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COVID-19 lockdown and remote attendance teaching in developing countries: A review of some online pedagogical resources

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The Corona Virus 2019 (COVID-19) pandemic has negatively impacted teaching and learning globally, imposing widespread closure of schools from the elementary to tertiary levels. As of 14 April 2020, teaching activities of over 1.75 billion students globally were disrupted in about 200 countries that have implemented full or partial lockdown across the world. At the time of writing, the duration of the current pandemic cannot be ascertained. Therefore, the teaching and learning process should also adapt to the new normal, which includes suitable social distancing, self-isolation and other disruptive guidelines outlined by the World Health Organization. Thus, more than ever, COVID-19 has now emphasized the necessity to embrace different and flexible methods of teaching and, by extension, learning. Therefore, e-teaching and e-learning have emerged as complementary solutions that reduce disruption to educational activities. Despite having a solution in online teaching to reduce the effect of COVID-19 on education, it's noteworthy that the solution is not available to every educator, learner and school, especially in developing countries. In developing countries, especially across Africa, lack of awareness of the existing online teaching resources and their suitability for remote attendance teaching and lack of skill sets required for using the resources are the issues impeding online teaching. This paper reviews and evaluates twenty-two (22) remote attendance teaching resources, their special features and system requirements. The technical requirements, suitability, and limitations of each application are considered. The implementation challenges of using the resources are discussed, and some solutions are recommended.

Keywords: COVID-19, online teaching resources, learning tools, web conferencing, digital divide

Introduction

Governments around the world have to close down educational institutions temporarily, from the elementary to tertiary levels, in an attempt to contain the spread of the COVID-19 pandemic. This is in addition to recommended non-medicinal intervention and preventive measures like social distancing, self-isolation and a high regime of personal hygiene through frequent hand washing (Viner et al. 2020; Remuzzi and Remuzzi 2020; Bayham and Fenichel 2020). Similar school closures took place during the 2009 Swine flu outbreak in the USA and Mexico, the flu pandemic in 1968 which originated from Hong Kong, Asian flu of 1958, and the 1918–1919 Spanish flu and Ebola Disease of 2014, among others as shown in Table 1. School closures and restriction of movement have been found to be effective in slowing down the spread of the infectious disease and allowing governments to buy time to conduct research into medical solutions to the disease (Cohen and Kupferschmidt 2020). The spread and effects of the COVID-19 pandemic are foreseen to have far-reaching consequences (Armitage and Nellums 2020; Li et al. 2020).

Developing countries are also affected by COVID-19, and most of them have taken similar measures as the developed world (Gilbert et al. 2020). However, the effect of the pandemic is more severe in developing countries as a result of a lack of preparedness and the absence of infrastructure, among other reasons (Lloyd-Sherlock et al. 2020). Currently, there is no certainty as to when schools will be reopened; hence, the loss to education cannot yet be estimated. Unlike money and materials that can be recovered over a period of time as the economic situation gets better, time cannot. This is particularly true for educational activities where examinations, resumption, holidays, teaching practice, fieldwork, and internships are tied to particular time and seasons of the year. The COVID-19 pandemic has placed urgent global needs for skilled workers with abilities to work under the new normal, with little or no personal contact, to deliver goods and services required for human survival. The world needs the services of more medical doctors, health workers, skilled volunteers, Internet-automated machine operators, researchers and teachers with special skills while the COVID-19 pandemic lasts. Only recently are developing countries enforcing and making gains in educating the vulnerable ones in the society such as children and women (King and Hill 1993; Patrinos and Psacharopoulos 2020). Therefore, more especially in developing countries, this is not the time to completely stop teaching and learning because of COVID-19 lockdown and school closure. It is rather a time to adopt new and flexible methods of teaching and learning while complying with the preventive measures against the spread of COVID-19.

Developing countries are more likely to be significantly impacted by the COVID-19 pandemic in terms of disruption to its educational institution. This is because most African schools, from elementary to tertiary, heavily depend on the conventional face-to-face teaching method and have rarely practised virtual teaching before the

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Table 1: Some notable disease outbreaks and duration of lockdown.

S/No.	Ref.	Disease Outbreak	Code Name	Year	Country of Origin	No. of Deaths	No. of Countries Affected	Duration
1	(WHO 2020b)	Corona Virus	COVID-19	2019	Wuhan, China	341,155[P]	Global	31 December 2019–Date
2	(Nature 2009)	Swine flu	H1N1	2009	United States and Mexico	12,220	208	18 March 2009–27th December 2009
3	(WHO 2020a)	Ebola Disease	EBOV	2013	Guinea	11,310	10	December 2013–Jan 2016
4	(Clark 2008)	Influenza	H2N2	1957	Guizhou, China	1–4 million	Global	February 1957–
5	(Tumpey et al. 2005)	Influenza pandemic	H1N1	1918–1919	Spain	50 and 100 million	Global	15 months (Spring 1918–summer 1919)

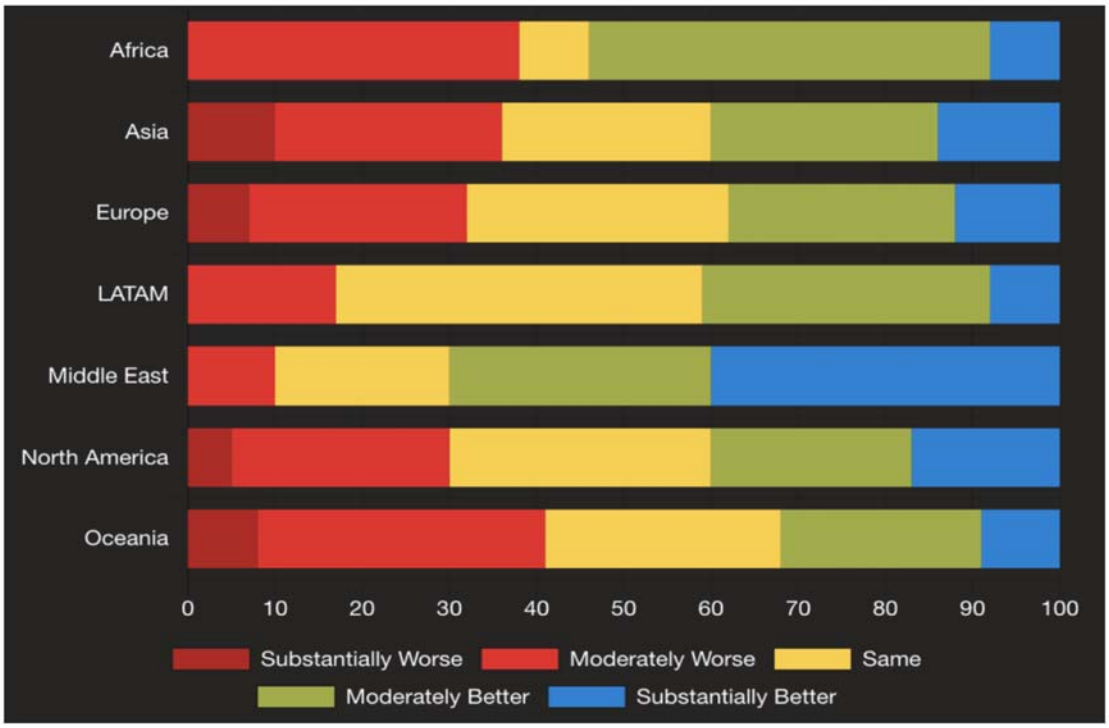

Figure 1: Short-term impacts of COVID-19 on their organizations and institutions (Monitor 2020).

COVID-19 pandemic due to the lack of supporting infrastructure and the skills required to use the online teaching resources (Adeyinka 1975; Kotoua, Ilkan, and Kilic 2015). A survey on the global impact of COVID 19 on organizations and institutions, including educational institutions is shown in Figure 1; it can be seen that the effect of COVID-19 on education is substantially worse in the developing world, especially in Africa. This is because a significant number of African parents have limited education or are not educated at all, and hence cannot engage their children in home teaching while the COVID-19 pandemic lasts. Many high schools and tertiary institutions in the developed countries have been practising online teaching before COVID-19 to complement face-to-face teaching thus having a notable presence on the Internet, and subscriptions to online teaching resources (Huwiler 2015). Conversely, only a few higher institutions in Africa had ever practised online teaching before the COVID-19 pandemic. Significant numbers of teachers and lecturers in African schools have limited or no access to the Internet (Karachiwalla 2019; James 2019; Warf 2019) and do not have exposure to online teaching resources despite their availability on the Internet (Warf 2019).

The result of a study on the accessibility to the Internet in some regions of the world is shown in Figure 2.

The aim of this paper is to examine web conferencing tools which are suitable for teaching and learning. Therefore, we use these words 'web-conferencing tool' and 'teaching and learning tool' interchangeably. The objectives of this paper are to (i) describe some notable online pedagogical resources that can be used for teaching while the COVID-19 pandemic lasts; (ii) compare and contrast the suitability and limitations of the resources; (iii) enumerate their technical features and requirements, and use cases; and (iv) determine the best among the resources, given the peculiarity of the African Continent and recommend them to teachers. The online pedagogical resources considered are RingCentral video, GoToMeeting, Pexip, zoom, TeamViewer, EzTalk, CISCO Webex, Skype, Apache Openmeeting, Join. Me, Google Hangout, Adobe Connect, BlueJeans, OmniJoin, Google Meet, Lookup, Vidyo, Avaya, Google Classroom, Star

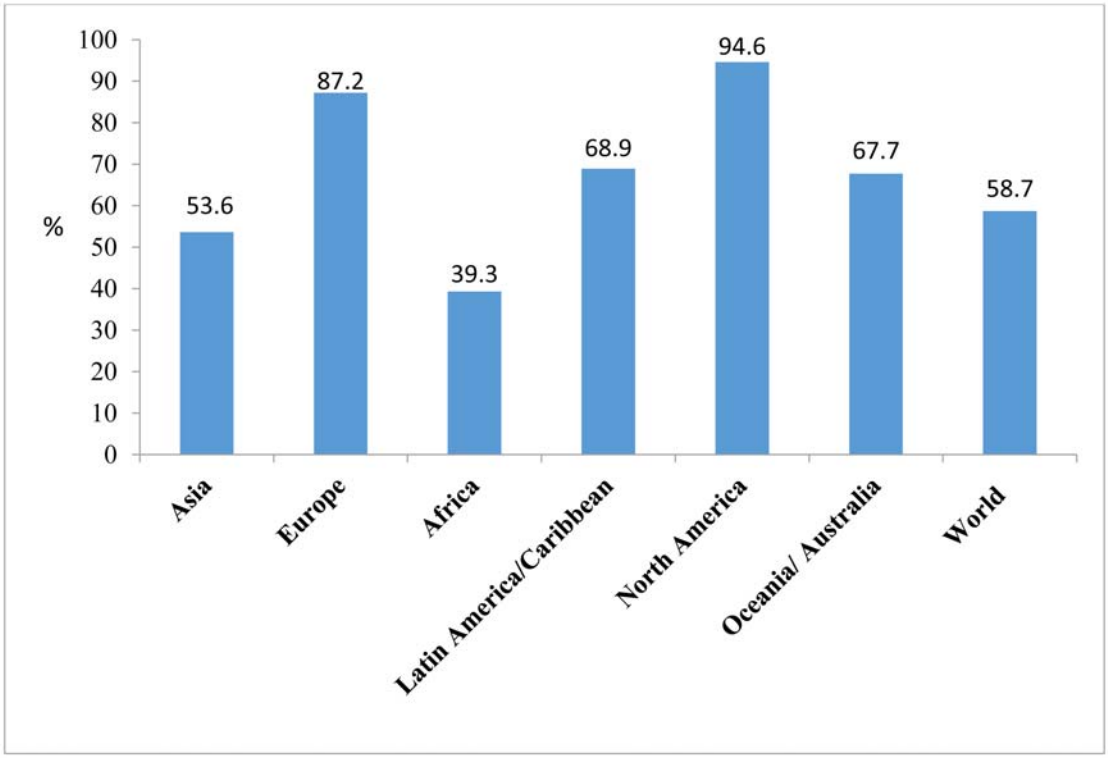

Figure 2: Percentage of Internet users per region for year 2019 (de Argaez 2020).

