Provide a case study or assessment that covers aspects of all learning objectives within this module – a final assessment of learning for the module.

APPENDIX B (CONTINUED)

FINAL ASSIGNMENT FINAL QUIZ

Summary and Additional Resources

Summary
Brief overview of what was learned in this module

Additional Resources
Links to additional articles, videos, or resources

Instructor Resources

Faculty Notes
If there are keys or answers to given problems in the learning objective practice and assessment, please provide the keys of assessment or answers to be used for faculty.

APPENDIX C

Detailed Sample of Online Course Module for Advanced Cryptography

Module Name	Advanced Cryptography
# Module Description and Learning Objectives	1
# Learning Objectives	5
# Quizzes	5
# Assignments	5
# Discussions	0
Faculty Name/s	Amos Olagunju
Email Addresses	aoolagunju@stcloudstate.edu
Pre-Req Knowledge or Courses – What should students know prior to taking this module?	Students should have completed a bachelor's degree that requires the knowledge of cryptography.

Module Description and Learning Objectives

This module covers cryptographic properties, mathematical ideas, complexity theoretic principles, privacy, and digital signature algorithms for complete understanding of advanced cryptographic methods.

Learning Objectives

After completing this module students will be able to:

1. Appraise the security of advanced cryptographic properties
2. Identify the mathematical principles underneath advanced cryptographic algorithms
3. Describe the complexity-theoretic foundations of cryptography
4. Implement advanced cryptographic algorithms to provide privacy and verification
5. Implement advanced two-party and multi-party protocols in cryptographic systems

APPENDIX C (CONTINUED)

LEARNING OBJECTIVE 1—CRYPTOGRAPHIC PROPERTIES

Introduction

Cryptography offers techniques with characteristics that allow a party to communicate securely in the presence of antagonists.

The design of information like equipment blueprints or cryptographic algorithm specifics cannot be protected. The Kreckhoffs's second condition (Kahn, 1967, p.235) of a cryptosystem was that "compromise of the system should not inconvenience the correspondents."

Knowledge

The sought-after security characteristics of cryptosystems consist of:

- Privacy that guarantees no enemy can find out any pertinent information about the transmitted message.
- Authentication that ensures the arriving message to the recipient came from the claimed transmitter.
- Signatures that enable the message recipient to prove to a third party the inward message came from the claimed signatory.
- Instantaneous exchange of signatures that guarantees secure delivery of transactions and goods between a sender and receiver.
- Harmonization that enables communication parties match up activities despite the existence of foes.
- Cooperation tolerance that allows sought after security characteristics to remain in effect if the number of adversaries is below the limit.
- Randomness required to perform randomized computations (Gill, 1974).
- Physical protection that enables each party to protect secret keys from enemies. The security design properties of information systems are:
- Channel properties for communication can occasionally be taken advantage of; for instance, Alpern and Schnider (1983) illustrate how to securely communicate on channels in ways that a listener cannot recognize the broadcaster of each bit. Eavesdropper with less reliable reception than the receiver, can be conquered (Wyner, 1975), or when the channel is analog instead of digital (Wyner, 1979a; Wyner, 1979b).
- The characteristics of important consequences of ill-used channels (Bennett et al., 1983). Moreover, adversaries without the specifics of application of spread-spectrum channels cannot discern them (Gerhardt & Dixon, 1977).
- Information-theoretic property that make systems like Vernam one-time pad (Kahn, 1967) secure since an adversary has insufficient information to break the code.

Key Points to Remember

- Computational complexity theory is used to design resilient systems to make the work of an enemy computationally infeasible.
- Cryptographic operators such as one-way functions and pseudo-random sequence generators are used to construct secure cryptographic systems.
- Cryptographic protocols are used to indicate initiation and response to messages, and initialization requirements.

APPENDIX C (CONTINUED)

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Assessment—Assignment 1

Compare and contrast the RSA algorithm and RSA-ECC Algorithm in terms of usage for signatures, authentication, and privacy.

Assessment—Quiz 1

Discuss how the designs of protocols and operations are independent.

LEARNING OBJECTIVE 2—MATHEMATICAL PRINCIPLES

Introduction

Most cryptographic methods rely deeply on notions of number theory. This module reviews certain rudimentary member-theoretic and computational details. More in depth coverage of simple number theory is available in Niven and Zuckerman, Le Veque, and Angluin (1972; 1977; 1982). An outstanding review of the difficulties with factoring integers, testing primality, and computing discrete logarithms is presented in Lenstra and Lenstra (1990).

The foundation of various cryptosystems is the computational complexity of factoring a large composite number into two large prime numbers. It is easier to determine whether a given number is prime or composite than to compute the prime factors of a composite integer. The creation of cryptographic operators often relies on the discovery large prime numbers.

There are two types of effective algorithms that execute in polynomial time to generate random k-bit prime numbers (Adleman & Huang, 1987; Adleman et al., 1983; Goldwasser & Killian, 1986; Rabin, 1980; Solovay & Strassen, 1977): Monte Carlo probabilistic algorithms do end in polynomial time all the time but may go wrong with small probability –they are reasonably efficient in practical applications. Las Vegas probabilistic algorithms always produce an accurate deterministic polynomial-time verifiable evidence of correctness –they execute in probable polynomial time. Moreover, Bach (1988) has designed an algorithm that makes use of primality testing to construct a random k-bit composite number in a factored format.

APPENDIX C (CONTINUED)

Knowledge

Suppose Z_n is the set of residue classes modulo n, and Z_n* is the multiplicative subgroup of Z_n of those residues that are relatively prime to n. the Euler's totient function ϕ(n) =|Z_n*|. Suppose Qn is the set of all quadratic residues (or squares) modulo n. That is, x ϵ Q_n if-and-only-if there exists a y such that x≡y^2 mod n.

The Jacobi symbol ( ) is defined for any X ϵ Z_n* and its values are in {-1, 1}. The law of quadratic reciprocity is used to compute (x/n) even when the factorization of n cannot be determined. Suppose Jn is the set {x|x ϵ Z_n* and ( )= -1}, and Q_n is the set of pseudo-squares modulo n (values of Jn that do not belong to Q̣n). If n is the product of two primes then |Q_n|=| Q_n|, and the function fy(x) = y.x maps Q̣n one-to-one onto Q_n for any pseudo-square y.

The foundation of some cryptosystems is the difficulty in solving the quadratic residuosity problem. That is, for any composite n and x ϵ J_n, investigate if x is a square or a pseudo-square modulo n.

Forming and obtaining square roots modulo n are useful operations in the design of cryptographic operators. X is a square root of y modulo n, only if X^2 ≡ y mod n. with $ prime factors of n, X can have up to $2^\$$ square roots. It has been ascertained by Rabin (1979) that factoring n is comparable to computing square roots modulo n in polynomial-time. In other words, with an efficient for obtaining square roots modulo n, it is possible to create an efficient algorithm for factoring n, and vice versa.

