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Transitioning Hands-On STEM Teacher Training in Ghana from an In-Person to Online Modality

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Abstract

COVID-19 provided an avenue for teaching and learning to be done remotely, hence Practical Education Network (PEN), a nonprofit organization in Ghana, took advantage of this to transition from an in-person to online training mode. This study aimed to determine how the efficacy of hands-on STEM teacher training in Ghana compared between fully in-person and fully online modalities as well as the best practices that can be elucidated from a Ghanaian training provider's transition between the two. In-person training content was converted into videos and PowerPoint presentations accessed asynchronously together with synchronous Zoom sessions for discussions. Between 2020-2021, two hundred and twenty (220) teachers who teach Science, Math and ICT were selected from 10 Regions of Ghana to participate across five (5) cohorts. Relying fully on locally available materials, PEN successfully implemented an online training on hands-on content, which is arguably a "pandemic-proof" approach. Results showed that teacher confidence and feasibility to implement hands-on activities increased with statistical significance and large effect size for both in-person and online training offerings. Hence, even with minimal technology, teachers across Africa could be trained online and experience meaningful learning. The key difference between the two modalities was the time involved, as the online offering was spread out over a longer period of time. This work can motivate other African education providers to pursue online offerings, as they are lower-cost, and can still be effective, despite contextual challenges.

Keywords: *STEM, Teacher training, In-person training, Online training, Locally available materials, Hands-on*

Introduction

The vast majority of education providers in Africa have traditionally relied exclusively on in-person offerings (Crawfurd, Evans, Hares, & Sandefur, 2021). The COVID-19 pandemic triggered a need for education and learning opportunities to be made available remotely. Closure of schools in the wake of the pandemic implied that innovative strategies needed to be employed for teaching and learning to continue while students were home. This was necessary to avoid disruptions in the educational sector (Addae, Amponsah, & Gborti, 2021). This presented a significant obstacle to be surmounted, given contextual challenges with online learning such as poor internet connectivity, low digital literacy levels, and the familiarity with in-person engagements for establishing connection.

Existing teacher training landscape in Africa

Teacher professional development is a necessary component of the provision of quality education. To be effective and remain relevant, teachers need to have periodic in-service training. However, an insufficient proportion of teachers in Ghana and Africa at large are afforded the opportunity to engage in this regularly (Sanyal & UNESCO, 2013). Several teacher training service providers operate in Africa, however most of them focus on general pedagogical practice. Only a few utilize digital modalities for training delivery, even after the pandemic. And even fewer focus on the unique needs that STEM teachers have.

Ghana is a rapidly developing economy, and the country is actively implementing a number of education reforms. Nonetheless, the same gaps mentioned in Africa's teacher training landscape hold in Ghana: few of them leverage digital approaches or provide STEM-specific content. The digital education interventions that exist in Ghana are generally directed at students, such as studying past questions for the national exams (eCampus, 2023) or learning to code (Suacode.ai, 2023). Almost no digital interventions in Ghana focused on teachers prior to the pandemic. The Center for National Distance Learning and Open Schooling

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(CENDLOS, 2023)and Ghana Society for Educational Technology (GSET, 2023) are two exceptions. The EdTech Readiness Index (Marin, Cobo, Cloutier & Lambert-Porter, 2021) shows six pillars on which a country's readiness to adopt EdTech could be founded. Many African countries will score relatively low on this. STEM-specific training content is highly needed in Ghana, given that those subjects are known to be most effective when taught in an experiential manner. The lack of hands-on learning is something that is often lamented amongst Ghanaian education stakeholders, utilizing the phrase "chew and pour" to describe the rote approach that pervades practice (Owusu-Acheaw, 2014), especially in STEM subjects. The traditional approach tends to encourage memorization and reproduction of facts, limiting learning outcomes (Nugba & Quansah, 2020). Regarding hands-on learning in Ghana, a small number of training providers include it in their offerings, mostly approaching it from a play-based learning approach, albeit not in STEM (Foundation First, 2023; Sabre Education, 2023; Right to Play, 2023). In addition to the Ghana Association of Science Teachers (GAST), Practical Education Network (PEN) is one of the few STEM teacher training providers in Ghana, and its program will be the subject of this study. PEN's approach of in-person training of teachers to leverage low-cost materials to teach hands-on activities in STEM subjects has had a significant impact on student attitudes and learning outcomes in Ghana (Babb & Stockero, 2020; Practical Education Network, 2020). The African and Ghanaian education landscapes experience a gap in training offerings for teachers both in the digital modalities and in a pedagogical approach targeted at hands-on learning. There is a need to scale up existing interventions that are effectively filling the gap.

Response of education stakeholders to COVID-19 in Africa

The disruption of education due to COVID-19 called for the development of innovation that could help the delivery of education remotely (Mukute, Burt, Francis, & De Souza, 2020). Most governments around the world called on their teachers to ensure continued learning in the pandemic, but few African governments were able to offer training or specific support for them to do so (Vegas, 2020). Nonetheless, several interesting interventions emerged on the continent. They can be categorized into those that facilitated passive learning and those that facilitated active learning.

African governments launched several educational programs, and largely passive learning approaches such as leveraged television and radio to do so (EdTech Hub, 2020). Countries like Nigeria, Tanzania and Sierra Leone broadcasted lessons on TV (Osman, & Keevy, 2021). Radio emerged as a popular tool for remote learning during the pandemic. Sierra Leone's Ministry of Basic and Senior Secondary Education turned to "Education Radio" (Government of Sierra Leone, 2020), "Rising on Air," an initiative from Rising Academies, was adapted for use in more than 10 countries (Flood, 2020), and Yiya AirScience in Uganda supported remote and out-of-school children (Kisakye, 2020). Challenges with radio include its ephemeral nature, the difficulty of monitoring its use, and the minimal interactivity levels it facilitates (Damani & Mitchell, 2020).

A few interventions emerged for active learning on the continent. Zoom and other video conferencing were some of the most popular online platforms for teaching and learning during the pandemic (Erna, Genisa, Muslaini, & Suhartini, 2022). Lower bandwidth options like WhatsApp were also used for running teacher training, as led by Nigeria's CCHub (Tijani, Madu, Falade, & Dele-Ajayi, 2021). In Sierra Leone, phone calls were used for live tutoring (Crawfurd, Evans, Hares, & Sandefur, 2021). More active approaches, such as these, should be considered as preferred options for learning. The role of the teacher is important for roles such as facilitating two-way dialogue, addressing misconceptions and increasing engagement (Munna & Kalam, 2021). To the authors' knowledge, no African service providers developed a digital offering for teacher training, and which facilitated a hands-on approach.

