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Abstract

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Keywords

agricultural transformation;COVID-19 response; digital agriculture;distance education;STEP program

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This strategy was conducted as a component of the Start Them Early Program (STEP) International Institute of Tropical Agriculture (IITA), an activity originally envisaged by its Director-General, Dr. Nteranya Sanginga, and supported by grants obtained from the International Development Research Center (Canada) and the Technical Centre for Agricultural and Rural Cooperation (CTA). The STEP Kenya team consisting of Lorraine Mutinda, Maryfaith Simiyu, Felix Kiprono, and Phillip Kioko, and STEP ICT team consisting of Christophe Byake (DR Congo), and Bekee Barivure (Nigeria) prepared an earlier internal document that described available ICT applications featured in this report. Exchanges were conducted with Dr. Jemimah Njuki (IDRC), Dr. Mpoko Bokanga (IITA), and Adedayo Adefioye (STEP Coordinator) concerning a project "pivot" in the face of the COVID-19 pandemic. The authors thank all these persons and their departments and organizationsfor their respective contributions *doi: 10.5191/jiaee.2021.28205*

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Introduction

COVID-19 is a growing pandemic with tangible effects on Africa's educational and agricultural sectors (Africa Arguments, 2020). In addition to the adverse effects on health, it affects the livelihoods of poor rural farmers who heavily depend on agriculture, and investment strategies must be adjusted to their new realities (International Fund for Agricultural Development [IFAD], 2020). An important element of this adjustment is the role of Information and Communication Technology (ICT) services as teaching and learning tools available to youth, including students and young farmers in COVID-19 response, recovery, and more resilient aftermath (Ngwacho, 2020). ICT in agriculture, increasingly referred to as digital agriculture (Tsan et al., 2019), offers distinct advantages in securing essential farm operations, keeping food supply chains moving, and reaching vulnerable populations (Bashuna & Addom, 2020).

To counter the COVID-19 pandemic, many countries quickly instituted precautionary lockdown and social distancing at its onset, while maintaining domestic agricultural production and its supply chains as essential human activities (International Monetary Fund [IMF], 2021). Schools were closed indefinitely with little or no provision to continue instruction.

In Nigeria, the first case of COVID-19 was confirmed on February 27, 2020, sparking a series of responsive measures including the commissioning of a task force on March 9 by the President. Subsequently, the Federal government ordered the closure of schools on March 19 in a bid to prevent the spread of the virus. This saw 35.9 Million secondary and primary school students out of school indefinitely out of which 81% attend public schools. From April 2020, the country shifted to radio and television means to deliver lessons to learners with new networks being launched for this purpose. However, this was not free from challenges to a majority of students which included the inability for families to purchase and subscribe to satellite networks, non-existent connectivity, erratic electricity supply, and lack of access to computers and other sophisticated ICT devices that aid internet-based learning (Samuel, 2020).

Kenya confirmed its first COVID-19 case on March 12, 2020, as relayed by the Ministry of Health (MoH) via a Presidential press release. The Government then announced abruptly the closure of schools as a preventive measure against the spread of the COVID-19 on 15 March 2020 affecting the lives of nearly 17 Million learners countrywide (Parsitau & Jepkemei, 2020). In May 2020, the Ministry of Education (MoE) declared public school classes, aligned with the school calendar, would be broadcast on multiple channels, such as radio, television, YouTube, and Kenya Education Cloud for a targeted 15 Million learners (MoE, 2020; Nzuki & Wanyama, 2020). However, this Basic Education COVID-19 Emergency Response Plan was marred and suffered several bottlenecks, including inaccessibility, insufficiency, low ICT literacy levels among students, parents, and teachers, and other social, health, economic and psychological factors brought about by the pandemic, and school closure. The MoE acknowledged that unequal access to learning portals would further create inequalities in access to education.