Leaf, Polycom and Skype for Business. Furthermore, this study is to create awareness for the resources and encourage teachers in developing countries to use them for teaching during and post-COVID-19 lockdown. In this paper, web conferencing solutions and web conferencing applications are used interchangeably. In most places where mentioned, web conferencing intends to capture online teaching. The research is also guided by the following research questions.

I. Which among the available video conferencing solution is/are suitable for e-learning in developing countries?
II. What are the possible implementation challenges hindering the switching over to e-learning platforms during the COVID-19 lockdown?

To guide literature search, the review, the choice of web conferencing applications, and the criteria for data analysis, the authors have developed a conceptual framework around two key components relating to web conferencing applications for online teaching in developing countries: (a) the applications that can replace or partially replace traditional face-to-face learning and teaching experience, and (b) the affordability of the applications considering the poverty level in developing countries. On the concept of traditional face-to-face learning, the authors consider the web conferencing solutions that allow teachers and students to see, hear, and interact with one another and get feedback in realtime. The affordability of the solutions, the cost of subscription and Internet data requirement by the applications to do video calls, audio calls, share screen and lecture notes between teachers and students and engage in team working would also be considered. The framework of this study is the ways and means to minimize the impact of the COVID-19 pandemic on education. The paper is not suggesting the permanent replacement of face-to-face classroom teaching with online teaching.

Conferencing applications used for online teaching and learning

Web conferencing has now become a huge and successful development in business communication as a result of improved telecommunication networks. Web conferencing is a multimedia communication system that allows the sharing of computer screens, web-based contents or individual applications in real-time among networked computers (Suduc, Bizoi, and Filip 2009). This is because web conferencing can be organized to support teamwork, engage in seminars/business meetings, give lead presentations, conduct customer-relation support and, more recently, conduct online education (teaching and learning). Some web conferencing applications used for online teaching has some other sophisticated features such as polling, whiteboarding and annotating, chat discussions, etc. (Suduc, Bizoi, and Filip 2009; Islam 2019) that make them suitable for real-time interaction between teachers and learners. Web conferencing creates a media space among participants in disperse locations through the Internet and some electronic technologies for the enablement of participants' presence to exchange ideas, information or knowledge (Alqurashi 2019; Winfield 2004). Web conferencing platforms can be accessed using a web browser or by downloading the app on various devices. However, it is often advisable to download and install the application client for a better experience. With web conferencing, one can bring together thousands of

people spread across the world with a similar interest to engage in communication. In general, web conferencing is a term that describes different kinds of collaborative services such as webcasts, webinars (web seminars) and peer-level web meetings that are available over the Internet. Web conferencing is possible with the use of TCP/IP connections over the Internet. Web conferencing solutions in their early stage could only send text messages over the Internet. Over time, the integration of audio and, finally, video was possible (Alqurashi 2019; Berry 2019).

Webcasts

A webcast is basically a broadcast over the Internet that can either be delivered live or on-demand (Sun and Liu 2019). It is a form of web conferencing which involves the integration of audio and video conferencing using the streaming technology to transmit a prerecorded event or live event over the Internet. Just like the traditional TV and radio broadcast, a webcast is usually deployed in a non-interactive linear setting, that is, its communication mode is one-to-many (Ana-Maria, Bîzoi, and Filip 2009). It can be extensively used in a university that offers some form of distance learning, an enterprise that wants to engage in a conference call, to hold a press conference, and lots more. It is important to note that webcast is different from conventional TV or radio broadcast because it is transmitted over the Internet using streaming media technology. Webcasting is characterized by a host, sometimes hosts, with a large audience who have the required multimedia application to view the broadcast on the Internet using any devices however they cannot interact with their presenter (Yu et al. 2000; Zoumenou et al. 2015).

Webinars

A webinar is a short-form of a web-based seminar. In other words, it is an interactive seminar, presentation, meeting, workshop, lectures, and teaching that are transmitted online (Kalinina 2015; Lieser, Taf, and Murphy-Hagan 2018). A webinar is another category of web conferencing that has more sophisticated features such as file/document sharing, shared desktop, polling, chat, whiteboarding, and lots more. These advanced features make them especially useful for teaching and learning. A webinar is basically designed for one-to-one (unicast), one-to-many (broadcast or multicast), many-to-many (multi-peer) or many-to-one (anycast) communications and said to be more collaborative because it involves the use of interactive features to engage in communication with its audience (Lieser, Taf, and Murphy-Hagan 2018). Figure 3 illustrates the one-to-many communications mode.

Benefits of web conferencing

Several reasons could hinder the physical availability of people with similar interest to meet up in a particular place at a particular time (Ana-Maria, Bîzoi, and Filip 2009). Web conferencing solutions ensure that people come together over the Internet using their networked devices in lieu of physical presence. Web conferencing allows employers to keep in touch with their employees, lecturers to reach out to students, trainers to instruct trainees, etc., with the use of Internet infrastructure and some collaboration techniques (Ana-Maria, Bîzoi, and Filip 2009).

One of the main objectives of using web conferencing is to bring people together in an online forum with no limitation of distance and time, thereby saving time, travel cost, and resources. Travelling down to a meeting point can be arduous and hectic, which might affect the efficiency of teamwork (Ana-Maria, Bîzoi, and Filip 2009; Weissman 2006). Some of the factors to consider when travelling down to a venue for a meeting or programme are flight cancellations or delays, traffic bottlenecks along the roads, etc. In setting up a face-to-face

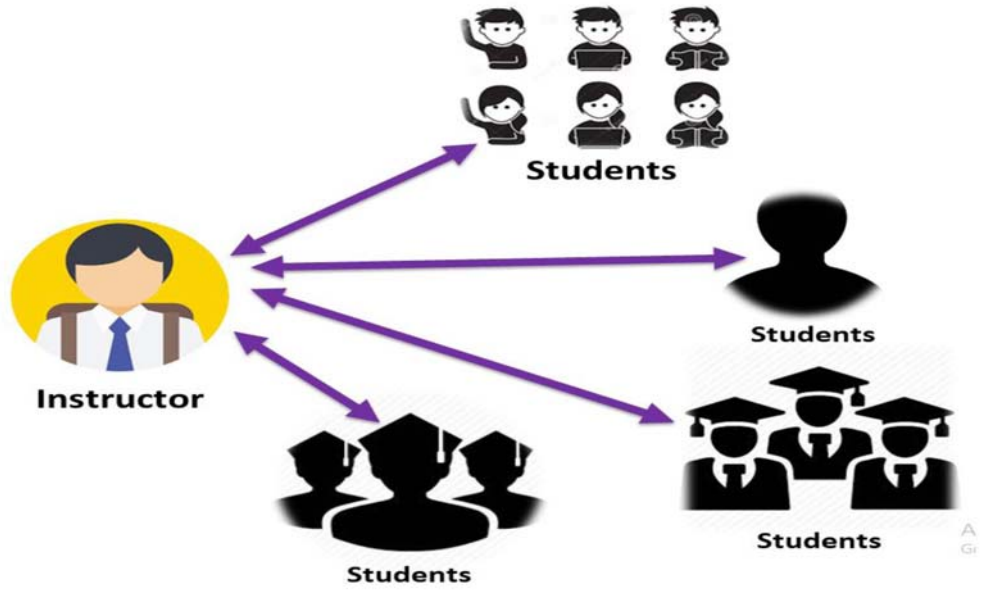

Figure 3: One-to-many communication.

meeting, there is at least an individual that will handle the organizing, booking the meeting room and scheduling the appropriate time for the meeting. These activities are also applicable to a university lecture. However, web conferencing is a more convenient way of setting up a meeting as it only takes less time by taking advantage of high-speed network and the web conferencing tool flexibility and also requires much fewer resources to set up.

Another benefit of web conferencing is the ability to bring colleagues in disparate locations together to discuss business, work on projects, and make important business decisions. With the special features in web conferencing solutions, a team can share important files and documents in a timely manner, thereby improving the efficiency and productivity of the business. Participants only make little effort in joining the meeting via web conferencing platforms. Web conferencing solutions have a feature to allow meetings with the likelihood of more users to join the meeting without distracting or interrupting the ongoing meeting. Through web conferencing, decisions are reached faster, and knowledge is shared widely, non-value-added expenses are avoided, and the business productivity is positively affected (Ana-Maria, Bîzoi, and Filip 2009; Twine and Brown 2011).

Web conferencing solutions are two folds. Not only can it provide official meetings such as lectures in universities, but it can also take advantage of the flexibility to aid online teaching. Web conferencing solutions have features to enhance learning via the web. With the range of amazing features available in those tools, learning will be easy as knowledge and ideas can be easily shared using the likes of annotating/whiteboarding, shared desktops, sharing of individual applications etc. (Weissman 2006).

Limitations of web conferencing applications for online teaching

The main drawback in the use of web conferencing resources for teaching and learning are the cost of purchasing the tools, Internet accessibility, and acquisition of skills required to use them. However, there are cheaper platforms with limited capabilities and features which can be successfully used in some cases (Ana-Maria, Bîzoi, and Filip 2009). Furthermore, in response to the effect of COVID-19 lockdown, some of the application providers now have free subscriptions, especially if used for educational purposes. However, teachers need to acquire the skill set required to use the applications. On the other hand, the cost of acquiring a high-end platform can be compensated for by the cost and time required to travel to schools or meeting places. Government intervention in subsidizing the cost of the Internet accessibility, training of teachers, and provision of online teaching resources can also reduce other liabilities of online teaching.

Other notable limitations of web conferencing, as it applies to online teaching, are miscommunication, lack of physical interaction and minimal supervision. Since class members are not physically together, effective communication must prevail to ensure the class achieves the highest level of productivity. It is also important that the class members or different groups understand their respective tasks and positions throughout the course of the engagement to achieve the aim and objectives of the interaction (Suduc, Bizoi, and Filip 2009). The effective use of communication skills, clarity of audio, enforcement of discipline, and thorough engagement of participants can be used to overcome some of the problems.

Review of some web conferencing solutions/software for online teaching

Web conferencing requires less time and effort to set up and engage participants in a meeting; hence, certain requirements must be satisfied for participants to have a smooth and better experience of the conference, more especially when it is used for teaching and learning purposes. Depending on the type of web conferencing platforms one purchases, every vendor has their unique conditions for setting up and using the platform.

Participants must have a compatible operating system installed in their PC (Windows, Linux, or Macintosh Platform) or mobile (Android, iOS or Windows) to support the sharing of file and application. A functioning and fast Internet connection, preferably high-speed is recommended, to ensure optimal delivery (Botchkarev, Zhao, and Rasouli 2010). Furthermore, a web browser that is compatible with the choice of the web conferencing solutions should be installed for a client to have a greater experience. A speaker, a working microphone and camera for optional video broadcasting are also necessary (Botchkarev, Zhao, and Rasouli 2010; Swanson, Renes, and Strange 2019). On most of these platforms, log-in credentials or authentication (single or multiple) are expected to be created or carried out for participants to log-in and ensure that there are no cases of security breaches. Security is important to ensure private and confidential meetings can take place on these platforms. Below is a brief review of some notable web conferencing applications used for online teaching. It is worth pointing out that the providers of these tools update the tools from time to time, and add more features or remove some other features based on need and complaints. The descriptions represent the current state of these tools.

