Challenges and Opportunities for Online Practical Work in Sub-Saharan Africa

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Keywords: *Science Education; Practical Science; Online Laboratory; Learning Technologies and Sub-Saharan Africa*

Abstract

Practical work is an integral part of teaching and learning in STEM. It can help to deliver many learning outcomes - manipulative skills, observation and description, motivation, creative thinking, problem-solving abilities, and critical attitudes, as well as conceptual understanding. In recent years the already weak provision of the STEM practical curriculum in Sub Saharan Africa (SSA) has been undermined further by pandemic constraints. Online practical work is expanding rapidly in both scale and sophistication worldwide and it offers a credible means of mitigating such problems and improving access in SSA.

This study examines issues and prospects for online practical work in SSA. It includes a brief summary of the present position and presents the views of stakeholders gathered using semi structured interviews. These focused on their attitudes towards introducing new learning technologies and related approaches in the teaching and learning of practical work in science.

The results showed that many of the educators interviewed are enthusiastic about the opportunities afforded by online practical work and see such innovation as a useful response to the pandemic. They also assert their readiness to embrace new technologies in STEM practical work but warn of the challenges, notably access to resources and the lack of the teaching skills required to engage learners in effective online practical work. The students have been disappointed by online versions of conventional face to face teaching and many are sceptical about online practical work. Resource and cost issues dominate their thinking. Science educators will require extensive training if online learning technologies are to be harnessed successfully to provide practical science activities in SSA.

Introduction

The nature and identity and purpose of ‘practical work’ is a topic that evolves and remains under discussion. Millar et al.. (1999) define science practical work as those activities that involve students in handling or observing the real objects or materials they are studying. Practical work may be performed in a laboratory or outside in the field or in an ordinary classroom. An elaboration came from Abrahams and Millar (2008) who preferred to use the term ‘practical work' rather than laboratory work because they claimed that the learning achieved is not characterized by the location but by the activities of students. They further asserted that science teaching must involve more than asserting or demonstrating facts. It includes putting learners into situations where they can observe for themselves.

The Science Community Representing Education (SCORE, 2009a) defines practical work in science as hands-on learning experiences that prompt thinking about the world in which we live. An associated report (SCORE, 2009b) listed eligible activities using two main categories; core and directly related activities. The former include; investigations, laboratory work, learning procedures and techniques, and fieldwork. These hands-on activities support the development of practical skills and help to shape students understanding of scientific concept and phenomena. The latter include; teacher demonstrations, experiencing phenomena, designing and planning investigations, and analyzing results. These are closely related to the core activities and are either a key component of an investigation or provide valuable first-hand experiences for the student.

The perceived importance of practical work in school science teaching cannot be overemphasized. The science laboratory has been considered by science educators to be of unique value in enhancing student interest in science and in developing new understanding of scientific concepts and procedures. Lunetta et al.. asserted that laboratory experiences help students to gain ideas about the nature of science that are crucial for their understanding of scientific knowledge (Lunetta, Hofstein & Clough, 2007).

Unfortunately, the broad aims of practical work are often neglected. In their study on the aims of practical work in SSA, Babalola et al.. (2020) found that educators prioritised understanding of content and reinforcement of theory. In effect, practical work was used to augment the transmissive content-led classroom. Often the activities were framed around equipment and tasks that were no longer relevant to modern science – any skills acquired had little professional relevance.

The rapid growth in the power and availability of ICT has provided new opportunities for educators, and online approaches have become widely used in many educational contexts. For example, web-based activities are used extensively in distance education courses and blended approaches are widely used to support teaching and learning activities (Rodriguesa et al., 2019). Recent technological innovations enable students to interact freely and usefully both within the classroom and beyond (Webb, 2010). Zhai et al.. (2012) have pointed out that video-based activities provide insights into real and often complex labs that are unavailable otherwise. The potential impact of ICT on practical work is already evident and its relevance is growing. Virtual labs, remote control labs, simulations, virtual reality and video-based labs allow access to rich experiences without on-campus presence. There are now numerous open and proprietary resources available to educators at primary through tertiary levels.

Triona and Klahr (2003) highlighted the advantages of virtual experimentation. These include portability, safety, cost -efficiency, minimization of error, adjustment of temporal and spatial dimensions, and flexible rapid data displays. These remain relevant but can be supplemented by ease of access, range of experiences, and relevance to contemporary scientific practice.