Key Points to Remember

- If n = pq, with p and q primes, and p ≡ 3 mod 4 and q ≡3 mod 4, then squaring modulo n effects a permutation of Q_n.
- The modular exponentiation, X^e mod n is one-to-one over Z_n if gcd (e, ϕ(n)) = 1, (Rivest et al., 1978). Modular exponentiation function is useful in public-key cryptosystems.
- The inverse operation to modular exponentiation will depend on whether to solve for e or x. the discrete logarithm of y modulo n with base x, X^e ≡ y mod n is used to compute an e (if any exists). Computing the e-th root of y modulo n is used to solve for x (if any) such that X^e ≡ y mod n.

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APPENDIX C (CONTINUED)

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Assessment—Assignment 2

One algorithm for Computing YX mod n Function ModulusExp (Y, X, n) is as follows:

```
{ int a=X, b=1, c=Y;
  While ( a != 0)
    { if ( a % 2 == 0) /* a mod 2 = 0 implies a is even
       { a = a/2;
         c = c*c mod n; /* square c and do nothing with b
         } else /* a is odd
       { a = a-1;
         b=b*c mod n; /*do nothing with c
       }
  };
  return b; }
```

Implement this algorithm using a conventional programming language and evaluate its efficiency.

Assessment—Quiz 2

List and justify the mathematical principles underneath AES, Diffie-Hellman, Rabin, and RSA algorithms.

LEARNING OBJECTIVE 3—COMPLEXITY-THEORETIC PRINCIPLES

Introduction

Computational complexity theory is the fundamental basis of recent cryptography. Today, there are cryptographic theories that are predicated on unproven postulations of complexity. These theories are used to solve some difficult problems by relying on operators such as one-way and trapdoor functions. This module is focused on a review of cryptographic operators.

Knowledge

Checksums and one-way functions

Checksums are the easiest functions for use in validating whether transmitted messages have been altered. For instance, a function f(M) = M(x) mod P(k) over a polynomial M(x) in Galois Field 2, GF(2) can be used to interpret bits of M as a checksum. When the pair (M, f(M)) is conveyed over a noisy channel, transmission errors can be sensed for the inward pair (x, y) that does not fulfill y = f(x). Unfortunately, this strategy cannot be used to ascertain any mischievous meddling by an antagonist, even though the tactic is very effective in identifying random errors. Consequently, checksums are inappropriate for use in classic cryptographic applications.

A one-way function takes a message M and effectively generates a value f(M) in a way that it is computationally impossible for an enemy, given f(M) = z, to discovers any message M′ at all (as well as M′ = M) such that f(M′) = z. Moreover, given f, it is infeasible for an enemy to derive any pair of messages (x, y) such that f(x) = f(y). The function f is said to be claw-free since it is impossible in practice to invert f at a given point z (Yuval, 1979).

There is an openly accessible one-way function that is suitable for many applications (Evans et al., 1974). In a time-shared computer system, for each password w, the value of f(w) is stored rather than keeping a table of login passwords. Passwords can be validated at login and even the system administrator cannot infer any password by looking at the stored table (Evans et al., 1974).

APPENDIX C (CONTINUED)

Trapdoor functions
A trapdoor function f has a secret inverse function f^{-1} (trapdoor) that enables its owner to efficiently invert at f at any time. Note that f should be easy to compute but computationally infeasible to invert without the awareness of f^{-1}. Trapdoor functions are the foundation for public key cryptography.

One-way and trapdoor predicates
A one-way predicate (Goldwasser & Micali, 1982, 1984) is a Boolean function B: {0, 1}*→{0, 1} such that (a) with input V ϵ {0,1} and 1^k, in probable polynomial time it is possible to select an X such that B(x) = V and |x| ≤ k, randomly and uniformly from all sets of X; (b) for all C > 0 and all adequately large k, no enemy in no polynomial-time, given x ϵ {0,1} such that $1/2+1/K^c$.

A trapdoor predicate is a one-way predicate in which for every k, the size of trapdoor information tk is bounded by a polynomial in and its knowledge allows the polynomial-time computation of B(x) for all x such that |x| ≤ k.

Crafting accurate complexity-theories suppositions

Asymptotic complexity is the basis of computational complexity theory. So as the size of a problem gets huge what transpires? The concepts of computational complexity theory are applicable to a family of cryptosystems or cryptographic functions characterized by a security parameter k. There may be a specific cryptosystem or function, or a family of cryptosystems or functions for each value of the security parameter k. A cryptosystem with security parameter k might have all strings of length k or an appropriate polynomial function of k for the inputs, outputs, and keys. The larger the security parameter becomes, the more the complexity of mathematical problems underneath the cryptosystem, and consequently the more security provided by the cryptographic algorithm in the system. But, since P ≠ NP, a "proof" of security will rely on the hypothesis that specific computational problems become difficult as the inputs get larger.

As an illustration, the conjecture that factoring integers is difficult can be reinforced as: for any probabilistic polynomial-time factorizing algorithm f, for all constants C > 0 and amply large k, the probability that f can generate a nontrivial divisor of its input (the product of two randomly selected k-bit primes) is at most $1/K^c$. Then a creative proof of security that demonstrates the ability of an enemy to setback the cryptographic system in a far less time will negate the presumed hard difficult problem.

Key Points to Remember

- In public-key cryptosystems, it is more efficient to sign f(M) instead of M itself because M may be very lengthy but f can be designed to result in a fixed-length, result –f(M) is called a message digest or fingerprint for M.
- In the one-way predicate, the probability is taken over the random selections by the enemy and X such that |x| ≤ k.
- The basics of one-way and trapdoor predicates are the foundation for the probabilistic creations for providing privacy and generating pseudo-random numbers.

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APPENDIX C (CONTINUED)

Assessment—Assignment 3

1. It is possible to prove that there is an algorithm that given a Turing machine M (of the type with a read/only input tape and a work tape), an input x and a space bound s, decides whether M(x) accepts and uses ≤ s bits of space; the algorithm uses O(s) bits of space. Using the above result, argue that if s(n) > log n is a function computable in O(s(n)) space, then SPACE(s(n) log n) 6⊆ SPACE(s(n)).
2. Design and implement an algorithm for validating whether a string of ones and zeros is a palindrome. What is the efficiency of your algorithm and why?

Assessment—Quiz 3

1. Show that if P = NP for decision problems, then every NP search problem can be solved in polynomial time.
2. Describe a function f for electronically signing a message and the issues it must resolve.

LEARNING OBJECTIVE 4—PRIVACY AND VERIFICATION ALGORITHMS

Introduction
The objective of privacy is to make sure that an enemy that eavesdrops on a message transmission cannot discover any tangible information from it. The conventional secret-key cryptosystems such as DES and AES use straight forward techniques to provide privacy for message transmission.

The problem with the secret-key cryptosystem is the distribution of the shared secret key to the communicating parties. To overcome this problem, Diffie and Hellman (1976) developed a clever exponential key exchange procedure. Suppose the two communicating parties A and B agree on a large prime P and generator g of the multiplicative group Z_p*. Then A and B select large secret integers a and b respectively, and interchange g^a mod p and g^b mod p with each other. Consequently, A and B can compute the same key g^{ba} mod p = g^{ab} mod p.

Knowledge
There is a variety of key verification algorithms in the literature. In 1977 Rivest, Shamir, and Adleman propositioned a public-key cryptosystem in which a pair (e, n) of integers, such that n = p*q with p and q two large primes, is the public key of each user, and gcd (e, ϕ(n)) = 1. The encryption operation C = M^e mod n is used to encrypt a message M to obtain the ciphertext C. The decryption operation is M = C^d mod n, where the private key is the pair (d, n) with d*e ≡ 1(mod ϕ (n)).