RingCentral VIDEO (RingCentral Inc)

This is a tool that provides instant messaging, voice call, group conferencing and screen sharing with recording facility on a RingCentral platform. It can be used on a browser, desktop or on a mobile device. It was developed by Ringcentral Inc, and it can host up to 500 participants with high-quality experience anywhere, anytime on a computer or mobile device. It has a free version that allows up to 100 users for 40 min (StarLeaf 2020). It also allows for screen sharing, file sharing or the use of whiteboards with the aim of getting work done faster. It allows participants to highlight the shared content with annotated tools. It allows for chatting between participants scheduling hosting and joining meetings. It is integrated with Microsoft Office and G-suit. For one-to-one video with none High Definition (HD) call 600 kbps is required for both upload and download; however, 1.2 Mbps is required for HD. It offers a maximum video

quality of 1280 × 720 at 30 fps. It is compatible with computers operating on Windows 7 and above, Mac OS X Snow Leopard and above, Android 5 and above. It currently only supports Chrome web browsers. It employs security standard such as Secure Real-Time Transport Protocol (SRTP) and Transport Layer Security (TLS) (StarLeaf 2020)

GoToMeeting (LogMeIn.)
It is a web-hosted real-time collaboration tool that markets itself as a user friendly and effective screen sharing tool. It is a software package that provides video conferencing, mobile conferencing, and recording facility between users. The screen of the host can be broadcasted to others. Like most of the other web conference tools, there are different packages with different offers. It can host up to 3000 participants for video conferencing with the enterprise package. Some of the packages allow for high-definition video, personal meeting rooms, and no meeting time limit, among other features (Lipschutz 2011). A user has the option to either use the device audio or select the option of using a phone call. It also allows for dial out to participants. It was created by LogMeln and all users using the app can chat with each other while on the meeting. It can be used on an Android device with Android 2.2 or higher Operating software, Windows 7 and above, Windows XP, Vista and Mac OS X 10.9 (Mavericks), Mac OS Catalina (10.15). The recommended requirement is 1 GHz CPU or higher. It also requires a 2GB or more RAM, in microphone and speakers if using the device audio. It requires a 2 GHz or more of processor speed and a minimum of 700 kbps bandwidth for screen sharing, a video and audio conferencing (Noll and Belur 2018). Depending on the selected plan, up to 25 participants can share their webcam at a time and up to 250 participants can dial in to join the meeting from their computer or mobile device. It employs the use of authentication provided by a Secure Socket Layer (SSL). It also uses authentication and end-to-end 128-bit Advanced Encryption Standard (AES) (Lipschutz 2011; Lynn 2010). The tool also allows for security features like locking meeting rooms, HIPAAA and risk-based authentication. The business account also includes features like transcripts. A participant can either be an organizer, attendee, or a presenter, each of them having a different level of access.

Pexip (Pexip Holding Asa)
Pexip is a software-based collaborative tool that provides seamless interoperability and collaboration service between technologies that offer video and audio technologies. It has the ability to allow users using different platforms like Skype for Business, Google Hangouts, Microsoft Team, among others to interoperate. It markets itself as a video communication tool that empowers people across borders that allows users to be seen, heard and included. It was a product of two merged companies; Pepis, founded in 2012 and Videxo founded in 2011(StarLeaf 2020). It requires a Pexip infinity environment using the infinity connect cable client that allows teams or organizations host web conferencing on-premises or on a cloud service, for example, Google Cloud, Microsoft Azure. The infinity connect can be used on Google Chrome version 27 and above, Mozilla Firefox version 20 and later, Microsoft Internet Explorer 10 and later versions and Apple Safari version 6 and later versions. On the desktop, it is compatible with Microsoft Windows 7 and later, Mac OS X 10.7 and later and Ubuntu Linux. It also requires about 0.5–3 Mbps per port, depending on the call control setup. It enables video conferencing, audio conferencing and meeting recording. It employs TLS certificates and authenticated SIP trunks for enhanced security (StarLeaf 2020).

Zoom (Zoom Video Communications, Inc.)
This is a tool that allows users to join meetings or webinars online using the zoom mobile app on Android and iOS, among others. It provides instant messaging, voice call, recording, screen sharing, video conferencing, keyboard and mouse sharing, active speaker and individual muting (Robertson 2020). Recently zoom became one of the most popular of the web conferencing facilities, and it markets itself as the leader in modern enterprise video communication with an easy and reliable cloud platform (Robertson 2020). Depending on the chosen plan, up to 49 participants can share videos on the screen at a time and up to 1000 video participants can join the meeting anywhere on any device. Zoom allows for both dial-in and dial-out, and it allows all participants to be able to share their screen, and take control of the other user's computer if permitted by the host. It offers both free and paid versions; however, the free version is limited to 40 min of meeting time. It also has a special educational package and allows users to chat during a meeting or webinar. It requires 800 kbps and 1.0 Mbps for upload and downloads, respectively, for high-quality video. It works on Mac OS X with Mac OS 10.7 and later versions, Windows XP or later, Ubuntu 12.04 or higher, Red Hat Enterprise Linux, Oracle Linux 6.4 or higher, and CentOS, among others. It is supported on browsers like Chrome H30+, Firefox, Mac Safari, Edge, among others. It is recommended that the system should have a minimum of 4 GB RAM memory and 1 GHz processor or higher. Zoom's architecture provides encryption and communication that are established using 256-bit TLS encryption while shared content uses AES-256 encryption. In addition, it offers the host the right to keep users in waiting rooms, lock meeting rooms, password protect meeting rooms and the ability to remove users, among other security features.

TeamViewer (TeamViewer GmbH)
This is a tool for remote control and remote support that markets itself a handy tool used in connecting remote devices. It was founded in Germany while equity firm Permira, took it over in 2014. Each user has an ID and a password and which, if shared, can allow another TeamViewer to take control of the other user's computer (Drugarin, Draghici, and Raduca 2016). It offers different packages from the free version to the paid version, allowing from three hour up to eight hour sessions. It is more of

a tool that allows remote access of another user's computer and connecting remote devices. It allows secure and flexible file sharing, remote printing, web conferencing online meeting and access to attendee's devices. It is supported on a variety of platforms, including Mac OS, Android, iOS, Windows and Linux, among others. Several remote sessions can run within the browser tabs concurrently on Mac OS. It requires at least 6Mbit/s and 1Mbit/s for download and upload connections, respectively. TeamViewer is built on end-to-end 256-bit AES encryption and two-factor authentication among other security features (Drugarin, Draghici, and Raduca 2016).

Eztalkss (ezTalks Technology Company Limited)
It is an enhanced quality cloud-based web conferencing, online meeting tool and hardware tool for large enterprises. It markets itself as the most secure video conferencing software that allows up to 100 participants in one conference and at no cost. It requires a camera, a codec unit, video display, microphone and speakers (Lee 2017). It also requires desktop endpoint software which is compatible with Mac, iOS and Android clients. It is also supported on browser Firefox and Chrome among others. It allows for instant messaging, meeting rooms, recording, whiteboard and screen sharing.

CISCO Webex (CISCO Company)
It is an enterprise solution video conferencing, audio conferencing, instant messaging, screen sharing and meeting recording tool. It markets itself as the leader in video and team collaboration. It is an American company formed in 2007 resulting from CISCO systems acquired Webex. It is a cost-effective solution that can host up to 100 participants in the video conference at a cheap monthly price depending on the user's requirement. It also markets a pack for education and classes (Webex 2014). The platform is enabled through the CISCO Webex Cloud, and participants can attend from various kinds of devices. Depending on the plan, up to 2000 participants can attend a web conference. CISCO Webex operates on Windows from Windows XP and later versions and Mac 10.6 Snow Leopard and later versions. It also works on a number of browsers such as Internet Explorer 8 and 9, Mozilla 10 and above, Safari and Google Chrome. It runs an end-to-end encryption service for those who require enhanced security. It also offers flexible meeting passwords and data centre security. It offers different features to different users, depending on the user's role, such as host, alternative host, presenter, panellist, attendee and site administrator (Webex 2014).

Skype/ Skype FOR BUSINESS (Microsoft)
This is a communication tool that allows audio conferencing, video conferencing, instant messaging, screen sharing and meeting recording between Skype users on computers, tablets, mobile devices, Xbox one game console and smart watches over the Internet. It is completely free to use with other Skype users. It was acquired by Microsoft in 2011 and allows users to register and have a unique Skype ID for free. To contact another user using Skype, a Skype ID is required. It can host up to 50 attendees from anywhere and all devices. However, it also offers services that allow a Skype user to call or send SMS to mobile phones and calls to landlines from a Skype account. This is charged at a different rate depending on the country and if it is a mobile or landline that is being called. However, it does not offer the ability to call emergency numbers in some countries while this service is offered in countries like the USA, UK, Australia, Denmark and Finland. It allows for messages to be sent to other users when they are offline and such messages can be retrieved when the user is online. It can be used on iOS, android Nokia X among others and on desktop the app can be installed on Windows, MacOS, and Linux. Skype also allows third parties to offer their services. Skype is widely used for educational purposes among teachers or even students and it offers services such as Skype in the classroom. The bandwidth requirement of Skype depends on the type of call and the number of participants. If it is used just (Berson 2005; Chen et al. 2006) for calling it requires about 30 kbps for both upload and download and 4 Mbps and 128 kbps for download and upload, respectively, with seven or more users making a video call. It works on Windows X and above but cannot be used on browsers without downloading the app. Skype is not considered to be as secure as it does not offer an end-to-end encrypted VoIP system. Skype for Business allows a large organization to add more people to join. Up to 250 people can join online meetings and it is integrated into Microsoft Teams. It offers enterprise-grade security. It does have its own app different from Skype.

Apache OpenMeeetings (Apache Software Foundation)
OpenMeetings is an open-source software, used for conferencing tools that provides audio conferencing, video conferencing, instant messaging, meeting recording and screen sharing. It is based on Red5 media server, HTML and Flash and it is based on open source. It's an open-source tool allowing developers from different countries to collaborate but the main project development moved to Russia in 2011. Collaboration is effortless using the Apache OpenMeeetings platform and it requires the installation of the app before it can be used. It can allow up to between 50 and 100 concurrent users using the open meeting. Each of the users can have about 20 users in each room. The capacity varies greatly depending on the web meeting type and number of speakers or listeners; it runs on the most widely used operating system such as Linux, Windows and Mac OS. It does not offer end-to-end encryption and has a number of security vulnerabilities due to the open nature.

Join.me (LogMeIn Inc.)
This is an online tool that offers audio conferencing, video conferencing, and screen sharing, for fast and easy meeting joining. It allows the use of whiteboards and also allows for personalized meeting invites. This makes it stand out from some other tool that allows for only a generalized invite. It markets itself as a tool that avoids pointless processes, politics and protocol by allowing more things to be done by a single click and better on

mobiles. It offers both free and paid packages with different features and it is available on Windows 7 and above Mac OS and Linux among other operating systems. Both the free and paid packages allow for meeting time as long as it is required. It offers dial-out options and VoIP. It offers unlimited bridged audio conferencing. It also allows the use of whiteboard among other features. It allows the integration of Microsoft office 365 and outlook. It does not require the attendee to download a plugin therefore it makes starting a meeting faster and easier. Depending on the plan, this platform can host up to 250 attendees in one conference. For security, it offers 256-bit TLS encryption and it claims it does not store any files image or data during meetings. A minimum of 1 Mbps of bandwidth is required for both the viewer and the presenter for sustained and full-screen sharing.