DR Congo announced its first COVID-19 case on March 10, 2020. By March 24, a state of emergency was declared restricting gatherings of more than 50 people and further closure of schools and universities. During this time, students were to continue education remotely where they struggled to access education through the internet and digital services; this has proved to be unequal for most students and their families (Ging, 2020).

Despite these government policies, it soon emerged that safety measures are not well understood and are weakly practiced. Public information campaigns were initiated, and enforcement intensified but the poorest in society are least able to comply with the stay-at-home requirements (IFAD, 2020; Ali et al., 2020). Chronically weak agricultural extension mechanisms are being further diminished by social disruption. Digital services are needed to fill the void, prompting the accelerated roll-out, promotion, and adoption of digital tools.

Farmer organizations and youth groups were less able to conduct conventional assembly activities and direct member services. Although their cooperative operations are an essential service, the inability to congregate has caused them to shift to safer, smaller groupings and digital information exchanges. The poorest small-scale farming households, however, are least able to cope with pandemic disruption and warrant special considerations in recognition of their services. COVID-19 is worryingly recorded in rural communities, where poverty, undernourishment, and lack of access to basic healthcare render the population highly vulnerable. Furthermore, rural women and girls are expected to increase their roles as household health and nutrition managers (Food and Agriculture Organization of the United Nations [FAO], 2011) and to responsibly supervise household pandemic recovery. At the same time, legions of economically marginalized youth engaged in daily income generation within informal economies (Alliance for a Green Revolution in Africa [AGRA], 2015) continue to resist compliance with public health measures, causing them to be seen as hazards to the population as a whole.

Continued operations of schools risked accelerated community contagion and are for the most part closed indefinitely, thus disrupting student progress (Ngwacho, 2020). Electronic teaching and learning have not met educational demands, particularly in poorer rural areas. This has not hampered the development and advancement of ICT learning tools and the attraction of developmental resources will hopefully lead to stronger educational systems in the pandemic aftermath. Mechanisms toward this end are described in this paper, which shows how a project devoted to agricultural education in three African countries; DR Congo, Kenya, and Nigeria is creating a new-normal for secondary schools through advances in electronic teaching and learning. This paper describes how ICT tools, teaching, and learning may be better offered at the secondary school level in response to the COVID-19 pandemic and its aftermath.

Operational Framework

Across the African continent, because of the COVID-19 pandemic, an estimated 297 million students have been affected by school closures. According to the United Nations Educational Science and Cultural Organization [UNESCO] (2020), the school closures worldwide had affected 1.29 Billion students in 186 countries (73.8%) of the world's student population. The United Nations International Children’s Emergency Fund [UNICEF] (2020) reported that a third of this population, 463 Million, globally were unable to access remote learning, a condition made by most governments as schools were closed.

Also affected was the Start Them Early Program (STEP), a pilot project intended to strengthen career pathways among secondary school students towards modernized agriculture that was initiated in September 2019 (Adefioye et al., 2019). It incorporates diverse Information and Communication Technology (ICT) strategies in support of client needs for electronic teaching (e-Teaching) by instructors and school systems, and electronic learning (e-Learning) among students and other youth. It is understood that many youths view farming in a negative light (Mulei et al., 2020; Sumberg & Okali, 2013), and STEP seeks to change this perception.

The agribusiness opportunities most attractive to youth are recognized and reinforced within the International Institute of Tropical Agriculture [IITA] Youth in Agribusiness Movement (Owoeye et al., 2016; Woomer et al., 2015), the necessary entrepreneurship mechanisms described (Lawson-Hall & Leke, 2019), and the technologies required to realize these ambitions are being mobilized (Technologies for African Agricultural Transformation [TAAT] Clearinghouse, 2018). STEP acknowledges that youth are particularly attracted to and adept in the use of electronic devices whose potential remains under-exploited as tools for education (e.g. E-teaching and E-learning).