There is abundant empirical evidence to support the use of learning technology in the teaching and learning of practical science. For example, an early study by Zacharia (2007) on undergraduate students following a pre-service course for elementary school teachers in Cyprus showed that those using virtual experiments achieved higher marks on circuit theory than those using hands-on approaches. Darrah et al. (2014) evaluated a comprehensive set of virtual labs for introductory level college physics courses at two large universities and compared them to the equivalent hands-on experiences. Findings from both university settings showed the virtual labs to be as effective as the traditional hands-on physics labs. A recent review of the literature on school-level practical science concluded that ICT mediated approaches offered several enhanced science outcomes, including theory, practice and social implications (Hogarth et al., 2020).

However, there is considerable inertia in pedagogy. In 2006, Millar observed that, in most science classrooms where technologies are deployed, they are generally used to support existing pedagogical approaches (Millar, 2006). In spite of the potential advantages, science educators have typically used ICT only when (i) a real laboratory is unavailable, too expensive, or too intricate; (ii) the experiment to be conducted is dangerous; (iii) the techniques that are involved are too complex; or there are time constraints (Kirschuner & Huisman, 1998). Steinberg (2000) as cited in Bhukuvhan et al. (2012) opined that science educators discriminate against virtual experimentation because they consider that, when using virtual experiments, they are asking their students to learn in a way that does not reflect the working practice of the corresponding group of scientists. It may be argued that such objections are in retreat but Eickelmann and Vennemann (2017) have identified a significant minority of sceptical and rejection-minded teachers in the three European countries they studied. Babalola (2017) found similar hesitations in educators in SSA.

The recent and ongoing pandemic has been a great challenge across the higher education landscape in Africa, where academics have had to switch to remote teaching, and make new arrangements for practical work. Many students have not been receiving face to face teaching and access to physical laboratory facilities has been very limited. An increasing number of universities have taken the steps necessary to transform their teaching, and are seeking ways of delivering practical-based learning.

However, there are considerable challenges in such innovation in countries that lack resources or educational capacity. Often, the existing physical teaching laboratories are outdated and are not appropriate to teach contemporary science. Many teachers and senior educators lack the professional skills for conventional delivery of the practical curriculum and concentrate on a narrow range of knowledge-based outcomes aimed at assessment requirements. This weak starting position disadvantages them in adopting new and rich ICT based solutions. In turn, these difficulties may lead to mistrust of new approaches. Students too lack awareness of potential and may be similarly resistant.

This study examines the views of stakeholders in SSA on the prospect of using technology in the teaching and learning of practical science in universities. It is mainly focused on Nigeria but incorporates some data from other countries in SSA. The aims are to assess the overall level of acceptance of such approaches and identify the issues that are of concern in moving towards implementation. These may be science specific or cultural. Systemic change is only achievable if educator and student concerns are addressed.

Research Methodology

The researchers adopted a qualitative research approach for this study and used purposive sampling techniques for data collection. The researchers recruited one hundred (100) students and twenty (20) lecturers from the Faculties of Science in two universities in Nigeria (table 1). Consent from the participant was obtained after being informed about the purpose of the study and research objectives at the start of the interview. Privacy and confidentiality were also assured.

The lecturers that participated in this study taught physics, chemistry or biological science courses. Interviews were conducted face to face and typically were brief, lasting 10-15 minutes. The students were enrolled on the same breadth of courses and were first year undergraduate science students. The students who were interviewed were rapporteurs from student focus groups organised within the two universities to discuss the interview questions. Rapporteurs were asked to voice the collective views of their groups. Each focus group comprised five (5) students making twenty (20) groups all together. There was no time limit on the focus group discussion – the duration depended on the discretion of the rapporteur.

The interview protocols were developed through informal discussion and simulated interviews with colleagues followed by a pilot in another university that did not form part of the study. Only minor changes were required after the pilot.

	Lecturers		Undergraduate students		
	University A	**University B**	**University A**	**University B**	**TOTAL**
Male	8	8	35	30	**81**
Female	2	2	20	15	**39**
TOTAL	**10**	**10**	**55**	**45**	**120**

Table 1 *The roles and gender of the participants.*

	University A		**University B**		**Totals**	
	Student Groups (11)	Lecturers (20)	Student Groups (9)	Lecturers (20)	**Student Groups (20)**	**Lecturers (20)**
Desirability of online practicals (positive, neutral, negative)	10 (3, 0, 7)	10 (8, 2, 0)	7 (2, 0, 5)	10 (7, 3, 0)	**17 (5, 0, 12)**	**20 (15, 5, 0)**
Network connection (positive, neutral, negative)	8 (0, 0, 8)	3 (0, 0, 3)	7 (0, 0, 7)	3 (0, 0, 3)	**15 (0, 0, 15)**	**6 (0, 0, 6)**
Power availability (positive, neutral, negative)	4 (0, 0, 4)	1 (0, 0, 2)	4 (0, 0, 4)	1 (0, 0, 1)	**8 (0, 0, 8)**	**2 (0, 0, 3)**
Mobile devices (positive, neutral, negative)	2 (0, 0, 2)	2 (2, 0, 0)	1 (0, 0, 1)	1 (1, 0, 0)	**3 (0, 0, 3)**	**3 (3, 0, 0)**
Teacher expertise (positive, neutral, negative)	0	2 (0, 0, 2)	0	2 (0, 0, 2)	**0**	**4 (0, 0, 4)**
Cost (positive, neutral, negative)	0	1 (0, 0, 1)	0	1 (0, 0, 1)	**0**	**2 (0, 0, 2)**