Google Hangouts (Google)
Google Hangouts is a communication software developed by Google for keeping in touch with one person or a group of people or friends. It is available on mobile or desktop and it provides instant messaging, audio conferencing, video conferencing, recording and screen sharing. It integrates VoIP, Google voice and IP telephony products. This platform is integrated into Gmail and Google+, and compatible with multiple computing devices. Chat history is saved online, thus allowing for synchronization when using multiple devices. It allows 25 concurrent users and offers an educational package. It allows for integration on both Android and iOS and it allows easy integration into Google Chrome where users do not need to install a plugin unlike if other browsers are used. It integrates different Google products such as Google chat Google voice and Google Meet among others. It works on Mac OS X, Windows, Chrome or Ubuntu. They are built into YouTube, Gmail and Google Voice. It requires a minimum of 256 and 512 kbps for upload and download, respectively. For the best experience and with more than two users on a call 900 kbps and 2 Mbps are recommended for upload and download, respectively. Google Hangouts has a number of security issues as only hangout conversations are encrypted and it doesn't offer end-to-end encryption; rather, messages are encrypted in transit.

Google Meet (Google)
Google Meet is Google's premium video conferencing software offered as part of the G-suite. It was originally paid only but recently offered free to use as a result of the challenges of COVID-19. It allows users to turn on and off their microphone and camera, share screen and see other participants. It allows for HD calls but does not allow additional effects like status messages or emojis like hangout. Unlike Google Hangouts one can change the layout of the screen to see who is currently talking or other users. Google Meet allows for users to easily join meetings on computers or on mobile devices. Its system requirements and many other features, like security, are the same with Google Hangout.

GOOGLE CLASSROOM (Google)
This is a free web service that is also developed by Google for schools and Universities. It is dedicated to making classroom requirements like allowing assignment and sharing of files between teachers and students. It incorporates other Google services like Google Drive, Google calendar and document and Gmail. Google Classroom allows students to be invited via the institution database or via the use of private code. Google Classroom allows for up to 20 teachers per class, 1000 members of a class (teacher and student) and also allows for live streaming for viewers within the same domain (Iftakhar 2016). It allows recording which can be saved onto the Google drive. It also allows the teachers to post announcements while students can comment on it. It allows for the incorporation of YouTube videos and it can be accessed via the web, Android or iOS devices.

Adobe Connect (Adobe Inc.)
This web conferencing tool provides audio conferencing, video conferencing; screen sharing, recording, breakout rooms, instant messaging and individual muting. Depending on the plan, the platform can host up to 1500 attendees. It markets itself as the most secure, and flexible with extensible features for web conferencing. It allows users to design their own experience with customized pods, images and personalized layout. It also allows a measure of how engaged the audience is through the multiple chat rooms and simultaneous breakout rooms. During a live session, it allows the presenter and the host to collaborate behind the scene. It offers both free and paid packages with different levels of features. It also offers educational packages where virtual classes can be conducted for up to 200 users. However, the webinar package allows up to 100 users. It recommends 256 kbps as the minimum bandwidth for participants or attendee of a meeting. It operates on Windows, Mac OS, Linux, mobile devices among others (Connect 2014). It can connect on major browsers, like Chrome, provided add-in is enabled. It is not end-to-end encrypted but offers transit encryption with a single key using the Transport Layer Security (TLS) encryption versions 1.1 and 1.2. It also offers encryption to passwords that are stored on its database.

LoopUp (LoopUp Group PLC)
This is a premium web conferencing tool that allows video streaming, and screen sharing among other features. It was founded by Steve Flavell and Michael Huges. It uses dial-out functionality while allowing the use of a link to join. After joining, a user is directed to a web page where the user would be able to see others on the call. Users can also be called on the phone with guidance on how to engage in a meeting. LoopUp markets itself as a collaborative software that allows for collaboration with simplicity. It is a premium service, hence does not have a free version except the free 1-month trial for 3000 min. It works on Google Chrome, Microsoft Edge and other major browsers with the latest release version. It also works on mobile browsers like iOS and Android devices. It requires 1000 kbps for

excellent video call and 150 kbps for an acceptable video call. The video streams are encrypted using AES 128-bit encryption.

Vidyo (Vidyo Inc.)
This is a video conferencing tool, founded by Ofer Shapiro, that provides software-based collaboration technology. It markets itself as a platform that integrates with any application environment, network and device with the aim of delivering quality experience while fostering long term relationships. It allows users to be able to join meetings without downloading the application. It operates on Windows 7 and above, Mac OS X 10.10 or higher. It offers security features that are protected through the use of IP addresses. It also offers encrypted services (Fernandes and Baron 2015).

StarLeaf (StarLeaf Limited)
This is a web conferencing tool established in 2008 by Mark Loney, Mark Richer and William Macdonald (StarLeaf 2020). It offers interoperability with Skype for Business, Zoom Polycom, Lifesize among other conferencing tools. It markets itself as a tool that is designed to enhance productivity and seamless collaboration. It offers messaging service, screen sharing, recording among other features. It requires 1.5 Mbps of bandwidth for both upload and download for ideal connection. It works on Windows 7, iOS9.0, Mac OS 10.12 and android 6.0 or the later versions. It offers robust security features such as encryption services endpoint authentication.

POLYCOM (Polycom Inc.)
Polycom offers video and voice services using its dedicated hardware. It was founded by Brian L Hinman and offers a wide range of hardware for video conferencing. Unlike some of the other tools discussed, it is not based on software. Their hardware is called a conference phone and it is connected with a telephone line or to a computer system. Unlike the conventional telephone line, it allows the use of Internet phone service using Voice over IP (VoIP) (Lambert 2004). The equipment can cost up to 100,000 USD and the subscription fee varies.

LIFE SIZE (Serenova, LLC)
This is a web conferencing tool that offers high-definition video conferencing and collaboration tools. It was founded by Crig Malloy and Michael Kenoyer in 2003. It markets itself as a high definition and anywhere experience. It works with Microsoft Team, Skype for Business, Outlook Polycom among others. It has a free version that allows for unlimited meeting time and other paid services with more features. It allows up to 1000 users for the enterprise version, chatting services among the participants, recording series and Microsoft integration. It requires a high-resolution webcam to experience the full resolution. A 2 Gbit of RAM and Quad processor is recommended. The bandwidth requirement depends on the resolution required. 1 Mbps can allow up to 15 fps at 720p resolution while 4k resolution will require about 4 Mbps.

BlueJeans (Verizon Communications)
BlueJeans markets itself as a world-leading provider of conferencing tools. It offers interoperable cloud-based service for webinars audio conferencing, video conferencing, screen sharing, recording, and instant messaging. This allows for users across different devices or platforms to interoperate. It is owned by BlueJeans Network based in the USA. This platform supports up to 100 interactive attendees in the meeting and, depending on the plan, can scale up to 5000 attendees. Attendees can join from anywhere on any device. The tool does not require users to download any software if it is used on major browsers like Chrome, Safari, Firefox, opera edge, among others. It is supported on Windows 7 and above Mac OS, Linux among other platforms. The recommended minimum bandwidth is 384 kbps a minimum of 750 kbps is recommended but to achieve an overall quality experience while 4.5 Mbps can be required if video content is being sent. It allows for either audio and video devices to be used or audio via a phone device. The calls are encrypted with TLS authentication and media with SRTP encryption though not end-to-end.

OMNIJOIN (Brother Industries)
This is a tool that can be used for both planned and ad hoc meetings. The platform allows for conferencing tools providing audio conferencing, video conferencing, and messaging. It is compatible with Android, iPhone and iPad. It offers a rich set of functionalities for flexible and various scenarios. It runs on Windows X, Mac OS X 10.6 and iOS 6 and their later versions. It offers a free trial service and allows about a maximum of 50 attendees as viewers while 20 attendees can have a video conference.

Interprefy
Interprefy is a remote web conference tool that allows for simultaneous interpretation platforms into multiple languages. The tool markets itself as a tool that breaks down barriers and ordered across the globe because of its interpretation facility. It offers an encrypted service, real-time streaming, live captioning and searchable recordings in multiple languages. The tool can be used when users are either onsite or offsite while attending a conference. It offers high-quality video and audio services. It does not offer a free service and services are charged per event.

Methodology
There are different web conferencing solutions, some of which are as described in the previous section with varying costs and feature that can be used for Unicast, Multicast and Anycast communications. Currently, some systems are more popular than others. Some offer more options and features at affordable prices, while some are more suitable for effective teaching and learning. In this work, 22 web conferencing solutions were purposively selected and assessed based on five aspects:

- Technical features
- Educational support
- Technical specifications
- Data rate requirements and
- Use cases.

These five criteria are set as necessary for a tool to be effectively used for teaching and learning. However, the cost of the tools is not explicitly included because a significant number of these tools are currently available for free, especially during the COVID-19 lockdown. The selected solutions are RingCentral Video, GoToMeeting, Pexip, Zoom, Google Meet, Adobe Connect, Loop Up, Vidyo, Omni Join, BlueJeans, Avaya, Webex, Life Size, Star Leaf, Polycom, Skype for Business, Team Viewer, ezTalks Meetings, Apache OpenMeeetings, join.me, Google Classroom and Google Hangouts. In the Appendix the reference links where additional features of each of the aforementioned tools could be obtained is provided. Figure 4 provides the taxonomy of the features used for the selection process and also used to classify the tools. As for the technical features, the paper looks at the ones that support instant messaging because this would allow for class interaction. The other features considered are multiple user voice calls, group conferencing, screen sharing, which are features needed for interactive teaching and learning to take place. The paper also considers the application that allows recordings such that students can go back and listen to the class especially for those who might have missed the class, those with technical difficulty and those with network issues during the class. Compatibility with mobile phones is also considered because mobile or smartphones are the most widely used, easily accessible and cheaper device in developing countries than computers or laptops. The data rate is also selected as one of the criteria because fast, affordable and reliable Internet facility in developing countries, especially in Africa is not widely available. This paper also considers the use case based on some peculiarities of developing countries.

Another feature considered is their level of support for educational services such as allowing for individual assignment, multiple classrooms, raising of hands by students and content sharing. The data rate requirement is also considered. The features in Tables 2 and 3 are used to prune down the list of 22 web conferencing solutions to the five top solutions, namely, Zoom, Skype for Business, Google Classroom, CISCO Webex and GoToMeeting. The selected five solutions were downloaded, installed and experimented. Layer 2 software assessments were conducted on the software where a meeting of a class size of 15 participants was used to explore the features of each of the five solutions. The five solutions were assessed based on data rate requirements and ease of use for teaching and learning purposes, as illustrated in Figure 4. Tables 2–5 provide the results of the assessments.

Results and discussion

Table 2 shows the taxonomy of web conferencing solutions based on technical features such as instant messaging, voice calls, group conferencing, screen sharing, muting, compatibility, recording and data rate demand.

Instant messaging allows real-time text-only conversation and 21 out of the 22 web conferencing solutions have this feature. The 22 web conferencing solutions have the voice call (VoIP/PSTN dial-in audio), screen sharing and group conferencing, recording and muting features. Most of the web conferencing solutions are compatible on Windows, Android, Linux, macOS and iOS except for a few like OmniJoin, LoopUp, Google Meet, Pexip and RingCentral Video which have one or two exceptions. The data rate demand for these web conferencing solutions are not so high; they require anything from 128 kbps. The web links to each of the applications are in the Appendix.