Response of education stakeholders to COVID-19 in Ghana

Ghana's national education response in the COVID-19 pandemic centered around the Ministry of Education's production of a TV broadcast of lessons for students (Dome & Armah-Attoh, 2020) and a radio reading program (US Embassy in Ghana, 2023). For the TV program, each class for primary and JHS had 35 minutes of content, whereas each class for SHS had 60 minutes of content per day (Ghana Education Service, 2020) As mentioned earlier, this platform facilitates passive learning, which has inherent limitations. High-end private schools were able to transition to fully remote offerings so as to enable a more active approach. This, however, only benefited a small minority of the population. Most students in Ghana found themselves largely devoid from structured learning from March to

December 2020. At the grassroots level, a few other interventions also emerged, such as a radio program in the Western Region. These did not, however, attempt to cover hands-on learning, and focused on delivering content knowledge.

Methods employed by hands-on education providers to transition online/remote

Globally, prior to the pandemic, most online courses lacked significant hands-on components (Eisenberg & Fischer, 2014). Enabling hands-on content online is a challenge that most education providers had not tackled until the COVID-19 pandemic provided a strong impetus. Efforts to transition hands-on learning online can generally be grouped into three categories.

1) Materials kits for each student. Several universities adopted this approach, packaging kits and shipping them to students (Halpern, 2021; Hart et al, 2021; Leung & Chu, 2020; McQuate, 2020; Travaglini, Sheppard, Chen, & Nittali, 2021; Wu et al, 2020).
2) Remote labs where students either observe a lab technician/teacher conduct an experiment or remotely control a pre-made experimental setup (Yeung, 2020).
3) Virtual labs using computer-based representations or simulations, usually involving animations (Advanced Tools for e-Learning, 2023; Pivot Interactives, 2023; University of Colorado Boulder, 2019).

These can be programmed for pre-determined modes of interactivity. Some of these virtual labs had been around for decades prior to the pandemic. Papers comparing all of these approaches (Bishop et al, 2021; Fox, 2020; Wijenayake et al, 2021) reveal challenges such as equitable distribution of materials and cost of implementation.

Using or adapting any of these three approaches to the African context presents a few challenges. With the first approach, the cost of shipping materials is high. At the onset of the pandemic, Ashesi University in Ghana adopted this approach to send engineering kits to all students (Ashesi University, 2020) but the cost prohibited its continued use. The cost involved in delivering materials to the "last mile" in rural Africa is significant. The need for using readily available materials has been mentioned (Larson & Farnsworth, 2020). A few educators developed innovative approaches for guiding their students to use materials they had around them, such as using a smartphone to measure focal length (Girot, Goy, Vilquin, & Delabre, 2020). With the second and third approaches, remote and virtual labs evade the tactical experience that facilitates deeper engagement, flexibility to test variations beyond the guided prompts and therefore greater connection to each individual's existing knowledge and constructs. Remote labs are more difficult to carry out given the generally low bandwidth and therefore short duration that video connection can be maintained in a group. Virtual labs inherently present a layer of artificiality to lab work which, in the authors' opinions, continues to evade the goal of engaging in real experiences students are craving. Also, these tools have not necessarily been designed for mobile usage, which is the dominant platform that African teachers would be using. There is a need for developing approaches to deploying hands-on learning remotely in a manner that is contextually appropriate for the African continent.

Practical Education Network (PEN) is a Ghanaian NGO with a mission to enable every African child to learn by doing. PEN's core programming is a hands-on STEM teacher training program, which builds capacity to leverage low-cost, locally available materials (Practical Education Network, 2024). PEN's definition of hands-on learning comes from the constructivist approach and necessarily utilizes physical materials to facilitate learning. PEN leaned into the challenges presented by the COVID-19 pandemic and successfully translated its hands-on teacher training from a fully in-person to a fully online offering. This paper highlights aspects of this translation, key lessons learned in the process, and the effect of the online training.

Two research questions are explored in this paper.

RQ1: "How does the efficacy of hands-on STEM teacher training in Ghana compare between fully in-person and fully online modalities?"

RQ2: "What best practices can be elucidated from a Ghanaian training provider's transition from in-person to online modalities?"

The translation process and resultant learnings are presented in this paper, with suggestions for how this model can be employed by other training providers on the continent to similarly transition to online modalities.

Methodology

COVID-19 challenged PEN to translate its purely in-person training into a fully online mode. Hence its content was converted into videos and PowerPoint presentations for participants to access asynchronously. This was complemented with live training and discussion sessions held on Zoom as well as assignments

offered in Google Classroom, a Learning Management System (LMS). To have an effective and successful online training, inclusion criteria were set. Teachers who had a good internet connectivity, access to a smartphone, laptop or desktop computer, and who were motivated and committed to completing an online training were included in the online training. Teachers' commitment to completing the training included attending all live training sessions, completing and submitting assignments. The assignments were in the form of watching videos and replicating hands-on activities in their classroom and uploading these videos on the LMS.

Figure 1 shows the process involved in implementing PEN's in-person and online training modes. Although both begin similarly, the online modality has a few additional elements that facilitate its delivery over a period of time. In the online training, a WhatsApp group was formed to facilitate communication between the organization and the participants. Then the same content was broken down into short modules complet-