Table 2 Themes and the number of respondents raising each theme. The figures in brackets indicate the number of respondents voicing a positive opportunity, a neutral view and a negative concern relevant to that theme.

The interviews were conducted around two questions that asked for their opinions on (i) the introduction of online practical work in science and (ii) the challenges to the adoption of such approaches. These questions were elaborated to clarify any opinions that had been expressed.

The audio recordings were transcribed and coded into thematic nodes by the researchers. The themes identified were potential value of ICT, network capabilities, power access, teacher expertise, and use of mobile devices. Each confirmed node contained a range of opinions. The quotes used in this paper are representative of statements made by several respondents.

In addition to the university-based interviews, previous interview data has been re-examined to incorporate opinions from a small number of stakeholders across SSA. The methodology was the same but the interview questions were embedded in a broader study on practical science. There were stakeholders interviewees from Ghana, Tanzania and South Africa. They consisted of headteachers, other senior educators and officials. The results are reported in Babalola (2017).

RESULT AND DISCUSSION

The issues raised by the respondents are summarised in table 2 together with an indication of the opinion on each theme. As can be seen the results for the two universities were similar and, for simplicity, the overall totals are combined in the last two columns. However there are significant difference between the responses from the lecturers and students and these are not combined.

The views of lecturers

The lecturers welcomed the possible introduction of learning technologies. They felt that such approaches would mitigate the effects of the pandemic and were necessary if Africa was not to be left behind in adopting global best practice. Many of the lecturers had been teaching their students via online media but very few of them had experience of teaching practical science online. Some of the lecturers tended to believe that online practical classes would reduce the cost of running physical laboratories and ease the maintenance burden. The following are verbatim excerpts from the lecturer interviews.

"Online practical class is a welcome development because it will reduce cost and ease maintenance burden."
(University A)

"Teaching practical science online will give the students opportunity to learn at their own pace and they will be able to perform many experiments that are difficult in the real laboratory."
(University B)

"Screen-based practical work saves time and effort unlike the real lab and also provides opportunities for us and students to keep up with the technological development in this digital age."
(University A)

"Engagement in online practical work is something we hope for because it will cushion the effect of dearth of materials but do we have the required skills to design this kind of experiments."
(University B)

"I know that online practical work provide flexibility in performing experiments, but we have other issues that acts as an impediment to adoption such as the accessibility and skills required for such activities."
(University B)

"Unfortunately, our students have not been exposed to online practical but I believe it will motivate both students and lecturers to acquire the necessary skills embedded in practical."
(University B)

"Due to the pandemic, we lecture the students remotely. Teaching practical work online will not be a bad idea but I think our laboratory technologist needs a special training on how to engage the learners in online practical activities."
(University A)

"Most of the students now have access to mobile devices, so switching to online practical work won't be a problem."
(University B)

"I think there is need for training on the use of learning technology for the teaching of practical work."
(University A)

"I'm not sure we will have the required skills to engage our students in screen-based practical work at the moment."
(University B)

"It is easy for us to give lectures via telegram, Whatsapp and video recordings. I'm not so sure how we can teach the students practical online. There is need for retraining on how to teach practical work with learning technologies." (University B)

https://doi.org/10.29311/ndtps.v0i17.4026

"Students had a lot of challenges in adapting to our online lectures. Some complain about lack of electricity, poor network and not even having the resources to join online classes. These might also be the bane of online practical sessions."
(University A)

The views of students

Many of the students had no previous exposure to online practical science. In framing their views, they extrapolated from experiences of online methods adopted in response to the pandemic. Such experiences vary but the comments suggest that their online learning was a poor substitute for traditional face to face methods. Many of their responses focused on practical concerns about their ability to access the resources remotely. Below are excerpts from the rapporteur interviews.