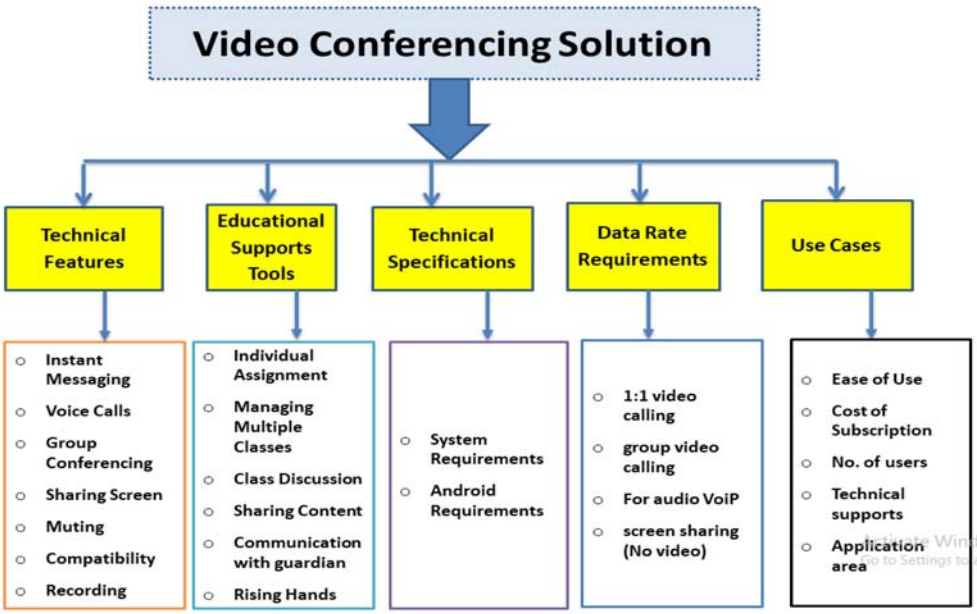

Figure 4: Taxonomy of selection features.

Table 2: Taxonomy of web conferencing solutions/apps based on technical features.

Video conferencing app	Instant messaging	Voice calls	Group conferencing	Screen sharing	Allow users to mute	Recording	Data rate demand
Adobe Connect	Yes	Yes	Yes	Yes	Yes	Yes	Low
Apache OpenMeeetings	Yes	Yes	Yes	Yes	Yes	Yes	Low
Avaya	Yes	Yes	Yes	Yes	Yes	Yes	Low
BlueJeans	Yes	Yes	Yes	Yes	Yes	Yes	Medium
ezTalks Meetings	Yes	Yes	Yes	Yes	Yes	Yes	High
Google Classroom	Yes	Yes	Yes	Yes	Yes	Yes	Low
Google Hangouts	Yes	Yes	Yes	Yes	Yes	Yes	Low
Google Meet	Yes	Yes	Yes	Yes	Yes	Yes	Low
GoToMeeting	Yes	Yes	Yes	Yes	Yes	Yes	Medium
join.me	Yes	Yes	Yes	Yes	Yes	Yes	Low
Life Size	Yes	Yes	Yes	Yes	Yes	Yes	High
Loop Up	No	Yes	Yes	Yes	Yes	Yes	Medium
Omni Join	Yes	Yes	Yes	Yes	Yes	Yes	High
Pexip	Yes	Yes	Yes	Yes	Yes	Yes	High
Polycom	Yes	Yes	Yes	Yes	Yes	Yes	Low
Ring Central	Yes	Yes	Yes	Yes	Yes	Yes	Medium
Skype for Business	Yes	Yes	Yes	Yes	Yes	Yes	Low
Star Leaf	Yes	Yes	Yes	Yes	Yes	Yes	High
Team Viewer	Yes	Yes	Yes	Yes	Yes	Yes	Low
Vidyo	Yes	Yes	Yes	Yes	Yes	Yes	Low
Webex	Yes	Yes	Yes	Yes	Yes	Yes	High
Zoom	Yes	Yes	Yes	Yes	Yes	Yes	Medium

Table 3: Taxonomy of web conferencing solutions/apps based on educational supports.

Software/ features	No of users	Individual assignment	Customize assignment	Manage multiple classes	Create class discussion	Share content	Communicate with guardians	Raising hands
Adobe Connect	500	Yes	Yes	Yes	Yes	Yes	No	Yes
Apache OpenMeeetings	100	No	Yes	No	Yes	Yes	No	Yes
Avaya	100,000	No	Yes	Yes	Yes	Yes	No	Yes
BlueJeans	150	Yes	Yes	No	Yes	Yes	No	Yes
ezTalkz Meetings	10,000	Yes	Yes	Yes	Yes	Yes	No	Yes
Google Classroom	1000	Yes	Yes	No	Yes	Yes	Yes	No
Google Hangouts	100	Yes	Yes	No	Yes	Yes	No	No
Google Meet	250	No	Yes	No	Yes	Yes	No	Yes
GoToMeeting	3000	No	Yes	No	Yes	Yes	No	No
join.me	250	Yes	Yes	No	Yes	Yes	No	Yes
Lifesize	500	No	Yes	No	Yes	Yes	No	No
LoopUp	150	No	Yes	No	Yes	Yes	No	No
Omnijoin	50	No	Yes	Yes	Yes	Yes	No	Yes
Pexip	Infinity	No	Yes	Yes	Yes	Yes	No	Yes
Polycom	Varies	No	Yes	No	Yes	Yes	No	No
Ring Central Video	500	Yes	Yes	Yes	Yes	Yes	No	Yes
Skype for Business	10,000	Yes	Yes	No	Yes	Yes	No	Yes
StarLeaf	100	No	Yes	No	Yes	Yes	No	Yes
TeamViewer	25	No	Yes	Yes	Yes	Yes	No	No
Vidyo	Infinity	No	Yes	No	No	Yes	No	No
Webex	1000	Yes	Yes	No	Yes	Yes	No	Yes
Zoom	1000	Yes	Yes	No	Yes	Yes	No	Yes

Table 3 provides the taxonomy of web conferencing solutions based on educational support such as the number of users or participants, individual and customized assignments, managing multiple classes, creating class discussions, sharing contents, communicating with guardians and virtual hand-raising. Each of the tools was earlier discussed in section 3.0. In this category, we have RingCentral Video, Adobe Connect and ezTalks Meetings supporting more features. GoToMeeting, Pexip, Zoom, Vidyo, Avaya, Webex, Skype for Business, ezTalks Meetings and Google Classroom support over 1000 users or participants.

Table 4 provides the taxonomy of web conferencing solutions based on capacity (Number of users).

Table 4: Taxonomy of web conferencing solution/app based on capacity (no of users).

	Package	
Software	Lower capacity (free or basic plan)	Higher capacity (enterprise)
Adobe Connect	100	500
Apache OpenMeeetings	NA	100
Avaya	200	100,000
BlueJeans	100	150
ezTalkz Meetings	25	10,000
Google Classroom	1000	1000
Google Hangouts	10	25
Google Meet	100	250
GoToMeeting	250	3000
join.me	10	250
Lifesize	300	500
LoopUp	50	150
Omnijoin	20	50
Pexip	100	Infinity
Polycom	NA	180
Ring Central Video	200	500
Skype for Business	250	250
StarLeaf	20	100
TeamViewer	5	25
Vidyo	50	Infinity
Webex	200	2000
Zoom	100	1000

GoToMeeting, Pexip, Zoom, Vidyo, Avaya, Webex, Skype for Business, ezTalks Meetings and Google Classroom support over 1000 users or participants. Pexip and OmniJoin have infinite capacity. The web conferencing solutions with the least capacity are TeamViewer and Google Hangouts. Table 4 shows the taxonomy of web conferencing solutions based on data rate requirements for some technical specifications. Google Classroom and Skype for Business has the least bandwidth requirement, 128 kbps (up/down) for one-to-one video calling, 128–512 kbps (up/down) for group video calling and 30 kbps for audio VoIP (up/down). GoToMeeting has the highest requirement of 700 kbps (up/down) and 2 Mbps for one-to-one video calling and group video calling, respectively. CISCO Webex requires 60–150 kbps for audio VoIP, which is the highest.

CISCO Webex is a cloud-based suite of productivity tools from CISCO. Beyond its technical features, it is very easy to participate in or host web conferences. There are currently three subscription plans – Starter, Plus and Business. The Starter plan costs $14.95 per month for up to 50 participants in a meeting. The Plus plan costs $18.95 per month for up to 100 participants in a meeting. And the Business plan costs $29.95 per month for up to 200 participants in a meeting. CISCO Webex has self-service support, live chat support and phone support. To join a meeting, there is usually an email invitation from an organizer. The participant is expected to tap 'Join' and enter the meeting password usually in the email invitation. CISCO Webex is suitable to use for secondary and tertiary education.

Google Classroom is a web-based platform that makes it easy to create classes, distribute assignments, communicate and stay organized. Google Classroom is usually integrated into G-Suite services, and the subscription plans are $6 per month for basic, $12 per month for business and $25 per month for enterprise. There are quite a number of technical supports available from Google Classroom like social contacts on Facebook, Twitter and LinkedIn. Also, there are Q&A websites, online forums and communities. Google Classroom is suitable to use for basic, secondary and tertiary education.

GoToMeeting has a web version and desktop app, and both interfaces make web conferences an easy proposition. All buttons and links are clearly labelled, which makes it easy to use, to join, to host and to schedule meetings. The cost of subscription ranges between $12 and $16 monthly for the Professional and Business plans, respectively. The Professional plan takes 150 participants, the Business plan takes 250 participants and the Enterprise plan takes 3000 participants. There is available technical support through calls to GoToMeeting partners or resellers. To connect to an online meeting, a 9-digit meeting ID or Personal Meeting Room provided by the organizer is required. GoToMeeting is suitable to use for secondary and tertiary education.

Skype for Business provides a great online meeting online experience and has more recognition among businesses. The cost for a subscription is about $5.50 and $12.50 monthly for Online Plan 1, Online Plan 2, Office 365 Business Essentials and Office 365 Premium. These subscription plans have a capacity of 250–10,000 participants. Additional enterprise plans are also available. Skype has a robust community and online forum for technical support. A Skype for Business account is

Table 5: Taxonomy of top five web conferencing solutions/apps based on data rate requirements for some technical specifications.

	Minimum bandwidth requirements			
Software/features	1:1 video calling	Group video calling	Audio VoIP	Screen sharing
CISCO Webex	500 kbps (up/down)	500 kbps (up/down)	60–150 kbps (up/down)	50 kbps
Google Classroom	128k bps (up/down)	128 kbps/512 kbps (up/down)	30k bps (up/down)	128 kbps (up/down)
GoToMeeting	700 kbps (up/down)	2 Mbps	60–80 kbps	40k bps–8 mbps
Skype for Business	128 kbps (up/down)	128 kbps–512 kbps (down)	30 kbps (up/down)	128 kbps (up/down)
Zoom	600 kbps (up/down)	800 kbps/1.0 mbps (up/down)	60–80 kbps	(no video thumbnail) 50–75 kbps (down)

Table 6: Taxonomy of top five web conferencing solutions/apps based on use case.