There is a range of public-key cryptosystems for providing privacy that are based on the knapsack problem. Given a vector a = (a_1, a_2 , . . . , a^n) of integers and a goal value C, the NP-complete (Garey & Johnson, 1979) knapsack problem is to decide if there exists a length-n vector x of zeros and ones such that a*x=c. The knapsack problem is used as public-key cryptosystem as follows: create a knapsack vector “a” as a public-key and publish it; a sender can transmit a length-n bit vector message M to you by computing the inner product C = M*a; to decrypt the ciphertext C, construct a trapdoor function into the knapsack to make the encryption operation one-to-one for easier decryption.

The probabilistic cryptosystems make use of one-way and trapdoor functions primitives to provide verifiable public-key encryption. Goldwasser and Micali (1982, 1984) pioneered the use randomized techniques to achieve a provable level of security in a probabilistic cryptosystem. In the probabilistic public-key encryption scheme Bob can send M = m_1, m_2, . . . , m_k in binary to Alice as follows:

APPENDIX C (CONTINUED)

```
For (i= 1 to k)
{
    Bob randomly selects r ϵ Zn;
    If Mi = 0 send Ci = r^2 mod n to Alice;
    If Mi = 1 send Ci = y.r^2 mod n to Alice.
}
```

Bob is either sending a random square or a random pseudo-square to Alice. Alice needs to include y in her public key for Bob to use in generating random pseudo-squares. Since Alice can recognize squares modulo n, she can decode the message.

Key Points to Remember

- Many knapsack schemes are susceptible to ingenious analysis and the use of powerful L^3 algorithm (Lenstra et al., 1982) for performing in Lattices; see Merkle and Hellman (1978), Shamir (1979), and Odlyzko (1984).
- Some knapsack schemes, such as the Chor-Rivest scheme (1988) and the multiplicative versions (Merkle & Hellman, 1978), remain unbroken.

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APPENDIX C (CONTINUED)

Assessment—Assignment 4

1. Write a program that makes use of the probabilistic encryption for Alice and Bob to exchange keys.
2. Design and implement a simple public-key cryptosystem using a knapsack scheme. Comment on the strengths and weaknesses of your algorithm.

Assessment—Quiz 4

1. Why are probabilistic encryption schemes immune to vulnerability of adversaries?
2. Why are information and signatures hidden in trapdoor knapsacks unbreakable?

LEARNING OBJECTIVE 5—TWO-PARTY AND MULTI-PARTY PROTOCOLS

Introduction

A challenge-response protocol is useful in the identification of a friend or foe between X and Y as follows: (a) X and Y share a secret key k; (b) X generate a random value V and transmits it to Y; (c) Y encrypts V using key k and transmits it to X; (d) X matches the inward ciphertext to the one X encrypts V with k—a match indicates Y is friendly party, otherwise the other party is an impersonator. Herein is a few two-party and multi-party cryptographic problems that have received attention in the literature.

Knowledge

The problem of flipping a coin over the phone has been recommended for use in trust validation by Blum (1982) supposes there is no trust between X and Y. They need an unbiased procedure that can generate a “head” or “tail.” X can apply probabilistic encryption to send encrypted types of the message’s “heads” and “tails” to Y. Y selects one of the ciphertexts and points out the choice to X. X finally discloses the secret encryption key to Y. There are fascinating variants and refinements of this problem in the literature (Cleve, 1986; Goldwasser & Micali, 1982).

An oblivious transfer is a strange protocol in which X transfers a message to Y in a way that: (a) the probability of Y receiving the message is 0.5, and the probability of Y receiving a rubbish is 0.5; (b) X has no knowledge that Y received the message at the end of this protocol. Although this protocol seems weird, there are some useful applications of it in the literature (Berger et al., 1983; Rabin, 1981). Indeed, Kilian (1988) demonstrated that the capability to execute oblivions transfers is an adequately resilient primitive for implementing any two-party protocol.

The contract signing problem deals with the instantaneous, interchange of digital signatures. How should a two-party protocol to support instantaneous signatures, (in which no party can get the signature of the other prior to exchanging signature), be designed? There are some exciting solutions to this problem in the literature (Ben-Or et al., 1985; Even et al., 1983).

Chaum promoted the use of anonymous transactions and digital pseudonyms to safeguard the records and transactions of persons in a database. With the use of pseudonyms, individuals are guaranteed of confidentiality of the transactions input into electronic systems (1981; 1983).

Shamir pioneered the development of a protocol for sharing a secret among n people by dividing it into pieces such that, only subsets of k persons can reconstruct the key (Shamir, 1979). Chor et al. (1985) noted that the protocol failed to cope with a dishonest secret dealer and some deceitful player. Consequently, they designed a verifiable secret sharing protocol based on the intractability of factoring.

APPENDIX C (CONTINUED)

Key Points to Remember

- In the usual multi-party protocol problem, a few parties work harmoniously on undertakings toward common goals.
- Multi-party protocols can be used in secret sharing, voting, anonymous transactions, and activities by honest parties.

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APPENDIX C (CONTINUED)

Assessment—Assignment 5
How might one play a game of cards, such as poker over the telephone? Design and implement a strategy to allow Bob and Alice to use the two-party protocol of RSA to securely play poker over the phone.

Assessment—Quiz 5
Is the challenge-response protocol secure? Why or why not?

Test Your Knowledge

1. List three approaches to message authentication.
2. List and briefly define three applications of a public-key cryptosystem.
3. What is a digital signature, and how is it implemented?

FINAL ASSIGNMENT

1. Suppose H(m) is a collision-resistant function that maps a message of arbitrary bit length into n-bit hash value. Is it true that, for all messages x, x' with x ≠ x', we have H(x) ≠ H(x')? Explain your answer.
2. Write a program to read a plaintext (PT) such as "good", and a key (K) such as "huge" , convert each character of the PT and K to the decimal, binary and base 3 number representation, and generates the ciphertext (CT) as PT [XOR] K, display the encrypted CT and K as binary, base 3 and decimal numbers. The program should also provide the option to read a CT and K, generate PT = CT [XOR] K, and display the PT and K as binary, base 3 and decimal numbers.
3. Let $n_1, \dots, n_k$ be integers greater than 1, which are often called moduli or divisors. Let N be the product of the $n_1 \dots n_k$. The Chinese remainder theorem asserts that if the n_i are pairwise coprime, and if $a_1, \dots, a_k$ are integers such that $0 \le a_i < n_i$ for every $i=1$ to k, then there is one and only one integer x, such that $0 \le x < N$ and the remainder of the Euclidean division of x by n_i is a_i for every i. This may be restated as follows in term of congruence equations: If the n_i are pairwise coprime, and if $a, \dots, a_k$ are any integers, then there exists an integer x such that

$$\begin{aligned} x &\equiv a_1 \pmod{n_1} \\ &\vdots \\ x &\equiv a_k \pmod{n_k} \end{aligned},$$

and any two such x are congruent modulo N

Here is an example of a problem that can be solved with Chinese Remainder Theorem (CRT).