E-Teaching integrates with traditional learning in ways that increase its practical application while E-Learning is designed to advance longer-term capacities, focus on an individual learner, and contribute to the culture of lifelong learning (Meena et., al 2017; Ghirardini, 2011). The concept of E-Teaching and E-Learning has gained momentum in recent times because of school closures arising from the COVID-19 pandemic. In DR Congo, Kenya and Nigeria alone, there are over 66 million students affected by school closure (UNESCO, 2020), most without access to distance learning resources.

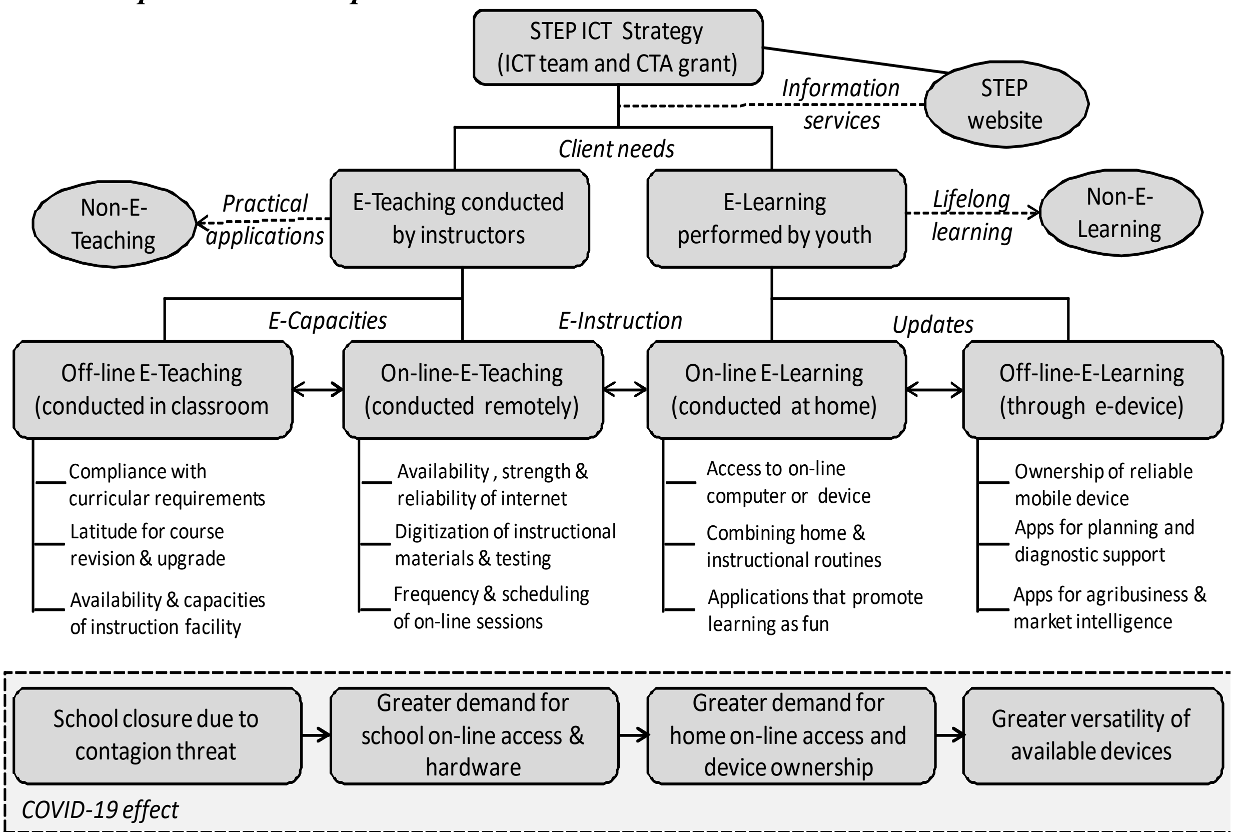
In the face of the pandemic, innovation has shifted from the periphery to the core of many education systems, and there is an opportunity to find creative methods that, if continued, will help young people get an education that will prepare them for changing times (Vegas & Emiliana, 2020). Karsenti et al. (2009) and Ghirardini (2011) show how students learn more and faster with ICT and online courses than in traditional classrooms. They affirm that ICT-assisted teaching and learning offers attractive, individualized options with many benefits, including flexibility, accessibility, enhanced communication and interaction, and a wider variety of teaching and learning modes.