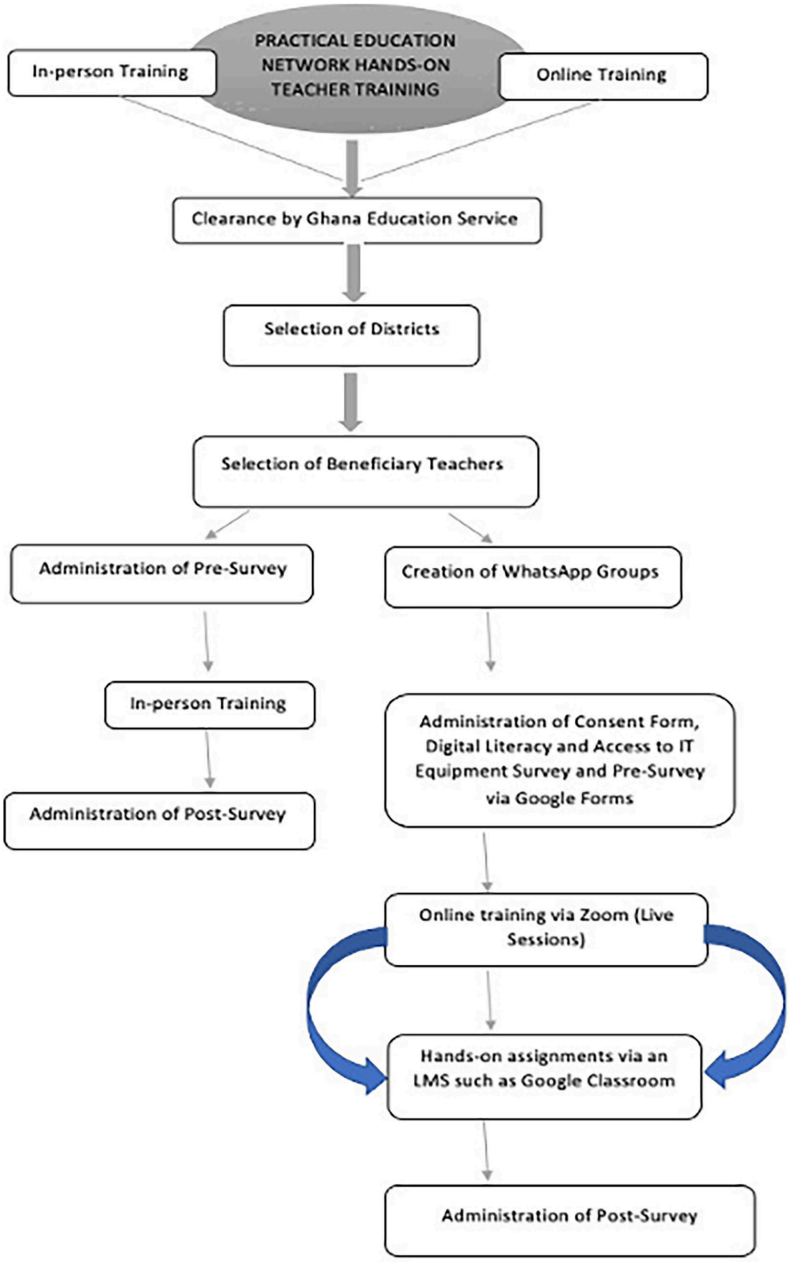

Figure 1. Process flow diagram of key steps used for in-person (left) versus online (right) trainings

ed over time. A cycle of live Zoom sessions and assignments on an LMS was repeated multiple times. The Zoom session served to first orient teachers to the program and then later served as a platform for experience sharing based on what they completed as their assignments. Short instructional videos on how to conduct each hands-on activity were shared on the LMS, the teacher was guided to gather the local materials in their own locality, reproduce the activity on their own, and upload a short video of them conducting the activity.

Over the period of 2014-2019, the in-person training program was rolled out for several cohorts across Ghana. In 2020-2021, this training program was rolled out fully online and for five different cohorts. Details of the online training cohorts are captured in Table 1. These covered various Districts and Regions within Ghana, some being urban, some peri-urban and some rural. The funder type also varied. In all cases, Ghana Education Service (GES) was closely consulted in the implementation. The cohorts will be referred to by their abbreviated names henceforth in this paper.

Baseline Information

A pre- survey, a digital literacy and access to IT equipment survey, and a consent form, developed as Google Forms, were administered prior to the training to collect baseline data. The pre-survey was used to assess teachers' teaching practice and knowledge of teaching using hands-on methods. The digital literacy and access to IT equipment survey collected data on the digital literacy levels of teachers prior to the intervention, whereas the consent form was used to officially seek the consent of teachers to participate in the online training. However, data analyzed to obtain baseline information was from the digital literacy and access to IT equipment survey. Data such as teachers' usage of video conferencing tools, participation in an online course before the training, access to digital devices and challenges faced while using the internet was collected and analyzed using simple descriptives. The survey had closed-ended questions which were analyzed quantitatively. The categories of questions asked sought to find out about teachers' proficiency in the use of video conferencing tools, challenges teachers faced while using the internet, teachers experience with taking courses online, among others as shown in the Appendix. The questions asked included "Have you taken an online professional course or class before, and Likert-scale questions on teacher confidence and feasibility of conducting hands-on activities in their classrooms.

Endline Information

A post-survey in the form of a Google Form was also used to collect data on the impact of the training on teachers. The course completion rate of the training compared to other Massive Open Online Courses (MOOCs) and challenges teachers faced while participating were determined at the end of the online training. The course completion was calculated as the percentage of teachers who completed PEN's online training divided by the percentage of teachers who signed up for the training. This figure was compared to that of other online courses. Both pre and post surveys asked the same close-ended questions on confidence and feasibility. These were analyzed quantitatively using simple descriptives. Sample questions asked included: "I can now carry out STEM-related hands-on activities in my classroom," "I know what to do to increase my students' engagement during a science lesson," "I am confident I can

Table 1. Details of the online training groups engaged during the period of the study

Training Cohort (Abbrev)	Number of Teachers	District; Region	Location Type	Field Partner	Funder
Presbyterian Schools in Ashanti Region (Kumasi Presby)	20	Various; Ashanti	Peri-Urban	Presbyterian Schools Coordinator	Private Individual
Public schools in Ahanta West (Ahanta West)	65	Ahanta West; Western	Rural	District Science Coordinator	Corporate
Public schools in Nzema East (Nzema East)	17	Nzema East; Western	Rural	District Science Coordinator	Corporate
Public schools in Greater Accra (SECF)	98	La Dadekotopon, Ga East and Ayawaso West; Greater Accra	Urban	District Science Coordinators	Family Foundation
Public senior high schools across Ghana (Ashesi EC)	20	Various; Various	Peri-Urban & Rural	None	University

Figure 2. Illustration of (a) a hands-on activity (Convection Currents) video shared with the teacher to replicate, (b) a teacher trying her hands on the activity, and (c) the Zoom depiction of the discussions on the activities done

teach my students using a hands-on approach today," "I am confident that I can address most of my students' concerns during science lesson using a hands-on approach." Pre-post comparison of teachers' confidence levels and feasibility to carry out hands-on activities during their lessons was done to determine change in teacher skills and attitudes over the course of the training. Paired t-tests, to determine p-values for statistical significance ($p < 0.05$) and Hedge's g test, to determine the effect size were done. The effect size was considered to be small if $|g| > 0.2$, medium if $|g| > 0.5$, and large if $|g| > 0.8$. These compared the change in confidence and feasibility levels from both the in-person versus online training modes. Learning gains were also determined for both online and in-person teacher participants. Teachers' learning gains per unit time were calculated as the difference in average scores of confidence and feasibility indicators, before and after the training, divided by the amount of time spent with each training cohort.

Figure 2 illustrates the key components of the training format, namely providing instructional video content that the teachers could watch asynchronously, teacher replicating the activities themselves and uploading a video as evidence, and finally a group Zoom session used to share experiences on the hands-on activities they carried out.

Field Visits and Interviews

After the training program was complete, PEN staff followed up on some teachers who were randomly selected from the Greater Accra Western and Ashanti Regions of Ghana. The selected teachers in the Greater Accra Region were visited in their schools and those in the Western and Ashanti Regions were interviewed on the phone six months after being trained. Pictures of teachers and their learners were taken, and the beneficiary teachers were also interviewed face-to-face during the field visits. Teachers in other regions outside Accra, were interviewed via phone calls. All interviews were transcribed verbatim, and stories were developed out of them.