Some jolly friends are planning to celebrate your graduation at Red Lobster. When the waitress decides to sit four to a row, two friends are left over; when she decides to sit five to a row, three friends are left over; when she decides to sit three to a row, one friend is left over. What is the smallest possible number of jolly friends? Write a program to use the CRT to solve these kinds of problems.

APPENDIX C (CONTINUED)

SUMMARY AND ADDITIONAL RESOURCES

Summary
This module presented the cryptographic properties, mathematical ideas, complexity theoretic principles, privacy, and digital signature algorithms for complete understanding of advanced cryptographic methods.

Additional Resources

Mathematical Principles

1) Basic Mathematics behind Cryptography

Complexity Theoretic Principles

1) Computational complexity theory
2) Kowalczyk, C. Theory of one-way functions. Crypto-IT. http://www.crypto-it.net/eng/theory/one-way-function.html
3) Merkle, R. (1990.) One-way Hash Function and DES. In Brassard, G. (Ed.). Advances in Cryptology: Proceedings of CRYPTO '89 (pp. 428–446). Springer-Verlag. https://link.springer.com/content/pdf/10.1007%2F0-387-34805-0_40.pdf

Privacy and verification Algorithm

1) Zhang, D., & Kifer, D. (2017). Automating Differential Privacy Proofs. In *POPL '17: Proceedings of the 44th ACM SIGPLAN Symposium on Principles of Programming Languages*. Association for Computing Machinery. https://doi.org/10.1145/3009837.3009884
2) Kasse, J. P., Xu, L., deVrieze, P., & Bai, Y. (2019). Verifying for Compliance to Data Constraints in Collaborative Business Processes. In *Collaborative Networks and Digital Transformation* (pp. 259–270). https://doi.org/ 10.1007/978-3-030-28464-0_23

Two-Party and Multi-Party Protocols

1) Goyal, V., Mohassel, P., Smith, A. (2008). Efficient Two-Party and Multi-Party Computation Against Covert Adversaries. In Smart, N. (Ed.) Advances in Cryptology—EUROCRYPT 2008. EUROCRYPT 2008. *Lecture Notes in Computer Science, Vol. 4965*. Springer. https://doi.org/10.1007/978-3-540-78967-3_17

Instructor Resources

Solution to Quiz 1
The implementation of an abstract data type may be independent of its use. Protocol designers assume that operators with specific security properties exist prior to constructing protocols. Operator designers put forward the realization of operators, and then show that the intended operators satisfy the worked-for properties.

APPENDIX C (CONTINUED)

Solutions to Assignment 5 and Quiz 5

1) An eavesdropper will probably learn nothing about K from inquiring several values of r encrypted with key K.

2)

a. Alice (A) and Bob (B) choose 52 different messages M_1, . . . , M_{52} as the cards, and a large prime p.

b. A and B selects e_A and e_B, and encryption functions $E_A(M)$ = MeA mod p, E_B (M) = M^{eB} mod p. A and B compute decryption function exponents d_A and d_B and define decryption functions $D_A(C) = C^{dA}$ mod P and $D_B(C) = C^{dB}$ mod P.

c. A, the dealer encrypts M_1, … M_{52}, permutes their order a shuffling scheme d. B chooses 5 cards and returns them to A who decrypts them for her hand.

e. B chooses 5 cards from the remaining deck as his own, encrypts them and sends the result to A. note that each card is of the form E_B(EA(Mi)) =E_A(EB(M_i)) because E_A and E_B commute.

f. A decrypts the 5 cards with D_A and return the result to B who decrypts them with D_B to obtain his hand.

At the end of the game, the parties reveal their secret keys to verify no cheating occurred.

Euclidean GCD Algorithm

In mathematics, the Euclidean algorithm[a], or Euclid's algorithm, is an efficient method for computing the greatest common divisor (GCD) of two numbers, the largest number that divides both without leaving a remainder. If (a < b) then swap (a, b) /* Make a > b, and compute
a = q1b + r1
b = q2 r1 + r2 r1 = q3 r2 + r3 r2 = q4 r3 + r4
: : :
rk-2 = qk rk-1 + rk
rk-1 = qk+1 rk + 0, GCD (a, b) = rk

APPENDIX C (CONTINUED)

Examples

1. Compute GCD (5, 46)

46 = 9(5) + 1 q1 = 9; r1 = 1

5 = 5(1) + 0 q2 = 5; r2 = 0; GCD (5, 46) = 1

2. Compute GCD (96, 14)

96 = 6(14) + 12 q1 = 6; r1 = 12

14 = 1(12) + 2 q2 = 1; r2 = 2

12 = 6(2) + 0 q3 = 6; r3 = 0; GCD(96, 14) = 2

3. Computing a^{-1} mod b and b^{-1} mod a using Euclidean GCD Algorithm

If GCD (a, b) = 1, that is a and b are relatively prime then (aX + bY) = 1

Set X0 =1; X1 = 0; Y0 = 0; Y1 = 1; Compute { Xi = -qi-1 Xi-1 + Xi-2; Yi = -qi-1 Yi-1 + Yi-2;

} for i = 2 to k+1

GCD (5, 46) =1; Note that q1 = 9 and q2 = 5

Set X0 =1; X1 = 0; Y0 = 0; Y1 = 1;

X2 = -q1 X1 + X0 = -9(0) + 1 = 1 –the solution for X Y2 = -q1 Y1 + Y0 = -9(1) + 0 = -9 –the solution for Y

X3 = -q2 X2 + X1 = -5(1) + 0 = -5 –computed to validate X Y3 = -q2 Y2 + Y1 = -5(-9) + 1 = 46 –computed to validate Y (aX + bY) = 46(1) + 5(-9) = 1

Note that 5-1 mod 46 = -9 = -9+46 = 37 and 5(37) mod 46 = 1

Note that 46-1 mod 5 = 1-1 mod 5 = 1 and 46(1) mod 5 = 1

Online Education/Virtual Collaboration/
Mitigating the Digital Divide

Narrowing the Digital Divide in Higher Education in LMIC

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ABSTRACT

To narrow the digital divide that has negatively affected mentee-mentor interactions, we proposed developing new tools and resources to support virtual education in resource-limited settings. EpiConsultAfrica (https://epiconsultafrica.org) is a virtual center for digital inclusion and education in Africa. It is a one-stop mentorship hub staffed by volunteer faculty to help graduate students and junior faculty develop their research skills. The program provides mentees access to a dedicated informal mentor willing to meet with the candidates virtually. Mentors are drawn from all over the world in a cloud environment. Mentorship is voluntary, and candidates are matched with the appropriate mentor. Upon completion, graduates will have gained skills in research methods, data management and analysis, and scientific communication.

Background

The COVID-19 pandemic in 2020 kept approximately 826 million students worldwide out of the classroom as nations desperately locked down to control the spread of the virus. Many lacked access to a household computer, and a majority lacked broadband access. In Africa, school closures due to COVID-19 and a lack of digital-based distance resources necessary for learning continuity has worsened the existing educational, economic, and gender inequalities that affect most of the continent.