Methods

This study was initiated in response to disruption resulting from school closure as a COVID-19 precautionary measure. The STEP project had started a few months earlier in a way that offered school-based activities to reinforce career pathways in several secondary schools (Mulei et al. 2020) and then found itself forced to adjust its approaches in absence of direct student interaction. Initially, the project had provided both computers, internet, projectors, and instructional software to participating schools to backstop electronic instruction but then found that those facilities could no longer be used and sought to understand the new pandemic situation in a more holistic manner. As a result, a qualitative research design was followed in this study. It is essentially a desk study conducted during the lockdown in Kenya between May and July 2020. At this point, we had, however, established communication with educators in several schools and ICT suppliers who then provided feedback to a series of queries addressing best steps forward under a very difficult situation. In addition, semi-structured interviews were used to collect information from these secondary schools and equipment, internet, and software suppliers. This in turn led to the design of the conceptual response diagram presented in Figure 1.

Figure 1

STEP's ICT Strategy Involving Electronic Teaching and Learning, and the Relationship to the Consequences and Response to the COVID-19 Pandemic



Efforts leading to the refinement of this model were systematic and span three countries i.e. DR Congo, Kenya, and Nigeria (Adefioye et al., 2019). First, the school system curricula were assembled to relate to agricultural instruction and rapport created with specific schools and instructors (Mulei et al., 2020).

The ICT facilities in those schools were then assessed and matched with the program's capacities to make improvements which included the design and installation of instructors' computer workstations described in Table 1. Support was also provided for modest computer learning laboratories open to teachers, students, and

Table 1

Components and options of STEP instructor's e-Training workstations in Kenya

Component	Description	Cost (US$) and access
Notebook Computer	Controlled by individual instructors, central to e-Teaching, lower-end models (<4 GB RAM, <500 GB hard drive) may operate too slowly, includes DVD and webcam, placed in lockbox when not in use.	$270 to $453 depending on capacities, purchased through competitive bids.
Projector	Projects computer screen to larger classroom, costs have decreased rapidly over time, a minimum 2000 lumens is recommended for lighted classrooms, placed in lockbox when not in use, cost and security advantages compared to mounted flatscreens.	$281 to $356 depending on resolution and intensity, purchased through competitive bids.
Printer	Allows instructor to print instructional materials and tests, students to print assignments, and club members to produce information materials, refillable color cartridges preferred, smaller models placed in lockbox overnight.	$45 to $186 depending on type and coloring, purchased through competitive bids.
Software	Computers run on MS Windows, latest version of Microsoft Office, and antivirus package also purchased and installed by the project. STEP provides instructional materials, other specific applications described in Table 2.	$87 for MS Office for six-users (annually renewed) and four-user antivirus for $30. Total $117, purchased through competitive bids.
Metal lockbox	Considered essential for workstation security, available as single compartment padlocked or up to four drawers inbuilt locked, placed in secure location, keys retained by partnering instructor.	$86 for single compartment and $271 for four-drawer, purchased through competitive bids.
Uninterrupted Power Supply (UPS)	Permits e-Training during intermittent disruption of electricity, at least 650 VA required by projector, duration of backup depends on battery capacity.	$55 to $85 depending on capacity, purchased through competitive bids
Miscellaneous supplies	Flash drive, printing paper, extension cables, laptop lock, external speakers (>50 W), mouse, external keyboard, screen protector, other e-Training supplies needed by instructor.	About $140, purchased through competitive bids.
Total cost		**$994 to $2008**

agricultural club members. Upgrading included installing new or improving, where applicable the schools' internet connectivity, computers, projectors, and audio systems. This approach also allowed for the construction of Tables 1, 2, and 3 relating to expanded ICT opportunities and their costs. This method was new and unplanned in that project pivots in response to a global pandemic of this nature had not been considered earlier in this (Adefioye et al. 2019) or most other projects (Banaszak et al. 2020; Chattopadhyay, 2020).