Results

Participant Demographics

In total, across the five cohorts, 220 teachers who teach Science, Math and Information and Communication Technology (ICT) were selected from 10 out of the 16 regions in Ghana to participate in PEN's online teacher training in the use of hands-on methods to teach STEM subjects. They were between the ages of 18 and 50 years. 57% of the teachers were males and 43% were females.

Baseline Information

Figures 3 to 8 capture key results obtained from the baseline data. These help to create a picture of teachers' access to digital devices as well as their digital literacy levels prior to the training.

Figure 3 shows teachers' exposure to selected video conferencing tools. Teachers surveyed across five training groups were generally not exposed to using video conferencing tools. However, teachers were more exposed to Zoom compared to other video conferencing tools.

Comparing teachers who had never used Zoom to those who had before the training, data collected showed that many teachers described themselves as being very good at using Zoom. 40% of the teachers were very good at using Zoom compared to 10% who had never used it. These exposure levels that teachers reported did not differ significantly whether they were based in rural or urban areas.

Figure 4 details the percentage of teachers who had taken any online course before the training. Baseline data collected before the online training. Baseline data

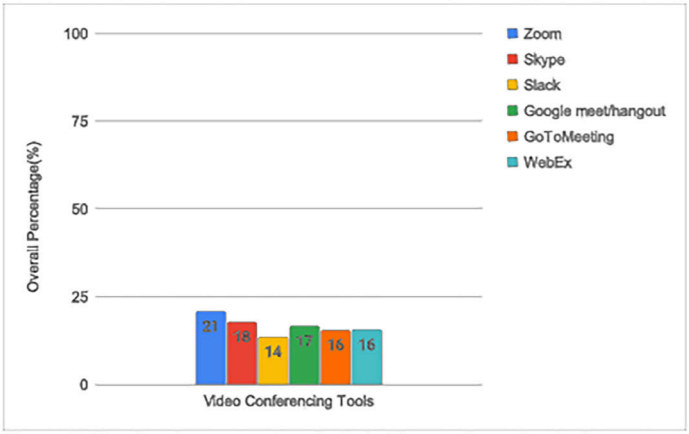

Figure 3. Teachers' exposure to selected video conferencing tools

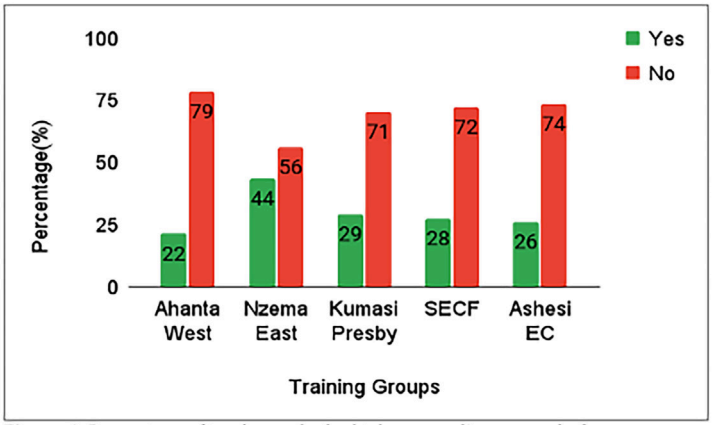

Figure 4. Percentage of teachers who had taken an online course before PEN's online training

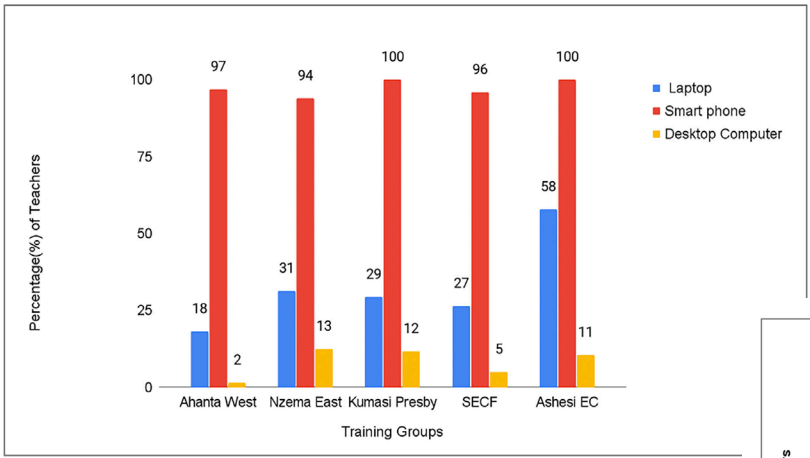

Figure 5. Percentage of teachers surveyed who had access to a personal digital device

collected before the online training showed that teachers were not used to or exposed to doing online courses or training. About 73% of the teachers had never done an online training prior to PEN training. Generally, teachers in all the training cohorts had a low level of exposure to taking an online course prior to the training. However, teachers from Nzema East which is a largely rural District had a relatively higher value (56%) for percentage of exposure to online training. This could be attributed to lower reliability, given that the Nzema East cohort had the smallest sample size.

Percentage of teachers who had access to a digital device prior to the training is shown in Figure 5. This data reveals that smartphones are by far the device which are most accessible to this teacher population, and therefore they will be relying mainly on them to engage with the online training. Only 6% of teachers owned desktop computers and 27% of them owned laptops.

Figure 6 shows the percentage of teachers who reported generally facing challenges while using the internet before the training. In aggregate across the five training groups, about 55% of the teachers surveyed said they faced challenges using the internet. Generally, the five cohorts reported similar responses, except for Nzema East, which again is likely attributable to the low sample size in that cohort.

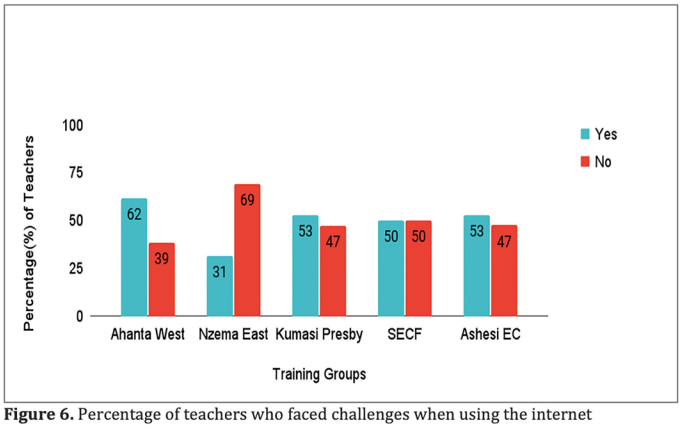

Figure 6. Percentage of teachers who faced challenges when using the internet

Figures 7 and 8 show the type of challenges teachers faced while using the internet prior to the training. The types of challenges faced include cost of purchasing internet data, poor internet connectivity, faulty device, and inability of device to download certain apps. Cost of data was the major challenge faced, with 44% of the teachers attesting to that, followed by poor internet connectivity (34%), inability of device to download certain apps (14%) and faulty device (8%).