Due to the high costs of internet and limited access to remote learning resources, the majority of students in higher education institutions in Africa have been hit particularly hard. In Uganda, where several colleagues and I have voluntarily mentored students as part of our post fellowship effort, a wide digital divide exists. The term digital divide refers to a gap between those groups who have good access to digital technology, including broadband, and those who don't. The digital divide is particularly acute in sub-Saharan Africa, where 89% of learners do not have access to household computers and 82% lack internet access. Most undergraduate and graduate students in Uganda fall into the latter category.

Though the urgency to narrow the digital divide is well recognized worldwide, the huge investments needed to build the necessary platforms and infrastructure have been lacking in sub-Saharan Africa. A survey of 10 African countries, conducted by Research ICT Africa between 2017 and 2018 as part of the Global South AfterAccess study, found that Uganda has one of the lowest (24%) internet penetration rates, far exceeding Rwanda (9%) and Mozambique (10%). In Uganda, although ownership of mobile gadgets that can enable access to information and communication has grown considerably, more than 86% of Ugandans live in locations without mobile networks.

The critical job of easing the digital divide for students in low income and access countries can be achieved through (1) providing students with low-cost take-home technologies (e.g., smartphones, tablets) that can be used remotely to access online learning resources; (2) increasing student access to learning resources through community centers and hubs equipped with computers and internet; (3) developing and implementing an online digital platform to provide access and a virtual environment for mentors and mentees to engage and access online resources to support learning; and (4) improving access to technology, including the quality of that access in their universities.

EpiConsultAfrica

EpiConsultAfrica (https://epiconsultafrica.org) is a nonprofit virtual organization that seeks to ease the digital divide. This digitally inclusive platform is at the center of the post pandemic education efforts in Africa. Through its virtual community hub of well-qualified educators, EpiConsultAfrica will provide students in resource-limited settings increased access to mentorship.

EpiConsultAfrica was conceived and incorporated by Drs. Abel Ekiri (University of Surrey), Margaret Khaitsa (Mississippi State University), and Patrick Pithua (Virginia Tech). Its goal is to improve the quality of research conducted in the field of biomedical sciences at higher education and research institutions in Africa.

The mentoring hub will be staffed by volunteer faculty that will help masters, doctorate, and postdoctoral students as well as junior faculty develop their research and other academic skills. These mentees will have access to a dedicated team of informal mentors willing to meet with the candidates virtually. In this program, mentors with the right qualifications will be drawn from all over the world in a cloud environment. Mentorship will be voluntary, and candidates will be matched with the appropriately qualified mentors depending on their academic needs.

The academic fields targeted include human medicine, veterinary medicine, public health, nursing, pharmacy, dentistry, and other relevant disciplines in the broader fields of biomedical sciences. Mentees will gain significant exposure to academic guidance and materials developed by the mentors at their respective institutions of higher learning. Upon completion, mentees will have gained skills in research methods, data management and analysis, and scientific communication.

Figure 1 outlines the structure of EpiConsultAfrica.

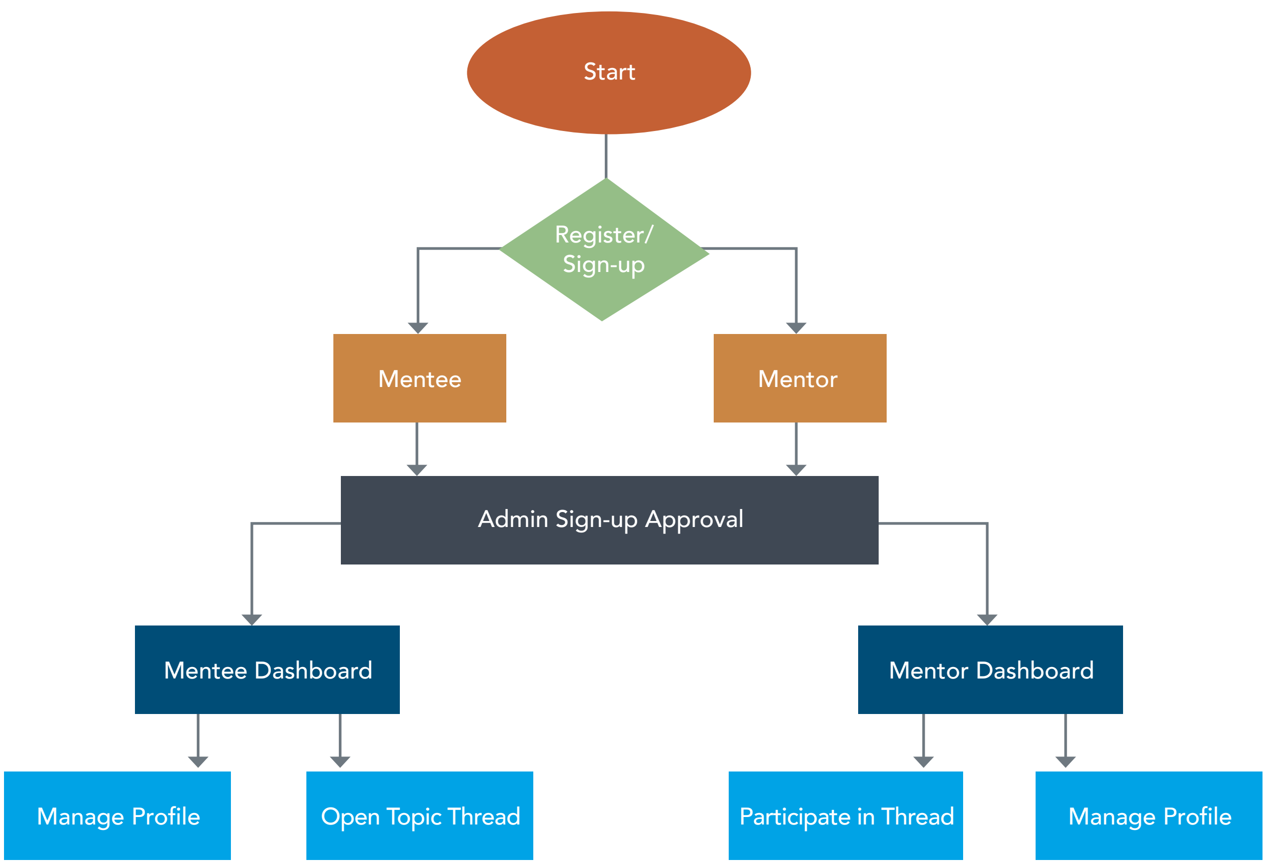
To address one of the key needs necessary to ease the digital divide for students in low income and access countries, EpiConsultAfrica proposes to develop and implement a web portal to provide a virtual environment for mentors and mentees to engage and address mentees' academic and research needs. In addition, creation of the web portal will increase student access to learning resources. All these services can be accessed directly on smartphones, tablets, and computers or via community centers and hubs equipped with computers and internet—or through technologies at home university institutions if available.

A high-level overview of the mentor-mentee web portal structure and functionality

Mentoring services and activities will be offered using an online platform managed by EpiConsultAfrica. The platform is a common point where mentors and mentees meet and engage. Mentors and the mentees seeking assistance must sign up and register online with EpiConsultAfrica. Registered mentees will be able to view expertise profiles of mentors and engage with the EpiConsultAfrica community initially by posting questions to a select topic thread in appropriate subject-specific forums to which mentors with the relevant expertise will respond. If needed, one-on-one mentor-mentee online chats will be arranged for in-depth discussions.