Results & Discussion

Offline E-Teaching is intended for the classroom and represents a better use of computer presentation tools, particularly digital projectors and display screens (Figure 1). It is a technological leap over classroom blackboards and chalk that is long overdue in Africa. STEP's experience in upgrading offline instruction is that efforts must comply with existing curricular content and requirements and especially in a country like Kenya which had just rolled out a new Competency-Based Curriculum (CBC), in January 2019 to replace what used to be a Summative Evaluation Based Curriculum (Maluei, 2019). However, STEP's target beneficiaries, secondary school-going youth, are still using the old curriculum, and as such there, is some considerable latitude for course revision and updating delivery modes in the three intervention countries overall.

Online E-Teaching involves linking to sources of information available over the internet and delivering educational material through others' computers (see Figure 1). The mass of information available on all subjects available over the internet is staggering, but efforts to supplement current curricula through information sources beyond outdated student textbooks are compelling. Online E-Teaching may be delivered within schools or remotely through a range of household electronic devices, including less expensive laptops, smartphones, and tablets.

STEP's support for E-Teaching is intended for instructors, their schools, and larger school systems (Figure 1). E-Teaching is subdivided into offline and online teaching, both requiring that ICT hardware and skills be available to its practitioners. The components of the STEP instructor computer workstation developed by STEP appear in Table 1. Students are particularly responsive to visual stimulus in the forms of photos, conceptual diagrams, and videos (Maal, 2004; Clarke et al., 2006; Valentinuzzi, 2015), and the use of electronic media such as television, radio, tape recorders, films, computers, projectors, telecommunication equipment, and the internet provides instructors many advantages (Classroom Teacher, 2008; Arora, 2015; Ezirim et al., n.d). However, it demands time for the development and upload of the material, and this requires the teachers to put in a little more effort than is needed in conventional teaching methods (Arora, 2015).

Table 2

Selected ICT Applications that Assist in Agricultural Decision-Making in Kenya

Application	Description	Access and cost
Agrobase	Provides agronomic information on pests, diseases and weeds, includes identification aids and country-based protection and treatment instructions, relates to livestock, horticulture, fruit, vegetable and field crop production.	Accessed through Google play store, costs through data usage.
Breeding Wheel	Allows users to access personalized data of dairy herd requirements including information on reproductive issues, service schedules, lactation periods, and calving.	Accessed through Google play store, costs through data usage.
Crop Farmers	Provides information about crop, fruit and vegetable growing. Details climate and soil requirements, harvesting, pests and diseases, their causes, symptoms, how they spread and preventive and control measures. Developed by Bivatec Ltd.	Accessed through Google play store, costs through data usage.
Dairy Live	Provides dairy producers interactive information on livestock events including pregnancy checks, vaccinations, semen inventories and breeding services through both computers and smartphones.	Accessible by downloading on Dairylive.com, onetime subscription cost of $459.
ICOW	Voice-based application provides information on animal breeding and feeding methods, users register animals free-of-charge and receive regular SMS updates, format available in different languages.	Accessible on USSD *285#, website at global.icow.co.ke, SMS is free.
Kilimo Salama	A climate-smart crop insurance scheme that enables producers to insure their agricultural input investments against adverse weather conditions and provides SMS messaging as seasonal insurance contracts are formalized.	Distributed through participating agrodealers and other participating retailers.
M-Farm	An e-commerce tool for Kenyan farmers using Safaricom; SMS from: 20255, and receive information on the retail price commodities, linked to buyers, allows purchase of farm inputs from manufacturers at discount.	Available through Safaricom via SMS for $0.01 for registration and $0.01 per usage.
M-Shamba	Regular SMS provides subscribers with information on production, harvesting, marketing, credit, weather and climate; customized to location, subscribers share information; accessible through smart and low-end phones.	The application is accessible through Safaricom, costs through mobile data usage.
MbeguChoice	Provides users with information on changing weather patterns, identifies drought-tolerant crop varieties recommending the top five varieties depending on location and altitude.	Download from mbeguchoice.com and Google app, costs through mobile data usage.
Mkulima Young	Connects young farmers and those aspiring with each other in a virtual space. This app provides an exclusive farmers marketplace where producers meet the buyers. An initiative by ACLECOPS.	Accessed through Google play store, costs through data usage.
Urban Farming	Provides information on vegetable production through interactive smart phone reminders, identifies common pests and disease, identifies “organic” options, and provides recipes.	Accessed through Google play store, costs through data usage.
Vet Africa	Provides diagnosis of livestock illness and identifies treatment options, intended for veterinarians, animal health professionals, agrodealers and producers, developed by Cojengo.	Accessed from cojengo.com, allows 15 entries before charges begin.