Endline Information

In Figure 9, the percentage of teachers who successfully completed the training program is presented. Teachers in the SECF training cohort had the highest percentage (85%) of teachers completing the training. Ahanta West training cohort had the least percentage (14%) of teachers completing the training. Across all cohorts the online training had an overall course completion rate of 48%.

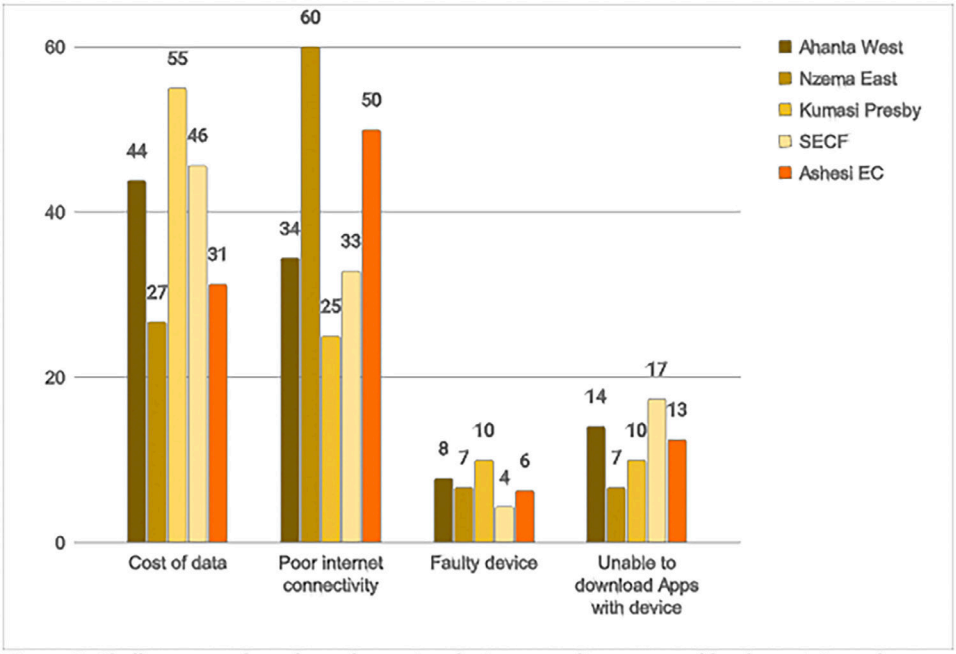

Figure 7. Challenges teachers face when using the internet, disaggregated by the training cohort

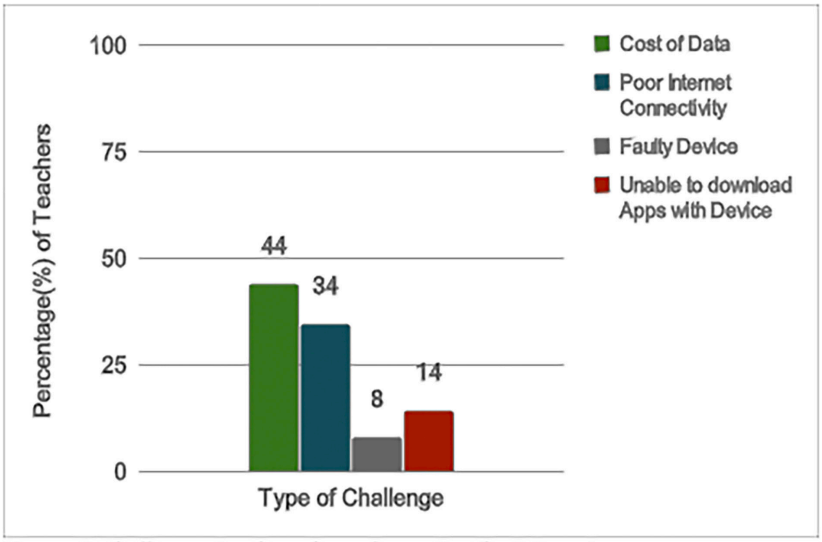

Figure 8. Challenges teachers face when using the internet

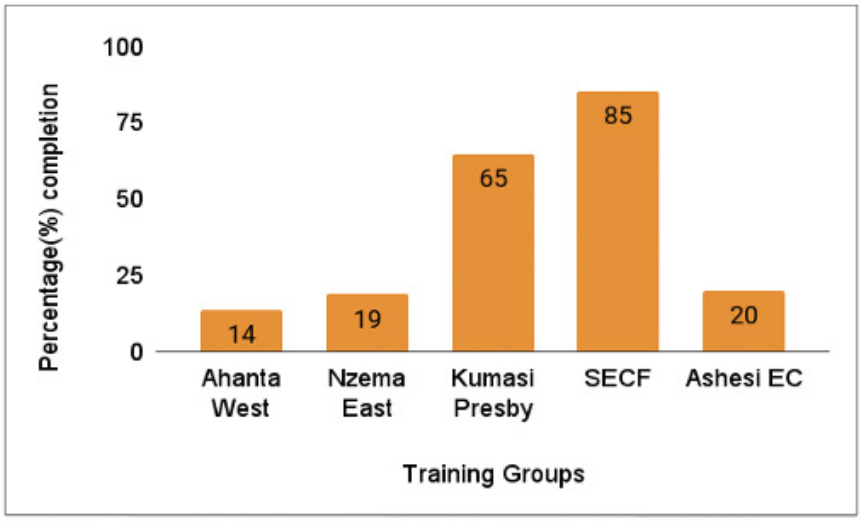

Figure 9. Percentage of teachers who successfully completed PEN's online training program

Table 2 shows the p-values of t-tests conducted on teachers' confidence and feasibility levels (scale of 1 to 5) before and after PEN's in-person and online hands-on training. The increase in teacher perceptions was statistically significant ($p < 0.05$) for both teachers participating online and in-person, and with large effect size ($|g|>0.8$). Teachers who participated in either online and in-person training all increased significantly in confidence and feasibility levels in the use of hands-on methods to teach STEM subjects after the training.

The learning gains achieved were higher per unit time in-person than they were online as presented in Table 3. On average, in-person training had 7.2 times higher learning gains per week than the online version, based on the feasibility metric.