FIGURE 1

Basic platform structure of EpiConsultAfrica



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Online Education/Virtual Collaboration/
Mitigating the Digital Divide

Online Delivery of Civil Engineering Courses in Tanzania—State-of-the-Practice

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ABSTRACT

The Coronavirus (COVID-19) pandemic caught many African higher education institutions off guard. On March 17, 2020, the Tanzanian government ordered the closure of all schools in the country, including higher learning institutions, to limit the spread of the pandemic. As a result, instruction stopped until June 1, 2020, when schools were allowed to reopen. Surprisingly, by the time of the COVID-19 outbreak, some institutions had procured similar e-learning platforms used in more developed countries, but instructors had not started using them. This paper is aimed at presenting the e-learning resources that Tanzanian higher learning institutions have at their disposal. It also discusses the extent to which online tools are used for instruction in Tanzanian higher learning institutions, specifically for civil engineering programs. The discussion is based on a survey distributed to the department heads and leaders of various sections within the civil engineering departments of the seven colleges that offer civil engineering in the country. The study reports the progress that has been made by comparing the use of e-learning tools pre- and post-COVID-19. This study could help administrators develop a roadmap for offering online and hybrid courses in civil engineering programs.

Introduction

On March 17, 2020, all schools in Tanzania closed to limit the spread of the Coronavirus disease (COVID-19). Because most schools were not prepared to teach online, instruction was stopped until June 1, 2020, when schools were allowed to reopen. After the COVID-19-induced campus closure, higher learning institutions in Tanzania explored the possibility of implementing e-learning technology. Dar es Salaam Institute of Technology (DIT), for example, procured an e-learning platform known as Canvas. This platform enables DIT to offer blended online courses when students are on campus and in case of campus closure, to continue instruction remotely using online tools.

Remote learning started gaining momentum in developing countries even before the pandemic. In 2019, a year before the COVID-19 outbreak in the United States, the Carnegie African Diaspora Fellowship Program (CADFP) supported a project in Ghana that explored the integration of massive open online courses (MOOCs) in engineering education (Table 1). In recognition of the importance of adopting online teaching resources, CADFP supported the follow-up fellowship in 2020 by the same fellow and host. The funding cycle that preceded the COVID-19 outbreak had three CADFP-funded projects that involved online teaching. Due to increased online teaching throughout countries in the developed world, online-teaching-related fellowships have doubled since the COVID-19 outbreak, As shown in Table 1 (from three in the March 2020 cycle to six in the November 2020 cycle).

DIT was among the recipients of the CADFP fellowship in the summer of 2021, a year after the COVID-19 outbreak. The fellowship involved training civil engineering DIT lecturers on effective online delivery tools. The fellowship participants (fellow and host) saw a need to document the state-of-the-practice of the online delivery of engineering courses, focusing on civil engineering courses. This paper discusses the findings of the survey conducted by DIT in collaboration with the University of North Florida to determine the state-of-the-practice of online course delivery for civil engineering courses in Tanzania.

TABLE 1

Previous CADFP Projects Related to Remote/Online Instruction

FUNDING CYCLE	PROJECT TITLE	COUNTRY
May 2019	Curriculum Co-development for Integrating MOOCs in Engineering Education; Collaborative Research to Evaluate the Effectiveness of Using MOOCs to Support Engineering Education; and Building Research Capacity	Ghana
March 2020	Curriculum Co-development for Integrating MOOCs in Engineering Education; Collaborative Research to Evaluate the Effectiveness of Using MOOCs to Support Engineering Education; and Building Capstone Project Supervision Capacity	Ghana
	Curriculum Co-development for Online/Blended Learning Courses and Develop Faculty for Online Learning and Teaching	Kenya
	Research Collaboration on Enhancing E-learning Using Artificial Intelligence Techniques and Mentor Graduate Students on How to Apply Machine Learning Techniques in Various Disciplines	Kenya
November 2020	Online Curriculum Co-development for Human Rights and Politics Short Courses	Ghana
	Confronting COVID-19 Online Modality Instructional Challenges Through Sustainable Online Curriculum Redesign of Educational Research Modules and Mixed Methods Re-search: Addressing COVID-19 Teaching/Learning Disruption; Faculty Challenges and Innovations Online Curriculum Development; Train Junior Faculty and TAs to Redesign Postgraduate Research Modules into Effective Synchronous and Asynchronous Online, Blended, Remote Learning	South Africa
	An Intensive Hands-On Program to Facilitate Civil Engineering Remote Instruction at the Dar es Salaam Institute of Technology (DIT) in Response to the COVID-19 Crisis	Tanzania
	eLearning Curriculum Co-development, Women and Gender Studies, and Student-Research Mentoring	Uganda
	Mentorship for Research Collaboration and Curriculum Co-development for Online In-stitute Course Works for Women in School Leadership at Makerere University, Ugan-da. Curriculum Co-development for Women in School Leadership for a Short-Term Workshop, and a Long-Term Institute Combined with Mentoring, Using a Hybrid Deliv-ery Modality Mentorship for Research Collaboration and Development of Dissemination Plans	Uganda
	Co-develop New Online Courses and Tools, Enhance Research Capacity and Online Instruction in Information Technology	Uganda

TABLE 2

A List of Tanzania Higher Learning Institutions Offering Civil Engineering Education

INSTITUTION	DIPLOMA	BS	MS	PhD
University of Dar es Salaam (UDSM)		●	●	●
Ardhi University		●	●	●
Dar es Salaam Institute of Technology (DIT)	●	●	●	
Mbeya University of Technology (MUST)	●	●	●	●
Arusha Technical College (ATC)	●	●		
Saint Augustine University of Tanzania (SAUT)		●		
Saint Joseph University in Tanzania (SJUIT)		●		

Civil Engineering Education in Tanzania

Until about two decades ago, the University of Dar es Salaam was the only institution that offered degrees in civil engineering in the entire country of Tanzania. Ardhi University started the civil engineering program about twenty years ago. In the mid-2000s, public institutions that were formerly known as technical colleges (diploma and advanced diploma level colleges) were converted to degree earning institutions to produce the much-needed engineering experts in the country. Two privately owned universities were later added to the list. Seven higher learning institutions currently offer degrees in civil engineering in Tanzania. Table 2 shows all seven higher learning institutions that offer civil engineering programs in the country. The last two are privately owned institutions.

Data Collection

This study used a questionnaire to gather information on the state-of-the-practice of civil engineering online course delivery in Tanzanian. The questionnaire was administered online using a web-based survey tool known as Qualtrics. The survey link was sent to heads of civil engineering programs, or their representatives, at all seven institutions. As shown in Table 3, the survey consisted of a total of 17 questions. The first five were nontechnical questions for the survey respondent identification purposes. For the most part, the respondents were supposed to select responses from a list of possible answers. As shown in Table 3, the survey consisted of questions related to the availability of e-learning resources, infrastructure, Internet access, and faculty readiness for online course delivery.