Software/ Features	Ease of Use	Cost subscription		Technical Support	Application Area	Remarks
		Students	Lecturers/ Organisers			
CISCO Webex	Very Easy	Free	$19–39/ month	Available	• Secondary education • Tertiary education	Required to join with a meeting number (access code) and a meeting password
Google Classroom	Moderate	Free	$6–25/month	Available	• Basic education • Secondary education • Tertiary education	Required to have a Gmail or institution email address and join with a class code or accept an invitation from a teacher
GoToMeeting	Moderate	Free	$12–16/ month	Available	• Secondary education • Tertiary education	A GoToMeeting ID or personal meeting room is required
Skype for Business	Very easy	Free	$2–12.5/ month	Available	• Secondary education • Tertiary education	An invitation link and/or conference ID is required to join the meeting.
Zoom	Very easy	Free	$14.99–19.99/ month	Available	• Secondary education • Tertiary education	A meeting ID is used to join and a password may be required.

needed to join or host meetings. Skype for Business is suitable to use for secondary and tertiary education (Table 6).

Zoom is also a reliable and easy cloud platform for web conferencing. There are four subscription plans, Basic, Pro, Business and Enterprise. The Basic plan is free and can host up to 100 participants. Pro plan costs $14.99 monthly and can host 100 participants with more features than the Basic plan. Business Plan costs $19.99 monthly and can host 300 participants. An enterprise plan is customized and can vary, its cost begins at $19.99 and can host 500 participants and above. Zoom is suitable to use for secondary and tertiary education.

Implementation challenges in developing countries

The described tools can be used for teaching and learning, especially given the current social distancing and lockdowns of educational institutions across the world. However, to implement the use of these tools, especially in developing countries, there is a need to have some policy adjustment while putting in place the necessary infrastructure. Some of these are: digital divide, cost of data rate, purchasing power, ownership structure, availability of online curriculum among others.

Digital divide

The Digital divide is the uneven distribution of access to Information and Communication Technology (ICT) that may exist between two distinctive groups. In Africa, the majority of the population lack basic access to ICT and reliable telecommunication infrastructure when compared to most parts of the developed world. There is also a significant divide between access to ICT infrastructure between the urban and rural areas and between age groups within Africa. Bello et al. (2016) found out that there is a significant digital divide among communities in Kwara State, Nigeria, especially between the State capital and the rural areas in the State. Ani, Uchendu, and Atseye (2007) also investigated the digital divide in Nigeria using the University of Calabar as a case study. The paper shows that there is a prevalence of a digital divide between gender group, marital status, age and educational level in the use of the Internet in Nigeria. Roycroft and Anantho (2003) show that a significant number of African nations are facing a dual digital divide. There is inadequate or even a lack of access to basic telecommunication and ICT infrastructure in some African communities and the cost of access is higher where available. One of the features of typical rural communities in Africa is a lack of infrastructure development, as most of these communities do not have access to electricity and good roads, thus drastically increasing the cost of initial deployment and maintenance of ICT infrastructure. Hence, the major problem would, therefore, lie with the financial sustainability of rural access schemes, as the majority of the rural populace in Africa is saddled with poverty and can't afford to pay for the services (Adediran et al. 2016; Faruk et al. 2017). The prevalent form of a digital divide in our communities is one of the factors that is preventing the use of digital tools in developing countries. The basic infrastructure needed is not available and, where available, they are very expensive. The digital divide and cost of deployments can be relaxed by deploying disruptive and innovative technologies such as the Television White Space (Opawoye et al. 2015; Faruk et al. 2015), energy and cost effective backhaul solutions

for last mile rural connectivity (Oloyede and Faruk (2018); Faruk, Abdulkarim et al. 2019) and sustainable business models (Oloyede et al. 2017, 2018, 2019).

High cost of data and low purchasing power

Affordability of the end-user (students/parents), considering the low purchasing power among the African populace is an issue. On the other hand, the cost to purchase a data bundle of mobile broadband data across low- and middle-income countries is high. Even though Africa experiences the most significant data cost reduction amongst other regions and an upsurge in access to technology, including the rapidly growing penetration of inexpensive smart mobile devices, the cost of mobile data is still prohibitively high when compared to developed countries. Hence, affordability will continue to be a major obstacle and barrier to access to the Internet.

Low public-private partnership (PPP)

Public-private partnership (PPP) is the collaboration between government agencies and the private sector. According to Delmon (2017), PPP can help to provide better infrastructure or solutions for telecommunication and ICT infrastructure than when it is left solely in the hands of either the government or the private sector. PPP allows for faster project completion as a result of synergy between the two groups. Osei-Kyei and Chan (2015) review the success factors for PPP around the world between 1990 and 2013. The paper shows that PPP is important to the development of a number of critical infrastructures around the world. Marine and Blanchard (2004) agree that PPP is a promising initiative that has been used by a number of countries to finance the necessary ICT and telecommunication infrastructure. Nucciarelli, Sadowski, and Achard (2010) examine the function of PPP in the development of broadband in Italy and the Netherlands. The paper shows that PPP is also helpful in aligning the interest of the different private, semi-public and public service as ICT is a critical infrastructure for all the sectors. The paper also shows that PPP has significantly helped the level of broadband infrastructure in those countries. Rahman (2016) examines PPP and how it has helped expand the ICT services in rural Bangladesh. The paper shows how Bangladesh tapped into the use of PPP to improve on the ICT infrastructure in some of the rural areas in the country. The paper shows that it is evident that neither the public nor the private sector alone can shoulder the responsibilities of providing the necessary ICT infrastructure in a country and that PPP is a viable option to expanding the digital Internet services to poor and marginalized rural areas in Bangladesh. The paper provides a practical illustration of how PPP can be used in the development of ICT infrastructure. The use of PPP to finance projects is low in a lot of developing countries. Adeogun and Taiwo (2011) show that a lack of commitment on the side of the government is one factor that accounts for low PPP in Nigeria. Jamali (2004) examines the success and failure factors of PPP in developing countries. The paper highlights that PPP concepts in some developing countries are mired in a muddle of conceptual ambiguities.

Device ownership

To access any of the tools that have been discussed in this paper, a computer device, either in the form of a Smartphone, Portable smart device, Laptop or a computer, is required. According to the ITU, only about 10.7% of the African population has access to computers. This is far less than the 51.9%, 43.5%, 66.3%, 78.0% and 65.7% of the populations in the Arab States, Asia Pacific, Commonwealth of Independent States (CIS), Europe and the Americas, respectively. The lockdown associated with COVID-19 means that everyone stays, works and learns from home. The inadequate or lack of computer at home is one of the factors that would prevent a large percentage of the population from adopting the use of web conferencing and online digital platforms for teaching and learning during the period of the lockdown. Such applications could be extended to health care delivery via online services (Faruk et al. 2017; Faruk et al. 2020). Apart from computers, smart handheld devices also play a significant role in accessing these digital tools. Smartphones and PDAs can be used to access most of the online digital tools, as described earlier. They have the advantage of allowing the users to move around when using the device to access digital teaching and learning tools or web conferencing. Handheld devices are widely used in developing countries as a result of high penetration of basic access to mobile phones and the boom experienced in the African telecommunication industry in the last few years. However, most devices are not smart devices; only about 34% of the devices were smart based on the survey conducted in rural communities in Nigeria (Faruk et al. 2017). This is because the smart devices are quite expensive. Forenbacher et al. (2019) examined the social-economic factors for mobile phone ownership in Nigeria. The paper showed the importance of smart mobile devices and enumerated some of the challenges in owning one, such as cost and lack of electricity.

Lack of comprehensive online curriculum

The curriculum and lecture notes used by the teachers in a lot of developing countries are not in digital form because the teachers are not accustomed to using technology to aid teaching and learning. The sudden transition to online learning as a result of COVID-19 lockdown would therefore be challenging in such a situation. The digital form of instructional materials would have made the transition smoother. The use of e-learning platforms in a situation of inadequate infrastructure and fear of change among the teachers has hampered full transition to e-learning during the period of lockdown is Nigeria. Oloyede, Ajimotokan, and Faruk (2017) have examined engineering education in Nigeria with its challenges. It is noted that the use of innovative approaches to teaching and learning is very essential. The exploratory survey conducted suggested that 100% of the respondents attested that the use of technological teaching aids and e-learning was long overdue. Hence, virtual learning system should be encouraged. Oye, Salleh, and Iahad (2011) examined the challenges of learning in Nigeria. The paper examined e-learning in

countries like the United Kingdom, France, Korea and Australia and compared it with that of Nigeria. The paper shows that e-learning in developing countries such as Nigeria is lagging behind and identified funding as one of the major challenges. A synchronous virtual learning system was developed by Bello et al. (2014). Kamba (2009) discussed the challenges and benefits of e-learning by reviewing the consciousness and willingness of some selected Universities in Nigeria. The study which was conducted across 18 selected Universities in Nigeria showed that e-learning application and awareness was very poor and below expectation. The research also found out that most staff only use their computer and the Internet to find out information without using it in teaching and learning.

Power supply

Power supply is a major problem in many developing countries around the world, especially in Africa. In most African countries, some challenges are generally being faced in energy production. Some of these challenges are discussed in Dorian, Franssen, and Simbeck (2006), Brew-Hammond (2010). These challenges lead to an incessant electrical power outage, especially in Sub-Saharan Africa. The outlined challenges are mainly as a result of insufficient capacity, lack or inadequacy of modern infrastructure, poor maintenance culture, low reliability, low energy efficiency, and lack of technical and institutional capacity, among others. Another main challenge is under-investment leading to a lack of basic electricity infrastructure in most countries in Africa. It is estimated by the World Bank that external spending on the entire continent's power sector is about $600 m a year. This is not enough to maintain the existing infrastructure, thus leading to problems in distributing the generated capacity. These challenges, if not properly addressed, can hinder economic growth and even growth in the use of digital and modern-day tools described earlier. Electricity is important as it is needed to power the Internet infrastructure and also in powering the device that would be used to access these online platforms. However, in Abdulkarim et al. (2018, 2019) micro grids of hybrid renewable energy solutions can upset the power deficit in most of African countries, for the fact that the region has abundance of natural resources, such as sunlight, that can be used to sustainably generate electricity.

Poor implementation of universal access schemes

According to the ITU 79.5%, 91%, 95.4%, 88.2% 96.6% and 99.1% of Africa, Arab States, Asia Pacific, CIS, the Americas and Europe, respectively have basic mobile coverage; however, only about 35% of Africans, and 67% of the Arab State have access to the Internet, which is necessary for using the tools discussed earlier in this work. None of these tools can work without access to the Internet. However, to improve Internet connectivity around the world, most countries adopt the use of universal access fund. The fund is meant to subsidies telecommunication access, including the Internet for rural areas because it is mostly not profitable for Internet service providers to provide Internet access in these regions. However, universal access scheme and fund are poorly managed in a significant number of developing countries. Telecommunication subsidies are generally an initiative of the government and the private telecommunication industry in a country. They are financed through universal service and access funds which are mainly generated through contribution and tax from mobile network operators and telecommunication companies operating within a country. However, the schemes and subsidies are expected to have a significant level of effect on the development, penetration, and access to telecommunication services, especially in rural areas around the world. Regrettably, these funds are sometimes not used for the original aim and are often inefficiently allocated, delayed or even diverted in some countries.

Internet and computer use literacy level

The use of online tools for teaching and learning requires some basic ICT skills which are lacking in a significant percentage of the population in a developing country. ICT/ Internet literacy is the set of individual characteristics or qualities that is developed over time from the use of ICT and the Internet. It is when people know and use these tools over time that they get acquainted with them. However, the usage of the Internet is generally low in developing countries.