Table 2. Change in perceptions of teachers who participated in PEN's online and in-person trainings

Training mode	Indicator	Period	n	Mean	S.D.	Sig. (2-tailed)	Hedge's g
Online	Confidence levels	pre post	108	3.06 4.64	0.95 0.52	2.71E-32*	2.80E+00 (large effect size)
In-person	Confidence levels	pre post	84	4.07 4.56	0.72 0.53	1.07E-07*	7.70E-01 (large effect size)
Online	Feasibility levels	pre post	83	2.59 4.46	0.92 0.70	5.45E-26*	2.27E+00 (large effect size)
In-person	Feasibility levels	pre post	83	3.02 3.95	0.96 0.86	6.64E-10*	1.02E+00 (large effect size)

Table 3. Learning gains per week of teachers who participated in PEN's online and in-person trainings with regards to feasibility to use hands-on methods to teach

	In-person			Online		
Training Cohort	Olag	Shai-Osudoku	Breman Asikuma	Nzema East	Kumasi Presby	SECF
Learning Gains/Week	3.498	6.995	6.995	0.361	1.122	0.945
Average	5.829			0.809		

Table 4. Learning gains per week of teachers who participated in PEN's online and in-person trainings with regards to confidence levels to use hands-on methods to teach

	In-person						Online				
Training Cohort	Oakwood School	Edify	Tema Ridge	St. Paul's Lutheran (2018)	St. Paul's Lutheran (2019)	TTI Fab Lab	Nzema East	Kumasi Presby	Ahanta West	SECF	Ashesi
Learning Gains/ Week	2.691	6.329	4.664	12.242	-2.798	5.316	0.329	0.987	0.709	0.810	0.102
Average	4.741						0.587				

Table 4 shows that on average, in-person training had 8.1 times higher learning gains per week than the online version, based on the confidence metric. Delivering the same training content online required a longer interaction time. Hence, although both modalities resulted in significant gains and with large effect size, the online modality required a longer time. It should be noted that the participants differed between the in-person and online cohorts, hence there is a limitation on how directly comparative this analysis can be. Nonetheless this highlights the main point that both offerings are effective, however, the online offering likely requires a longer time to achieve the same learning outcomes.

Field Visits and Interviews

Staff from PEN visited a few of the training participants in their respective schools six months after finishing the online training. The following three stories from the field and quotes capture some ways in which the online training was seen to have made an impact on teachers and students. These teachers shared staggering testimonies about the positive effect of the training. They testified about the significant knowledge and skills they have gained to help improve the teaching and learning of STEM subjects.

Madam Ama (pseudoname) teaches Primary 5 in one of the public basic schools in Accra. After receiving PEN's training, she now uses hands-on methods to teach science, and this is empowering her students. This was very evident in the confidence with which her learners answered science questions asked them during our visit. As seen in Figure 10, the students happily showed some innovations they created out of their experiences with hands-on teaching and learning. They went beyond the curriculum and decided to apply the hands-on approach to creating designs of ideas they generated. Madam Ama informed us that all the students in her class, even those who previously were not doing well in science, gained more interest, became innovative and performed better in their science tests.

Figure 10. Innovations (an LED lamp and electrical circuit) created by students out of their experiences with hands-on teaching and learning

Figure 11. Locally available materials gathered by a teacher and her learners to be used to teach science practically

Madam Efe (pseudoname) says that before attending this training, when she needed to teach her learners about temperature, she would walk to a nearby hospital to borrow a thermometer. But after being exposed to the possibility of using everyday materials in our environment, she now uses her own plastic bottles, alcohol, and straws to demonstrate the concept. She has seen that her students understand concepts better than before and do not easily forget them. Moreover, her students always inquire about what the next topic to be treated is, so that they can help look for the associated local materials and bring them for their next science lesson. Madam Efe even noted that truancy levels reduced because her students have become more engaged in her lessons. Figure 11 shows an example set of local materials that a teacher and their students gathered to facilitate this type of learning.

Madam Helen (pseudoname) is a Primary 5 teacher in the Greater Accra Region of Ghana. She is a class teacher who teaches subjects including science in a public school. Madam Helen mentioned that prior to the intervention, most of her students were not interested in science, hence were not doing well in it. However, when we visited the school, we clearly observed learners who were actively engaged in their science class. Madam Helen testified of a particular learner of hers who was originally quite disinterested in science and math, but now had become proactive and eager to engage in lessons, whenever practical activities were involved. She testified of yet another learner in her class who surprised her with a significant positive change. Even that learner's mother noticed the changes in her attitude towards learning, since before she saw her as being duller than her siblings. However, that learner now eagerly volunteers to act as secretary for her group and contributes during lessons. Previously, she did not like doing assignments that were given - her work was mostly incomplete - but she now does well to complete them.

The quotes below exemplify some of the feedback received from teachers when they were interviewed.

> *"Thank you. What I have to say is that this training is not only teaching us practical science. We have also learned educational technology using the phone. With this new curriculum, we can see that most of the topics need IT in teaching the children."*- **Female (Maths and Science Teacher-Greater Accra Region)**

> *"We came in empty but now we can say that we are full because there is a change in behavior. Learning has also taken place. Sometimes when it is time for science lessons, it becomes so dull especially with the new curriculum because we do not have any approach to get the practical way of teaching this lesson. But this time it is not that."* - **Female (Science Teacher-Greater Accra Region)**

"I personally enjoyed it because I am not the science type. But this has given me courage to teach my kids. It has boosted my confidence to teach a science topic and I never regretted joining the course."- **Female (Science Teacher-Western Region)**

"With the aid of PEN, I have learned how to improvise with available materials for my science practicals."- **Male (Science Teacher-Western Region)**

"Previously, I taught science using the 'lecture method' where I just talked and talked. We had limited teaching aids, and my teaching was mainly me standing in front of the class and just talking. My headteacher recommended me for this training and I must say this training has expanded my horizon. I will say, I had a holistic experience. First, we started off learning how to use Zoom and Google classroom. This was a plus for me as I am now literate in the use of these tools." - **Female (Science Teacher-Ashanti Region)**

The teachers who benefited from PEN's training shared very positive feedback about the impact of the training, revealing it to be a unique offering within the ecosystem and highly effective in spite of the online nature. They testified of significant improvements in their teaching, increases in their students' interest, and improvements in their students' learning outcomes in STEM subjects, even highlighting "turnaround" cases for specific learners.

Discussion and Conclusion

An online version of a hands-on STEM teacher training offering was successfully created and implemented across five training cohorts in Ghana. This offering fills a unique gap in the African education landscape and opens up possibilities for what other service providers can similarly do. Leveraging its focus on the use of locally available materials, PEN has arguably created a "pandemic-proof" model of its training. By relying fully on the use of items that can be procured or gathered in one's own environment, hands-on education can continue to be offered. Moreover, this offering was successfully deployed in a landscape where the use of digital tools has been relatively nascent. This fact should also challenge education providers to lean into this in order to scale impactful interventions on the continent.