An intermediary approach to school-based, online E-Teaching is the establishment of WiFi systems that allow electronic devices to interact with one another, including a server containing large databases of educational material, without necessarily being connected to the worldwide web, however, this option restricts access to information and does not apply to more remote E-Learning. One important factor within schools that limits online E-Teaching capacities is the frequency and scheduling of online teaching sessions when the facilities are spread too thin across numerous instructors and classes.

E-Learning as advanced by STEP applies to secondary school students of participating schools and school systems. It is prompted by online E-Teaching materials as led by the instructor, in many cases via home computer systems and mobile electronic devices. As it is promoted by STEP, E-Learning is intended to both contribute to students' learning experience and the growing culture of lifelong learning, particularly with agricultural production and agribusiness skills. For practical purposes, it is separated into online and offline E-Learning (see Figure 1).

Within the context of distance learning among secondary students in African public schools, a severe limitation exists in their access to the internet and adequate online computers and other suitable devices (Burns, 2020; Mukuni, 2019). Internet access requires payment, and the poorest households have to balance this cost with other more pressing demands. Another factor in rural areas includes how best to combine instructional schedules and home routines as stay-at-home youth are increasingly held responsible for household and farm chores (Lowe & Phiona, 2017; Vargas-Lundius & Suttie, 2014). A partial list of the 12 digital applications providing agricultural support available in Kenya and elsewhere appears in Table 2. In many cases, these applications have both offline and online features, where routine queries are handled through resident databases while the more complex features are uploaded and then responses downloaded, often seamlessly. Examples of this software include diagnostic services where plant and soil conditions (e.g. pests or disease and deficiency symptoms) are photographed, electronically diagnosed, and recommendations issued.

Similar applications assist in agribusiness planning, but when used to acquire market intelligence or conduct E-commerce, direct internet access is required unless interactions are based solely upon Short Message Service (SMS) or USSD codes (Unstructured Supplementary Service Data). But even offline applications must be loaded in the first place and periodically updated, and that requires connectivity.

Strong overlap exists between STEP's approaches for assisting youth along career paths in modern agriculture and the larger efforts directed to the digitalization of agricultural extension and marketing services (Tsan et al., 2019). Extension services in Africa have never been able to satisfy client demand (Rivera et al., 2005) and digitization is seen as the inevitable next development in agricultural information services. It is an opportunity that is especially the case fitting for youth who already possess skills in multiple device usage and are destined to become young commercial farmers and who already possess skills in multiple device usage (Beza et al., 2018; Edeoghon & Okoedo-Okojie, 2015).