TABLE 3

Questions Asked in the Survey

NUMBER	QUESTION	ANSWER OPTIONS
1	Name of the participant	
2	List of courses that you teach at your institution	
3	Email address	
4	Phone number	
5	Name of the institution	
6	What e-learning resource/platform does your institution use for teaching?	
7	Do you use applications to share course content? (mention)	i. WhatsApp ii. Telegram iii. None iv. Other (mention)
8	Have you used tools such as Zoom or Microsoft Teams for teaching?	i. Zoom ii. Microsoft Teams iii. Other (mention)
9	Does your institution have content creation resources, such as a studio for recording lectures? (list them)	i. Yes ii. No
10	How do you teach students when you are away for official duties?	i. Cancel the class ii. Exchange with another lecturer iii. Find an appropriate time to cover the missed class iv. Record lectures v. Other (mention)
11	Would you consider offering a virtual laboratory course? (hybrid/completely virtual)	i. Yes ii. No
12	Does your institution have a room that students can use to listen to lectures offered either synchronously or asynchronously?	i. Yes ii. No
13	Is there free internet access to students on campus for them to use for accessing online content?	i. Yes ii. No iii. Maybe
14	Is the internet reliable on campus for students to use for online course delivery?	i. Yes ii. No iii. Maybe
15	Can students access content online at home?	i. Yes ii. No iii. Maybe
16	Do you think lecturers/professors can comfortably use e-learning resources to offer civil engineering courses?	i. Yes ii. No iii. Maybe
17	Is training needed for faculty members to be able to offer courses online?	i. Yes ii. No iii. Maybe

Data Analysis and Results

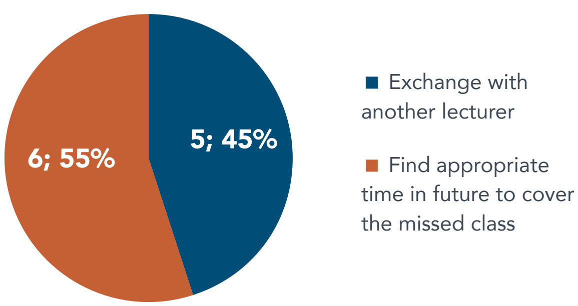
All seven higher learning institutions that offer civil engineering degrees responded to the survey. The following sections provide the analysis and discussion of the results of the study. The two numerals depicted in the pie charts are the number of respondents and the percentage of the total responses, respectively.

Missing Classes Due to Attending Other Official Duties

It is common for Tanzanian academicians to miss classes due to attending other official duties. The survey respondents were asked how they teach students when they are away for official duties. As shown in Figure 1, based on the survey results for this question, online teaching (including recording lectures) has not been implemented yet by any of the surveyed institutions. Instructors either exchange class periods with other lecturers or find an appropriate time to cover the missed classes. It has been observed that make-up lectures have sometimes been scheduled on the weekends due to the challenge of getting appropriate time slots during weekdays.

FIGURE 1

Responses on How Instructors Teach Students When They Are Away for Regular Duties



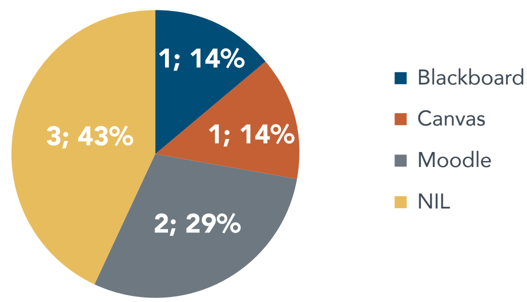
One of the major impacts of online course delivery is the potential to eliminate unnecessary canceling of classes, leading to inconsistencies in teaching and instructors not being able to complete the syllabus. It is common to cancel classes when an instructor is not on campus for various reasons, including work-related excuses such as travel to conferences and attending other university duties. Classes are also often canceled when an instructor cannot make it to class due to health or family issues. Virtual instruction will address these concerns because teaching can be done remotely, either synchronously (via live streaming) or asynchronously (using prerecorded lectures). Even students who are not able to attend a lecture due to unavoidable circumstances would benefit from recordings of live-streamed lectures.

E-Learning Platforms

One of the key resources for online course delivery is an e-learning platform. These platforms facilitate archiving and organization of instructional content. They also provide tools for communication, collaboration, assignments, and grading, among others. In Tanzania, an e-learning platform is commonly referred to as a learning management system (LMS). There are many such platforms; most of them are proprietary, but a few are open source. Figure 2 summarizes the survey responses regarding the e-learning resources (LMSs) used.

FIGURE 2

E-Learning Platforms Used by Tanzania Higher Learning Institutions



Only four out of the seven surveyed higher learning institutions use an e-learning platform, based on the results. University of Dar es Salaam, the largest and oldest higher learning university in the country, uses Moodle, an open-source LMS. After the COVID-19-induced campus closure, DIT procured an e-learning platform known as Canvas. According to the survey, Saint Joseph University in Tanzania, a small private university, uses Blackboard. The other three institutions (43%) do not yet possess any LMS.

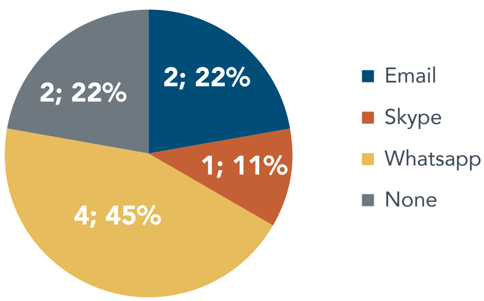
Use of Social Media Applications

One of the survey questions was aimed at gathering information on methods used by faculty for communication. Nearly half (45%) of the respondents reported using WhatsApp to communicate with students. Interestingly, less than a quarter of the respondents use email for communication (Figure 3). It was observed that only faculty and staff had official school emails. While students were not provided with school email addresses, faculty and staff preferred using personal emails for official communication, partly due to the instability of the school internet network.

According to the results presented in Figure 3, only one respondent reported using Skype. Two institutions indicated

FIGURE 3

Internet Communication Applications Used for Sharing Course Content



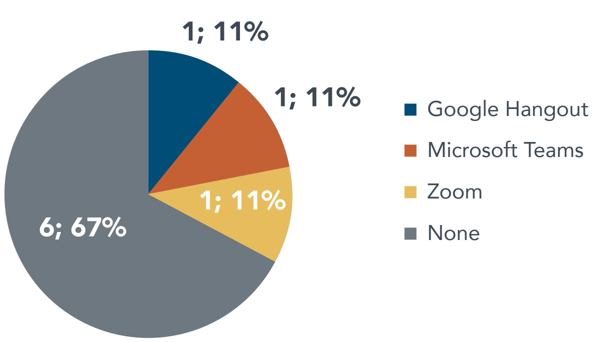
that they do not use any technology to communicate with students. While WhatsApp is an informal communication tool, mostly for social groups, it is used more widely in Africa than in the United States. This might have contributed to WhatsApp being the most preferred method of sharing course content. During the CADFP visit at DIT, it was observed that lecturers send course content to a class representative (student leader), who then distributes the content to the rest of the class. The course content sent through WhatsApp ranged from PowerPoint slides and assignment sheets to video clips.