In answering Research Question 1, the evidence suggests that the fully online modality of this hands-on STEM teacher training in Ghana had equally strong outcomes on participating teachers as those who participated in the fully in-person version. For the two key metrics measured regarding outcomes at the teacher-level, confidence to teach using a hands-on approach and feasibility of teaching with a hands-on approach, both in-person and online participants experienced statistically significant gains and with large effect sizes as a result of this training. This indicates that regardless of the modality, the training offering is impactful. The key distinction between the two offerings is the duration of time required. In translating the training content to an online modality, the material was broken down into short components so as to enable the participants to go through the material without demanding too much data at a time and without experiencing digital fatigue. This meant that while the same training (Introduction to Hands-on Science) was covered during a one day in-person session, it required being spread out over several weeks when offered in an online format.

In answering Research Question 2, two best practices are put forward. One is to leverage the use of locally available materials so as to enable hands-on, experiential education. Even in a remote learning setting, one need not ship materials to each participant nor set up a virtual lab in order to ensure that practical learning takes place. Second is to translate existing training content into short videos that can be accessed asynchronously and provide specific instructions. This ensures that participants are engaged in the digital setting and that they also are guided on specifically what they can practice.

This online training can be considered as a strong alternative along different dimensions. First, it is comparatively cost-effective especially with the use of locally available materials which are readily available in each person's respective environment. The use of pre-recorded videos makes watching and/or downloading them more feasible than streaming live videos, both from a cost and flexibility in time standpoint. The completion rate for this online training based on data collected was 48%. This is relatively higher than the completion rate of most MOOCs. A study conducted in Indonesia saw 100% completion rate of a teacher training in-person or hybrid, but only a 31% completion rate when offered online (Burns, 2013). Again, the average

completion rate of courses offered at University of Pennsylvania through Coursera ranged from 2-14% (Perna et al, 2013).

Persistence levels through the training varied by cohort. A separate study investigated the factors at play in the course completion rate for these cohorts (Hanson & Beem, 2022). It revealed that the majority of teachers who made it to the Onboarding stage, persisted through to course completion. The largest drop-off was between signing up (Enrolling) and attending the first zoom session (Onboarding). Hence, the level of sensitization to the concept of online training may be one of the most significant factors to address to improve persistence. For most teachers, if they commenced the training, their individual motivation and drive saw them through to the end. Although it is easy to fall on the dominant narrative that poor internet connectivity is the key factor in inhibiting digital modes of education from sticking in this context, other factors such as the motivation level of the participant and the commitment level of the field partner should be considered. In spite of the expected challenges associated with delivering an online training in this context, many teachers persisted to complete the training, and those who did benefited tremendously. Based on field visits to some of their schools and phone interviews with others, multiple stories and anecdotes were shared of how this training impacted their teaching and their learners' learning. This study can serve as an example to other African education service providers to lean into the opportunities that translating their content into digital modes can provide.

References

Addae, D., Amponsah, S., & Gborti, B. J. (2021). COVID-19 Pandemic and the Shift to Digital Learning: Experiences of Students in a Community College in Ghana. *Community College Journal of Research and Practice, 46*(1–2), 101–112.

Advanced Tools for e-Learning. (n.d.). *Conceptual learning and interactive training for today's world*. Advanced Tools for e-Learning (ATeL).

Ashesi University. (2020). *Thank you to all our lab managers*. Instagram. Retrieved September 28, 2023.

Babb, J., & Stockero, S. L. (2020). Impact of Practical Education Network on students in selected Ghanaian junior high school science classrooms. *African Journal of Research in Mathematics, Science and Technology Education, 24*(2), 216-228.

Bishop, Z. K., Howard, T., Lazari, P., Taylor, B., Trend, P., & Funnell, A. (2021, April). Student experiences of practical activities during the COVID-19 pandemic. In 2*021 IEEE Global Engineering Education Conference (EDUCON)* (pp. 619-623). IEEE.

Burns, M. (2013). Staying or leaving? Designing for persistence in an online educator training programme in Indonesia. *Open Learning: The Journal of Open Distance and e-Learning, 8*(2) pp 141-152.

Center for National Distance Learning and Open Schooling [CENDLOS]. (2023). *Center for National Distance Learning and Open Schooling*. September 26, 2023.

Crawfurd, L., Evans, D. K., Hares, S., & Sandefur, J. (2021). *Teaching and Testing by Phone in a Pandemic* (No. 591). Center for Global Development.

Damani, K., & Mitchell, J. (2020). *Rapid evidence review: Radio*. EdTech Hub.

Dome, M. Z., & Armah-Attoh, D. (2020). Ghana's e-learning program during pandemic may present access challenges for many students. *NewsGhana*, 20 July, 2020.

Ecampus. (2023). *eCampus-Student.*

EdTech Hub. (2020). *The Effect of Covid-19 on Education in Africa and its Implications for the Use of Technology: A Survey of the Experience and Opinions of Educators and Technology Specialists*. UKAid.

Eisenberg, M., & Fischer, G. (2014). *MOOCs: A Perspective from the Learning Sciences*. Repository.isls.org.

Erna, N., Genisa, R. A. A., Muslaini, F., & Suhartini, T. (2022). The Effectiveness of Media Zoom Meetings as Online Learning during the Covid-19 Pandemic. *ELT-Lectura, 9*(1), 48-55.

Flood, Z. (2020, April 15). How Africa's tech innovators respond to the coronavirus pandemic. *Al Jazeera*.

Foundation First. (2023). Foundation First: Putting young children first.

Fox, M. F., Werth, A., Hoehn, J. R., & Lewandowski, H. J. (2020). *Teaching labs during a pandemic: Lessons from Spring 2020 and an outlook for the future*. arXiv preprint arXiv:2007.012711

Ghana Education Service (2020, May 5). *Ghana Learning TV May Timetable from KG to SHS*. Ghana Education Service - GES.

Ghana Socieity for Education Technology[GSET]. (2023). *Ghana Society for Education and Technology*. September 26, 2023.

Girot, A., Goy, N.-A., Vilquin, A., & Delabre, U. (2020). Studying ray optics with a smartphone. *The Physics Teacher, 58*(2), 133-135.

Government of Sierra Leone. (2020). *COVID-19 Education Emergency Response Plan*. Ministry of Basic and Senior Secondary Education.

Halpern, J. (2021, October 29). Women's Technology Program 2021: The sweet sound of success. *MIT News*. Massachusetts Institute of Technology.

Hanson, M. A., & Beem, H. R. (2022, November). Role of digital literacy and tools in teacher persistence in an online hands-on science training in Ghana. In *2022 IEEE IFEES World Engineering Education Forum-Global Engineering Deans Council* (WEEF-GEDC) (pp. 1-5). IEEE.