Table 3

Structure and Components of the STEP Mobile Agricultural M-Learning Toolkit

Mobile component	Description	Cost (US$) and access
Smartphone or Tablet	Many models available with at least 2Ghz RAM, 32GB storage, voice recognition included, Android version 9.0 upwards is recommended. Non-removable lithium batteries preferred.	$140 to $230 depending on model and capacity.
Protective case and cover	Provide good grip, is slim, fits perfectly on the device, gives good access to all buttons/connectors/speakers and adds enough protection against falls; especially at the corners of the device.	$35 in local stores.
Resident software	Inbuilt in device, upgrades and downloads possible, applications described in Table 2, linkage to e-Teaching platform required.	Varies among models.
Learning Management System/Platform (LMS)	Most modern LMSs are web-based. Allows one to create different types of users (hierarchy) and integrate course materials, articulate learning goals, align content and assessments, track studying progress, create customized test, allow different multiple question types, and answers, including essay ones. Can reach marginalized groups through special settings, streamline, feedback mechanism included.	Price depends on individual platforms/systems. STEP's selection starts from $0.25 per subscriber. Subscribers require signing in, and internet connection.
Website	Publicly accessible, allows for interactivity between the site owner and site visitors/users. Includes features that can support distance learning programs and providing additional links to complementary sources of electronic information and the LMS.	Requires domain registration and hosting charges.
Voice recognition	Inbuilt in upper-end models or available in apps. Enables voice recognition in Google Voice, many voice-activated queries remain unrecognized because of a dissimilar accent of speaking.	Inbuilt in high end phones and integrated in some apps. Requires signing in/activation and internet connection.
Connectivity	Enables accessibility to internet.	Based on monthly charges or pre-paid data subscription.

Having a handheld device that can serve as an all-in-one extension adviser and business organizer, offering both offline and online services is timely. The components of such a mobile "toolkit" assembled by STEP appear in Table 3**.** A powerful toolkit includes Artificial Intelligence Voice Recognition (AIVR) as illustrated in Table 2, where users ask questions and receive reliable audio responses and are linked to additional sources for detailed information.

The perennial problem of incorrect or contradictory information persists, and it is therefore important that device operators do not rely exclusively upon electronic information. They should instead use it to build a body of heuristic knowledge (Childs et al., 2013; Anderson & Freebody, 2012) that in turn allows them to serve as more reliable peers in the future. Another concern is that some sources of information are based upon restrictive ideology, overly politicized, or even result from mischievous or malevolent misinformation, and the abundance of information for the case of Online E-learning; so growing perspective is always required in interpreting and relaying electronic information and maintaining the focus of the main objective (Keshavarz, 2014; Meena et al., 2017).

The scope of the changes in ICT applications to agricultural instruction in Africa envisaged in Figure 1 is well beyond the scope of any one project, including STEP. STEP's efforts are designed to better understand how best to undertake these changes, what options are available, and how to prioritize interventions that support youth pathways toward productive careers in modern farming and agribusiness. The approach also presents a model that weighs key options among ICT applications, particularly E-Teaching vs. E-Learning and offline vs. online applications. E-Learning, through online applications, offers the greatest potential but is most difficult to achieve among low-income families.

The start of the COVID-19 pandemic prompted the abrupt closure of schools which disrupted classroom instruction, field practicals, and students' young farmer clubs that STEP sought to strengthen in the partnering school systems. Pilot field demonstrations in modern agriculture that had been established were passed to caretakers rather than managed by students as first intended. The E-Teaching facilities provided to the schools were now no longer in use, and near-instantaneous demand was created for E-Learning for students that were confined to their homes.

Device ownership among students' households immediately became an issue that was beyond the scope and ability of the project to rectify except in a superficial manner. Remote learning sessions on agriculture were encouraged, but the project was in no position to subsidize them as the public-school systems as a whole were incapable of offering such services. The project had however intended to examine the possibilities of handheld devices as agricultural learning tools, and so the development of mobile-based toolbox as described in Table 3 was accelerated, but these applications were only accessible by the minority of students who held smartphones or other compatible devices in the first place.