Conclusions and recommendations

This paper has examined twenty-two (22) web conferencing applications that can be used for remote teaching and learning in order to minimize the disruption to education as a result of the COVID-19 lockdown. The 22 web conferencing applications are RingCentral Video, GoToMeeting, Pexip, Zoom, Google Meet, Adobe Connect, Loop Up, Vidyo, Omni Join, BlueJeans, Avaya, Webex, Lifesize, Star Leaf, Polycom, Skype for Business, Team Viewer, ezTalks Meetings, Apache OpenMeeetings, join.me, Google Classroom and Google Hangouts. All the applications do not require physical contact between/among teacher(s) and student(s) and therefore can help to slow down the spread of COVID-19 infection by maintaining social distance. The suitability of the applications for online teaching was analyzed based on their capacity for instant messaging, voice call, group conferencing, screen sharing, allowing instructors to mute users to minimize disruption and background noise, operating systems compatibility, capacity for audio-visual recording, and data rate requirement. The applications were further analyzed based on another set of criteria which includes the features that allow individual students to perform homework and assignment, the number of participants the application can take, the ability to manage multiple classes at the same time, provision for students to raise hands and ask questions, and the capacity to share contents or lecture notes and engage participants in group discussion. Consequently, the provision for lower capacity enterprise and higher capacity enterprise versions of the applications regarding the class size or the maximum carrying capacity were also

considered. Based on the three sets of criteria enumerated in Tables 2–4, the five most suitable online teaching web conferencing applications, namely; Zoom, Skype for Business, Google Classroom, CISCO Webex, and GoTo-Meeting were identified.

Google Classroom and Skype for Business require the lowest Internet bandwidth for video calls and Audio VoIP as well as screen sharing. Therefore, they are the cheapest in terms of Internet accessibility. GoToMeeting (high capacity enterprise) is found to be the best, among the top five applications, for large class sizes. It has capacity for 3000 participants which is higher than the maximum capacity allowed by Google Classroom and Skype for Business. GoToMeeting is also compatible with all computer operating systems and does not require special computer specifications. Zoom, CISCO Webex, and Google Classroom offer free subscriptions for educational purposes in order to ease the negative impact of COVID-19 lockdown on education. Teachers and students with institutional affiliations can use them free of charge. Technical support for using these applications is also available free of charge. The links to each of the software have been provided in the Appendix. The links also provide a referral on where to find users manuals that can be used to address the skill gap.

The challenges and limitations of online teaching using web conferencing applications were also considered and appropriate solutions were recommended. Poor access to the Internet, lack of supporting infrastructure, absence of a comprehensive online curriculum, and the lack of skills required to use the online teaching applications were identified as the major challenges. Lack of physical interaction, poor supervision, and misconceptions were identified as the major limitations of online teaching when compared to face-to-face teaching. Government intervention in subsidizing Internet subscriptions, strong Public-Private Partnership, increased funding of education, provision of supporting infrastructure (including electricity) by governmental and private organizations, regular training of teachers, and provision of a comprehensive online curriculum were recommended as necessary steps to overcome the challenges facing online teaching. This paper recommends that despite the challenges faced by developing countries, web conferencing tools can be used to keep the education sector moving despite the COVID-19 lockdown. The paper also recommends that teachers should not restrict themselves to any particular tool; the tool chosen would depend on the requirements of the class. Most of these tools offer free versions which can be used to save costs.

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References

Abdulkarim, A., N. Faruk, A. O. Oloyede, L. A. Olawoyin, M. F. Akorede, I. Madugu, S. M. Abdelkader, J. D. Morrow, and Y. A. Adediran. 2019. "Reliability Study of Stand-Alone Hybrid Renewable Energy Microgrids." *Iranian Journal of Science and Technology, Transactions of Electrical Engineering* 43 (1): 411–425.

Abdulkarim, A., N. Faruk, A. O. Oloyode, L. A. Olawoyin, S. I. Popoola, A. I. Abdullateef, and Y. A. Adediran. 2018. "State of the Art in Research on Optimum Design, Reliability and Control of Renewable Energy Microgrids." *ELEKTRIKA-Journal of Electrical Engineering* 17 (3): 23–35.

Adediran, Y. A., J. F. Opadiji, N. Faruk, and O. W. Bello. 2016. "On Issues and Challenges of Rural Telecommunications Access in Nigeria." *African Journal of Education, Science and Technology* 3 (2): 16–26.

Adeogun, Olumiyiwa B., and Abraham A. Taiwo. 2011. "Housing Delivery Through Public-Private Partnership in Nigeria and the Case for Beneficiaries' Involvement." *Journal of Construction Project Management and Innovation* 1 (2): 63–79.

Adeyinka, A. Adeyinka. 1975. "Current Problems of Educational Development in Nigeria." *The Journal of Negro Education* 44 (2): 177–183.

Alqurashi, Emtinan. 2019. "Technology Tools for Teaching and Learning in Real Time." In *Educational Technology and Resources for Synchronous Learning in Higher Education*, edited by Jiyoon Yoon and Peggy Semingson, 255–278. IGI Global.

Ana-Maria, Suduc, Mihai Bîzoi, and F. G. Filip. 2009. "Exploring Multimedia Web Conferencing." *Informatica Economica Journal* 13: 5–17.

Ani, Okon Edet, Chika Uchendu, and Emmanuel U. Atseye. 2007. "Bridging the Digital Divide in Nigeria: A Study of Internet Use in Calabar Metropolis, Nigeria." *Library Management* 28 (6/7): 355–365.

Armitage, Richard, and Laura B. Nellums. 2020. "COVID-19 and the Consequences of Isolating the Elderly." *The Lancet Public Health* 5: e256–e257.

Bayham, Jude, and Eli P. Fenichel. 2020. "Impact of School Closures for COVID-19 on the US Health-Care Workforce and Net Mortality: A Modelling Study." *The Lancet Public Health* 5: e271–e278.

Bello, O. W., N. E. David, J. K. Ayeni, N. Faruk, and N. A. Balogun. 2014. "Towards the Design of a Synchronous Virtual Learning System." *Covenant Journal of Informatics and Communication Technology (CJICT)* 2 (2): 59–74.

Bello, O. W., J. F. Opadiji, N. Faruk, and Y. A. Adediran. 2016. "Opportunities for Universal Telecommunication Access in Rural Communities: A Case Study of 15 Rural Villages in Nigeria's Kwara State." *The African Journal of Information and Communication (AJIC)* 17: 139–163.

Berry, Sharla. 2019. "The Role of Video and Text Chat in a Virtual Classroom: How Technology Impacts Community." In *Educational Technology and Resources for Synchronous Learning in Higher Education*, edited by Jiyoon Yoon and Peggy Semingson, 173–187. IGI Global.

Berson, Tom. 2005. "Skype Security Evaluation." *ALR* 31: 2005-031.

Botchkarev, Alexei, Lian Zhao, and Hamed Rasouli. 2010. "Designing a Truly Integrated (Onsite and Online) Conference: Concept, Processes, Solutions." *arXiv preprint arXiv:1001*.1794.

Brew-Hammond, Abeeku. 2010. "Energy Access in Africa: Challenges Ahead." *Energy Policy* 38 (5): 2291–2301.

Chen, Kuan-Ta, Chun-Ying Huang, Polly Huang, and Chin-Laung Lei. 2006. "Quantifying Skype User Satisfaction." *ACM SIGCOMM Computer Communication Review* 36 (4): 399–410.

Clark, William R. 2008. *Bracing for Armageddon? The Science and Politics of Bioterrorism in America*. New York: OUP.

Cohen, Jon, and Kai Kupferschmidt. 2020. *Countries Test Tactics in 'War' Against COVID-19*. Washington DC: American Association for the Advancement of Science.