Hart, A. J., Wendell, D., Liu, J., Lewandowski, J., Funes-Lora, M., & Shih, A. J. (2021). Teaching manufacturing processes using a flipped classroom model. *Procedia Manufacturing, 53*, 773-781.

Kisakye, F. (2020, October 14). Digital pilot program transforms learners' lives in N. Uganda. *The Observer*.

Larson, J. S., & Farnsworth, K. (2020). Crisis teaching online: Reaching K-12 students through remote engineering lab-based Activities during the COVID-19 pandemic. *Advances in Engineering Education, 8*(4), n4.

Leung, J. K., & Chu, S. K. (2020). Inspiring Makers in First-Year Engineering under Emergency Remote *Teaching. Advances in Engineering Education, 8*(4), n4.

Marin, S. V., Cobo, C., Cloutier, M-H. & Lambert-Porter, E. (2021, September 20). *Where is EdTech working? Leveraging data for better EdTech policies.*

McQuate, S. (2020, April 16). "Hands-on" classes online? How some instructors are adapting to a new teaching environment. *UW News*.

Mukute, M., Burt, J., Francis, B., & De Souza, B. (2020). Education in Times of COVID-19: Looking for silver linings in the Southern Africa's educational responses. *Southern African Journal of Environmental Education*, 36.

Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: a literature review. International *Journal of Humanities and Innovation, 4*(1), 1-4.

Nugba, R. M., & Quansah, F. (2020). Students' perception of lecturers' assessments: A case of university of Cape Coast, Ghana. *European Journal of Education Studies, 7*(11).

Osman, A., & Keevy, J. (2021). *The impact of COVID-19 on education systems in the commonwealth*. London: Commonwealth Secretariat.

Owusu-Acheaw, M. (2014). Reading habits among students and its effect on academic performance: A study of students of Koforidua Polytechnic. *Library Philosophy and Practice* (e-journal). 1130.

Perna, L., Ruby, A., Boruch, R., Wang, N., Scull, J., Evans, C., & Ahmad, S. (2013, December). The life cycle of a million MOOC users. In *MOOC Research Initiative Conference* (Vol. 5).

Pivot Interactives. (2023). *Pivot Interactives*.

Practical Education Network. (2024). *Practical Education Network*.

Right To Play in Ghana. (2023). Retrieved from https://righttoplay.com/en/countries/ghana/

Sabre Education. (2023). *Early Years Education in Ghana*. Sabre Education.

Sanyal, C. & UNESCO International Institute for Capacity-Building in Africa. (2013). *Quality Assurance of Teacher Education in Africa*. UNESCO.

Suacode.ai. (2023). *Learn to code on your phone with friends and Kwame, our AI teaching assistant*.

Tijani, B., Madu, N., Falade, T., & Dele-Ajayi, O. (2021, April). Teacher Training during COVID-19: A Case Study of the Virtual STEM Project in Africa. In *2021 IEEE Global Engineering Education Conference* (EDUCON) (pp. 226-234). IEEE.

Travaglini, S., Sheppard, S., Chen, H. L., & Nittala, S. (2021, July 26). *Augmenting Activities in Engineering Courses with Tools, Technology, and Kits for Remote Experiential Learning*. Asee.org.

U.S. Embassy in Ghana. (2023). *U.S. Partners with Ghana to Launch Learning Radio Program to Improve Reading for Ghanaian Children*.

University of Colorado Boulder. (2019). PhET Interactive Simulations. PhET.

Vegas, E. (2020). School closures, government responses, and learning inequality around the world during COVID-19. Brookings.

Wijenayake, C., D'souza, M., Khatamianfar, A., Bialkowski, K., Ros, M., & Sutton, P. (2021, December). Managing Hands-on Electrical and Computer Engineering Labs during the COVID-19 Pandemic. In 2021 *IEEE International Conference on Engineering, Technology & Education* (TALE) (pp. 1051-1056). IEEE.

Wu, L. L., Zhu, E., Callaghan, C., Irwin, D., Reinsdorf, D., Swanson, V., ... & Reinkensmeyer, D. (2020). Rapidly Converting a Project-Based Engineering Experience for Remote Learning: Successes and Limitations of Using Experimental Kits and a Multiplayer Online Game. *Advances in Engineering Education, 8*(4), n4.

Yeung, Y-Y. (2020). *Remote vs virtual labs.* (2020, August 25). THE Campus Learn, Share, Connect.

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APPENDIX
PEN Online Teacher Training- Digital Access & Literacy Survey

1. Full Name (as it appears on your ID card)
……

2. Telephone/WhatsApp Number
……

3. What position(s) do you hold in your school? e.g. head teacher
……

4. What STEM subject(s) do you teach? e.g. integrated science
   - O Integrated Science
   - O Mathematics
   - O Other ……..

5. What is the name of you school?
……..

6. Which class(es) do you teach currently?
   - O J.H.S 3
   - O J.H.S 2
   - O J.H.S 1
   - O Class 6
   - O Class 5
   - O Class 4
   - O Class 3
   - O Class 2
   - O Class 1

7. Type of school/institution
   - O Private
   - O Public/Government

8. In which region is your school located? e.g. Ashanti Region
……

9. In which district is your school located? e.g. Ahanta West District
……

10. Which of the following devices do you own and can use consistently throughout the months of the online training? (Select all that apply)
    - O Laptop
    - O Desktop computer
    - O Smart phone

11. What is/are your preferred social media channel(s)? (Select all that apply)
    - O WhatsApp
    - O Instagram
    - O Twitter
    - O Facebook
    - O LinkedIn

12. Do you have challenges when using the internet?
O Yes
O No

13. If yes, what are the challenges you face when using the internet? (Select all that apply)
O I cannot afford the cost of buying data continuously
O The internet connectivity is poor at my location
O I have a problem connecting to the internet with my device
O The specification of my device makes it challenging to download apps
O Other……..

14. What best describes your proficiency/usage level in using any of these video conferencing tools? (Range = Very Good - Never Used it)

	I am very good	**I am not too good**	**I am not good at all**	**I have never used it at all**
Zoom	0	0	0	0
Skype	0	0	0	0
Slack	0	0	0	0
Google meet/hangout	0	0	0	0
GoToMeeting	0	0	0	0
WebEx	0	0	0	0

15. Have you ever used the Google Classroom?
O Not at all
O Very little
O To some extent
O A lot

16. What days of the week will be most favourable to participate in live sessions?
O Monday
O Tuesday
O Wednesday
O Thursday
O Friday
O Saturday
O Sunday

17. What time of the day will be most favourable to participate in live training sessions?
O 9-11am
O 12pm - 2pm
O 3pm - 5pm

18. Have you taken an online professional course or class before?
O Yes
O No

19. How has COVID-19 affected your professional development?
……