Use of Video Conferencing Tools

Most administrative meetings became virtual after COVID-19 induced campus closures in Tanzania. Higher learning institutions in Tanzania adopted platforms, such as Zoom, that allowed administrative activities to continue when the campuses were closed. However, the schools were not prepared to deploy the same tools to create virtual classrooms. Figure 4 summarizes the survey responses on the use of video conferencing tools. The survey asked to list some video conferencing tools that they have used for instruction. Only a third (33%) of respondents indicated using several video conferencing tools, such as Google Hangouts, Microsoft Teams, and Zoom. Two-thirds (67%) of the respondents have never used video conferencing for teaching.

FIGURE 4

Survey Responses on the Use of Conferencing Tools for Teaching Civil Engineering Courses



Internet Access

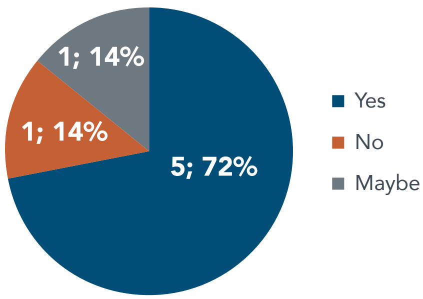
Internet access is a necessity for remote instruction. Students and instructors need a reliable and affordable internet source. Also, they need a reliable device (smartphone, tablet, or computer) to connect to the internet. Most college students in Tanzania have devices, at least smartphones, that can connect to the internet. Some institutions have free Wi-Fi for students to use for academic purposes. According to the survey results depicted in Figure 5, most institutions (72%) indicated that students have free internet access on campus to use for remote instruction. However, the responses for the follow-up question, which aimed to determine the reliability of the internet on campus, showed that less than 60% of the responding institutions have reliable internet access on campus. Interestingly, although the study did not examine the stability of the internet connectivity at home, 71% of the responses indicated that students could access online instruction content from home. The remaining 29% of the respondents were not sure (they answered maybe).

Instructor Readiness

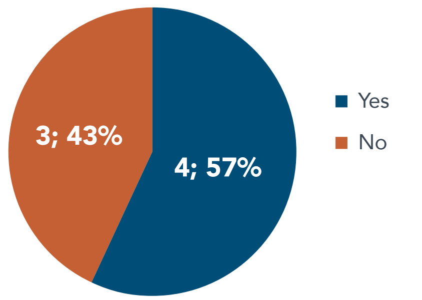
The success of remote instruction largely depends on faculty preparedness and familiarity with online teaching resources. The results of the survey on this topic are summarized in pie charts depicted in Figure 6. Some engineering educators would argue that civil engineering laboratory courses are hands-on and cannot be taught online. It was revealing to observe that most institutions (86%) indicated their willingness to consider offering virtual laboratory courses (hybrid or completely virtual). Only two institutions (29%) indicated that the faculty could comfortably use e-learning resources to offer engineering courses. Four institutions (57%) were not sure (they answered maybe). Furthermore, the response from one institution suggested that the academic staff was not ready to use e-learning resources. When asked about the need for training, responses from all institutions (100%) overwhelmingly noted the need for faculty training to facilitate online teaching. The survey results clearly show a need for institutional support for faculty to be ready to offer remote instruction effectively.

FIGURE 5

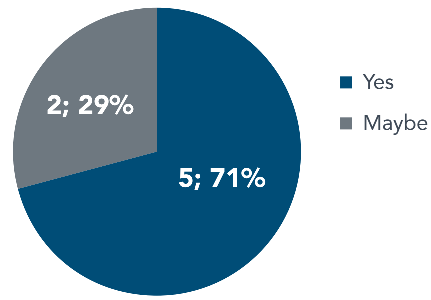
Survey Responses on Internet Access



Is there free internet access to students on campus for them to use for accessing online content?



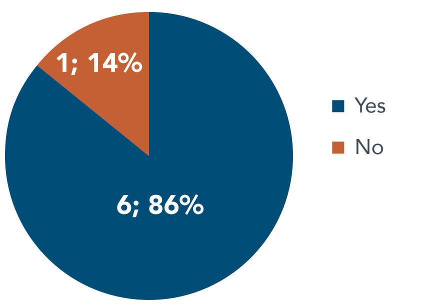
Is the internet reliable on campus for student to use for online course delivery?



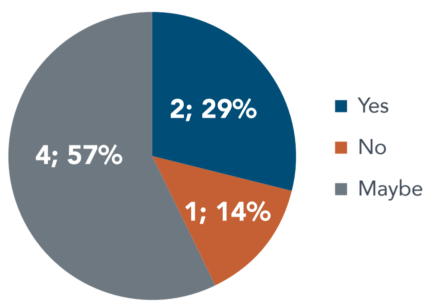
Can the students access content online at home?

FIGURE 6

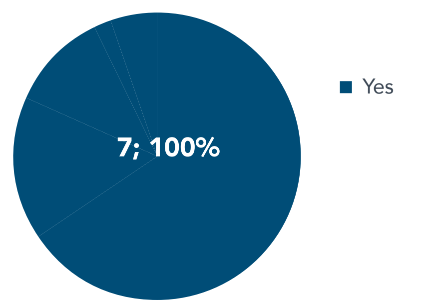
Survey Responses on Instructor Readiness



Would you consider offering a virtual laboratory course (either as a hybrid or a complete virtual course)?



Do you think lecturers/professors can comfortably use e-learning resources to offer civil engineering courses?



Is training needed for faculty members to be able to offer courses online?

Concluding Remarks

This paper documented the state-of-the-practice of online course offerings for civil engineering programs in Tanzania. The study was based on a survey that was conducted on seven institutions in the country that offer civil engineering degrees. Overall, the results of this study show a clear digital gap that exists in the use of e-learning to enhance teaching in higher learning institutions. The results show that institutional readiness stems from lack of resources and less emphasis on online teaching.

The results show that most institutions in Tanzania do not have e-learning platforms. These platforms are essential for effective online teaching. They support content sharing, online assessments, student and instructor feedback, and are built to replicate classroom student-to-student and instructor-to-student interaction.

The results revealed individual efforts from some instructors who use internet applications such as WhatsApp to enhance communication with students. There was less usage of video conferencing platforms such as Zoom and Microsoft Teams that have tools for replicating a virtual classroom. Based on the results of this study, internet access on campus is an issue that needs to be addressed to facilitate online teaching. While the survey suggests that students may access the internet off campus, affordability may still be an issue for most students.

Last but not least, the results show that instructors need training before they can comfortably and effectively teach online courses. Training should not be limited to using online tools for teaching; it should extend to pedagogies that are effective for online teaching.

In closing, the COVID-19 crisis has disrupted academic timetables all over Tanzania, and it is unlikely to be the last crisis to cause disruption. Starting to move some of the course content online and provide remote instruction would enable the continuation of instruction should another crisis occur in the future that would cause the schools to close. Based on emerging teaching technologies that have been widely adopted post-COVID-19 in the developed world, the future of engineering education will involve online instruction. Higher learning institutions need to set a comprehensive online teaching agenda to avoid being left behind.

Once remote instruction is mainstreamed in Tanzanian higher learning institutions, it will be easier to leverage the expertise of academicians in the diaspora who can then either teach an entire course remotely or co-teach a course with a local lecturer (e.g., diaspora lecturer teaches the lecture part and the local lecturer administers a laboratory session).

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