Connect, Adobe. 2014. Adobe Connect.
de Argaez, Enrique. 2020.
Delmon, Jeffrey. 2017. *Public-Private Partnership Projects in Infrastructure: An Essential Guide for Policy Makers*. Cambridge: Cambridge University Press.
Dorian, James P., Herman T. Franssen, and Dale R. Simbeck. 2006. "Global Challenges in Energy." *Energy Policy* 34 (15): 1984–1991.
Drugarin, C. V. Anghel, Silviu Draghici, and Eugen Raduca. 2016. "Team Viewer Technology for Remote Control of a Computer." *Analele Universitatii'Eftimie Murgu'* 23 (1): 61–66.
Faruk, N., A. Abdulkarim, N. T. Surajudeen-Bakinde, and S. I. Popoola. 2019. "Energy Efficiency of Backhauling Options for Future Heterogeneous Networks." In *Advances on Computational Intelligence in Energy: Green Energy and Technology*, edited by T. Herawan, H. Chiroma, and J. Abawajy, 169–194. Cham: Springer. ISBN: 978-3-319-69889-2.
Faruk, N., Y. A. Adediran, A. A. Ayeni, O. Kolade, N. T. Surajudeen-Bakinde, and O. W. Bello. 2015. "Geo-Spatial Approach to Quantifying TV White Space in Nigeria in the UHF Band." *JNIT: Journal of Next Generation Information Technology* 6 (4): 1–13.
Faruk, N., O. W. Bello, J. F. Opadiji, and Y. A. Adeniran. 2017. "Socio-Economic Challenges of Rural Telecommunication Access Schemes in Nigeria." *Information Technologist (The)* 14 (1): 193–216.
Faruk, N., A. A. Oloyede, A. Abdulkarim, L. A. Olawoyin, and Y. A. Adediran. 2019. "Energy Savings in Heterogeneous Networks with Self-Organising Backhauling." In *Advances on Computational Intelligence in Energy: The Applications of Nature-Inspired Metaheuristic Algorithms in Energy, Green Energy and Technology*, edited by T. Herawan, H. Chiroma, and J. Abawajy, 99–124. Springer. ISBN: 978-3-319-69889-2.
Faruk, N., N. T. Surajudeen-Bakinde, A. Abdulkarim, A. A. Oloyede, L. Olawoyin, O. W. Bello, and T. O. Edoh. 2020. "Rural Healthcare Delivery in Sub-Saharan Africa." *International Journal of Healthcare Information Systems and Informatics* 15 (3): 1–21.
Faruk, Nasir, Nazmat T. Surajudeen-Bakinde, Abdulkarim A. Oloyede, Olayiwola O. Bello, Segun I. Popoola, A. Abdulkarim, and Lukman A. Olawoyin. 2017. "On Green Virtual Clinics: A Framework for Extending Health Care Services to Rural Communities in Sub-Saharan Africa." *Paper Read at 2017 International Rural and Elderly Health Informatics Conference (IREHI)*.
Fernandes, J., and Thomas Baron. 2015. "Vidyo@CERN: A Service Update." *Journal of Physics: Conference Series* 664: 052011. doi:10.1088/1742-6596/664/5/052011.
Forenbacher, Ivan, Siniša Husnjak, Ivan Cvitić, and Ivan Jovović. 2019. "Determinants of Mobile Phone Ownership in Nigeria." *Telecommunications Policy* 43 (7): 101812.
Gilbert, Marius, Giulia Pullano, Francesco Pinotti, Eugenio Valdano, Chiara Poletto, Pierre-Yves Boëlle, Eric d'Ortenzio, Yazdan Yazdanpanah, Serge Paul Eholie, and Mathias Altmann. 2020. "Preparedness and Vulnerability of African Countries Against Importations of COVID-19: A Modelling Study." *The Lancet* 395 (10227): 871–877.
Huwiler, Anja G. 2015. "Library Services for Distance Students: Opportunities and Challenges." *Journal of Library & Information Services in Distance Learning* 9 (4): 275–288.
Iftakhar, Shampa. 2016. "Google Classroom: What Works and How." *Journal of Education and Social Sciences* 3 (1): 12–18.
Islam, Chhanda. 2019. "Using Web Conferencing Tools for Preparing Reading Specialists: The Impact of Asynchronous and Synchronous Collaboration on the Learning Process." *International Journal of Language and Linguistics* 6 (3): 1–10.
Jamali, Dima. 2004. "Success and Failure Mechanisms of Public Private Partnerships (PPPs) in Developing Countries." *International Journal of Public Sector Management* 17 (5): 414–430.
James, Jeffrey. 2019. "Confronting the Scarcity of Digital Skills Among the Poor in Developing Countries." *Development Policy Review* 39 (2): 324–339.
Kalinina, Svetlana D. 2015. "Webinar as a Form of E-Learning in Higher Education." *Herald of the MGIMO* 2: 41.
Kamba, Manir. 2009. "Problems, Challenges and Benefits of Implementing E-Learning in Nigerian Universities: An Empirical Study." *International Journal of Emerging Technologies in Learning (iJET)* 4 (1): 66–69.
Karachiwalla, Naureen. 2019. "A Teacher Unlike Me: Social Distance, Learning, and Intergenerational Mobility in Developing Countries." *Economic Development and Cultural Change* 67 (2): 225–271.
King, Elizabeth M, and M Anne Hill. 1993. *Women's Education in Developing Countries: Barriers, Benefits, and Policies*. Washington DC: The World Bank.
Kotoua, Selira, Mustafa Ilkan, and Hasan Kilic. 2015. "The Growing of Online Education in Sub Saharan Africa: Case Study Ghana." *Procedia - Social and Behavioral Sciences* 191: 2406–2411.
Lambert, Dave. 2004. "Polycom Video Communications."
Lee, C. 2017. "Benefits and Risks of File Sharing for Enterprises." *ezTalks*.
Li, Sijia, Yilin Wang, Jia Xue, Nan Zhao, and Tingshao Zhu. 2020. "The Impact of COVID-19 Epidemic Declaration on Psychological Consequences: A Study on Active Weibo Users." *International Journal of Environmental Research and Public Health* 17 (6): 2032.
Lieser, Ping, Steven D. Taf, and Anne Murphy-Hagan. 2018. "The Webinar Integration Tool: A Framework for Promoting Active Learning in Blended Environments." *Journal of Interactive Media in Education* 2018 (1): 1–18.
Lipschutz, R. P. 2011. GoToMeeting 3.0 Review.
Lloyd-Sherlock, Peter, Shah Ebrahim, Leon Geffen, and Martin McKee. 2020. *Bearing the Brunt of Covid-19: Older People in Low and Middle Income Countries*. London: British Medical Journal Publishing Group.
Lynn, S. 2010. "GoToMeeting 4.1." *Retrieved July* 8: 2011.
Marine, Souheil, and Jean-Marie Blanchard. 2004. "Bridging the Digital Divide: An Opportunity for Growth for the 21st Century." *Alcatel Telecommunications Review* 3: 308–313.
Monitor, I. C. E. F. 2020. Survey Measures the Expected Impacts of COVID-19 Across Education Sectors and Regions.
Nature. 2009. "Timeline: Swine Flu." *Nature*. doi:10.1038/news.2009.416.
Noll, Josef, and Sarbani Banerjee Belur. 2018. DigI: Digi Consortium GoToMeeting Jan 2018.
Nucciarelli, Alberto, Bert M. Sadowski, and Paola O. Achard. 2010. "Emerging Models of Public–Private Interplay for European Broadband Access: Evidence from the Netherlands and Italy." *Telecommunications Policy* 34 (9): 513–527.
Oloyede, H., A. Ajimotokan, and N. Faruk. 2017. "Embracing the Future of Engineering Education in Nigeria: Teaching and Learning Challenges." *Nigerian Journal of Technology* 36 (4): 991–1001. doi:10.4314/njt.v36i4.1.
Oloyede, A. A., and N. Faruk. 2018. "Spectrum Auction for Dynamic Spectrum Access with Energy Efficiency." *Bayero Journal of Engineering and Technology (BUKJET)* 13 (2): 151–158.
Oloyede, A. A., N. Faruk, L. A. Olawoyin, A. Abdulkarim, and Y. A. Adediran. 2017. "Economics of Dynamic Spectrum Access." *International Journal of Information Processing and Communication (IJIPC)* 5 (1): 23–37.
Oloyede, A. A., N. Faruk, L. Olawoyin, and O. W. Bello. 2019. "Energy Efficient Dynamic Bid Learning Model for Future Wireless Network." *Journal of Siberian Federal University. Engineering and Technology* 12 (1): 113–125.

Opawoye, I., N. Faruk, O. W. Bello, and M. Olufemi. 2015. "Recent Trends on TV White Space Deployments in Africa." *Nigerian Journal of Technology* 34 (3): 556–563. www.nijotech.com.

Osei-Kyei, Robert, and Albert P. C. Chan. 2015. "Review of Studies on the Critical Success Factors for Public–Private Partnership (PPP) Projects from 1990 to 2013." *International Journal of Project Management* 33 (6): 1335–1346.

Oye, N. D., Mazleena Salleh, and N. A. Iahad. 2011. "Challenges of E-Learning in Nigerian University Education Based on the Experience of Developed Countries." *International Journal of Managing Information Technology* 3 (2): 39–48.

Patrinos, Harry Anthony, and George Psacharopoulos. 2020. "Returns to Education in Developing Countries." In *The Economics of Education*, 53–64. doi:10.1016/B978-0-12-815391-8.00004-5.

Rahman, Syed Mohammad Aminur. 2016. "Prospects of PPP in Expanding ICT Services in Rural Bangladesh: A Case of Union Digital Center." *International Journal of Economics and Finance* 8 (2): 163–170.

Remuzzi, Andrea, and Giuseppe Remuzzi. 2020. "COVID-19 and Italy: What Next?" *The Lancet* 395 (10231): 1225–1228.

Robertson, Julia. 2020. Zoom Guide.pdf.

Roycroft, Trevor R, and Siriwan Anantho. 2003. "Internet Subscription in Africa: Policy for a Dual Digital Divide." *Telecommunications Policy* 27 (1-2): 61–74.

Starleaf. 2020. StarLeaf App User Guide.

Suduc, Ana-Maria, Mihai Bizoi, and Florin Gheorghe Filip. 2009. "Exploring Multimedia Web Conferencing." *Informatica Economica* 13 (3): 5.

Sun, Jianqin, and Zhe Liu. 2019. "Analysis of Public Satisfaction on the Webcast in Taiyuan City, Shanxi Province."

Swanson, Joan, Susan Renes, and Anthony Strange. 2019. *Collaborative Learning: Collegiate Pedagogy Utilising Web Conferencing*.

Tumpey, Terrence M., Christopher F. Basler, Patricia V. Aguilar, Hui Zeng, Alicia Solórzano, David E. Swayne, Nancy J. Cox, Jacqueline M. Katz, Jeffery K. Taubenberger, and Peter Palese. 2005. "Characterisation of the Reconstructed 1918 Spanish Influenza Pandemic Virus." *Science* 310 (5745): 77–80.

Twine, Andrew, and Irwin Brown. 2011. *Evaluating Web Conferencing Tool Effectiveness*.

Viner, Russell M., Simon J. Russell, Helen Croker, Jessica Packer, Joseph Ward, Claire Stansfield, Oliver Mytton, Chris Bonell, and Robert Booy. 2020. "School Closure and Management Practices During Coronavirus Outbreaks Including COVID-19: A Rapid Systematic Review." *The Lancet Child & Adolescent Health* 4 (5): 397–404.

Warf, Barney. 2019. "Teaching Digital Divides." *Journal of Geography* 118 (2): 77–87.

Webex, C. I. S. C. O. 2014. "CISCO Webex Meetings." *Luettavissa.* http://www.webex.com/products/web-conferencing.html. *Luettu* no. 18:2014.

Weissman, Jerry. 2006. *Presenting to Win: The Art of Telling Your Story*. Noida: Pearson Education India.

WHO. 2020a. Ebola Virus Disease.

WHO. 2020b. WHO Timeline – COVID-19.

Winfield, L. 2004. "Web Conferencing Made Simple." *Communications News – Wheaton* 41: 14–16.

Yu, Tai-Ping, David Wu, Ketan D. Mayer-Patel, and Lawrence A. Rowe. 2000. "dc: A Live Webcast Control System." *Paper Read at Multimedia Computing and Networking 2001*.

Zoumenou, Virginie, Madeleine Sigman-Grant, Gayle Coleman, Fatemeh Malekian, Julia M. K. Zee, Brent J. Fountain, and Akela Marsh. 2015. "Identifying Best Practices for an Interactive Webinar." *Journal of Family & Consumer Sciences* 107 (2): 62–69.

Appendix

Web Conferencing App	References
Adobe Connect	https://uis.jhu.edu/adobe-connect/adobe-connect-faq/
Apache OpenMeeetings	https://cwiki.apache.org/confluence/display/OPENMEETINGS/2017+OM+Users+variety
Avaya	https://www.google.com/amp/s/www.uctoday.com/collaboration/video-conferencing/covid-19-ultimate-guide-to-free-video-conferencing-collaboration/amp/
BlueJeans	https://support.BlueJeans.com/s/article/Maximum-number-of-participants-allowed-in-a-meeting
ezTalks Meetings	https://www.ezTalks.com/pricing
Google Classroom	https://cwiki.apache.org/confluence/display/OPENMEETINGS/2017+OM+Users+variety
Google Hangouts	https://webapps.stackexchange.com/questions/53098/how-many-people-can-be-on-a-google-hangout
Google Meet	https://gsuiteupdates.googleblog.com/2019/10/host-hangouts-meet-meetings-with-up-to-250.html?m=1
GoToMeeting	https://www.GoToMeeting.com/meeting/pricing
join.me	https://reviews.financesonline.com/p/join-me/
Lifesize	https://www.lifesize.com/en/video-conferencing-app/pricing
LoopUp	https://LoopUp.com/us/
Omnijoin	http://www.notebookreview.com/news/omnijoin-review-videoconference-with-co-workers-from-anywhere/
Pexip	https://docs.pexip.com/admin/infinity_features.htm#connect
Polycom	https://www.google.com/url?sa=t&source=web&rct=j&url=https://support.polycom.com/content/dam/polycom-support/products/uc-infrastructure-support/collaboration-conferencing-platforms/release-notes/en/rmx-release-notes–8-8-1.pdf&ved=2ahUKEwii0uSr__foAhWNEBQKHWgMBq4QFjABegQIDBAG&usg=AOvVaw0xIcUH6GBE6ueo0kad_dXa&cshid=1587419878357
RingCentral Video	https://support.RingCentral.com/s/article/4629?language=en_US
Skype	https://support.microsoft.com/en-us/office/what-is-a-Skype-meeting-broadcast-c472c76b-21f1-4e4b-ab58-329a6c33757d?ui=en-us&rs=en-us&ad=us
StarLeaf	https://support.starleaf.com/using/conferencing-and-recording/conference-licenses/
TeamViewer	https://www.TeamViewer.com/en/licensing/newtvorder.aspx?license=S312&_ga=2.160054713.529503111.1587376018-642384978.1587376018
Vidyo	https://support.Vidyocloud.com/hc/en-us
Webex	https://help.Webex.com/en-us/WBX26731/What-is-the-Maximum-Number-of-Participants-in-a-Webex-Session-or-Call
Zoom	https://support.zoom.us/hc/en-us/articles/201362823-What-is-a-Large-Meeting-?mobile_site=true