As the STEP website was being tested and improved, features that could support its role in distance learning programs were further developed. This entailed uploading the improved learning tools originally intended for use by the individual schools and providing additional links to complementary sources of electronic information and the Learning Management System (LMS). Several LMSs were tested and eliminated by accessibility; cost to the Project, and ease of use by students and teachers; and functionality. STEP settled for Google Classroom, an interactive Edu-platform that has high student engagement, and automated classroom management tasks, including attendance. This brought together Online E-teaching with instructional support from instructors remotely, Online E-Learning for students already with access to gadgets, and Offline E-Learning. Only students residing in urban areas had better access to the Google Classroom owing to device ownership, connectivity, and parental and instructor support, and were also accessible for other forms of support, communication, and engagement via social media. In all the three intervention countries, Kenya had the largest number of students engaged in this way, with several in DR Congo, and barely any in Nigeria (data not presented).

Non-E-Learning is designed to serve the purpose of out-of-school learning (Figure 1). STEP designed a Home Agribusiness Challenge to improve students' skill sets, enable them to assimilate learned content through the formal curriculum with actual experiences from home, move from conventional to space-optimized agriculture, creatively increase interest, feed homes, make some income, and bring about a gradual positive change of their perception of agriculture. STEP provided interested students with standardized packages modeled to their available home-spaces. These included seedlings of several crops and vegetables, manure, and fertilizer. No chemical-based products were included in the package for the students. Participating students receive communication via Short Messages Services (SMS) and WhatsApp from their Agriculture instructors to avail themselves to collect the inputs, all safety protocols against the spread of COVID-19 in place and observed. Good Agricultural Practices (GAPs) are communicated in the same channels and through social media.

STEP's resolve is for E-Learning to contribute to students' learning experience and the growing culture of lifelong learning, particularly about agricultural production and agribusiness skills. In effect, the STEP project that started six months earlier pivoted to adjust its efforts towards confronting the greatly altered COVID-19 learning environment but was in a weak position to offer scheduled electronic learning to students that lacked internet access.

Recommendations

The widespread attention to E-Learning that was accelerated by COVID-19 must coincide with efforts to promote device ownership and improved infrastructure for easier internet access. In addition, the importance of hands-on learning must not be overlooked and some form of home practice is encouraged. As a result, several parallel skills are reinforced including digital literacy, communication, time management, and practical analyses despite the closure of schools. The means to achieve this homeschooling balance should be further explored.

The restrictions to internet access by a large majority of the students should be overcome through the promotion of Offline E-Learning, particularly via applications loaded into handheld mobile devices that are periodically updated through WiFi access. The means to organize these updates within the context of lower-income African communities requires further attention.

An ongoing evaluation system should be incorporated to ensure improved, sustainable delivery of reliable applications, as well as offer access to monitor skills development of learners. In many cases, this involves improved computer literacy among instructors.

To tackle the hurdles faced by school closures, upgraded instructor workstations established within school computer laboratories should be redirected toward home-based E-Learning. This requires that a balanced assortment of software applications be adopted and mobile-based all-in-one toolkits for agriculture students and young farmers be designed and distributed. This approach offers benefits into and beyond the COVID-19 aftermath.

Conclusions

While the various digital applications offer exciting implications for agricultural modernization, they must be kept in perspective, both in terms of E-Teaching and E-Learning. E-training is intended to supplement practical understandings and experiential learning, not replace it. Students of agriculture should spend as much, if not more, time engaged in field practicals as in front of screens. While young farmers should be proud of their digital toolkits and the number and types of applications they contain, the device itself should be used in a way that supplements farm productivity and food systems transactions, not replace them. This "reality check" applies to the anticipated COVID-19 aftermath where a boost in agricultural modernization is needed. The focus must remain to digitize the next generation of farmers and agribusiness persons for productivity to secure Africa's economic future with the recognition that digital tools complement production operations in terms of better farm planning, field diagnostics, and market intelligence, but does not replace them. These digital technologies then serve to enhance the quality and impact of agricultural teaching and learning for food security and rural development in Africa through effective interventions in their design and use.

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