"I think I will prefer to do practical work online rather than the physical lab because we work in group due to insufficient equipment and the practical session is always rowdy and not well organized."
(University B)

"Online practical work most especially in physics and chemistry will go all long way in solving most of the problems we encountered when performing experiments in the physical laboratory." (University A)

"Learning practical science online will save us of the stress and rowdy sessions associated with the physical laboratory."
(University A)

"We have a lot of challenges like inadequate equipment and not having enough time to perform experiments because other groups are waiting to enter the lab… Online lab will help in solving some of these Challenges."
(University B)

"We've had experiences with online classes for our lectures due to the pandemic but I think having experience of online practical class will be a worthwhile thing to explore."
(University A)

"Currently we do have some of our classes online via telegram while some via face to face. We are yet to have any experience of online practical."
(University B)

"Online practical will consume a lot of data and will also need a good internet connection."
(University B)

"There is problem with power supply, poor network connection which might hinder the effectiveness of online practical classes.''
(University A)

"The virtual practical work is okay but the physical laboratory is always better when we have enough resources to go round."
(University A)

"We hope that the pandemic is over and we get back to the physical classroom. It is not easy getting along with the virtual mode."
(University B)

"The online classes we had during this pandemic are not encouraging at all, is better we go back to our usually face to face method. I don't think running practical classes will help either."
(University B)

"Online classes are not helping us, most of us had issues with poor network and in some cases, and we don't know when the lectures will hold online".
(University A)

"Sometimes, we do have problem connecting to the internet within the university….running online practical session might be very difficult."
(University B)

https://doi.org/10.29311/ndtps.v0i17.4026

"Some of us are not having android phones, so accessing online lectures/practical will be very difficult." (University A)

Stakeholder in sub-Saharan Africa also cherished the idea of a screen-based practical work. They acknowledge the need for expertise teachers who are vast in the use of learning technology in teaching practical science. Below were some of the excerpts from the interviews:

"I think we need good quality teachers who know how to use the software because experiments can be simulated. But my teachers prefer students to do hand-on." (Principal, SA)

"I have seen in some schools where they are provided with a mobile lab and I think it will do us good." (HoD, GH)

"Educators themselves must be encouraged to use the internet where they can download practical software." (Senior Official, SA)

Discussion

Although this study is limited in the number and diversity of respondents, there are some clear trends. The attitudes of both lecturers and students are coloured by their previous experience or lack of experience of online learning. Both groups acknowledge that the introduction of ICT as a means of reducing CoVid 19 transmission has been problematic and they believe that the difficulties they had already encountered in attending theoretical classes online would also be applicable to the practical aspect. However, most of the lecturers remain optimistic that online practical work would ease the maintenance burden and provide flexibility in performing experiments. This is in line with Zhai et al. (2012). To some extent their comments reflect the supply side advantages to staff of ICT use.

The students are much less optimistic. They focus on the difficulty of accessing online experiences. Some of the students asserted that they are unable to purchase data to connect with online lectures and others mentioned that they did not have android phones. It should be remembered that mobile networks are the overwhelming data carrier in SSA. In 2017, less than 1% of people had a fixed broadband connection compared with 38% in the UK (Ofcom, 2017). By contrast, mobile phone ownership is broadly comparable with economically developed countries (about 80 phones per 100 people vs about 120 per 100 people). Many available online experiences are optimized for large screen delivery and the construction of software that is mobile phone optimized is an obvious need and opportunity.

Poor electricity supply was also mentioned by the students. In 2019 just 54% of Nigerian households had mains electricity (World Bank, 2019). This supply is not robust and there are frequent outages. Understandably there is deep scepticism about a learning delivery mechanism that is so easily disrupted.

Some of the lecturers interviewed were concerned about the ability of staff to create and oversee online practical work. This may stem from a general lack of professional skills in practical science teaching or from specific ICT concerns. It is very likely that lecturers have little awareness of the volume and quality of existing open-source software and web sites as there was no mention of such resources providing a potential way forward. Students did not raise this skill issue – they remained very focused on the problems of connectivity. However, the views expressed in this study triangulate with views from wider SSA. Some stakeholders in sub-Saharan Africa cherished the idea of screen-based practical work while acknowledging the need for enhanced teacher expertise in the use of learning technologies (Babalola, 2017).

Students did not mention cost worries directly, possibly because such concerns were conflated with technical access issues. However, some lecturers did voice their worry about students being able to find the necessary connectivity.

Some potential issues were not mentioned at all. It might have been expected that some respondents might have had views on the validity of online practical work, the potential isolation from class mates or the erosion of the teacher-student relationship. These are all issues that have been raised in the literature on practical work in countries with developed economies and were voiced by stakeholders in wider SSA. However, it might be that the present respondents had been sensitized to more immediate problems of ICT delivery in a country with effective mobile networks but considerable infrastructure weaknesses and limited personal resources.

Conclusions

There is a need to mitigate the loss of opportunity for conventional practical classes due to the pandemic. Online experiences could offer a solution. Their implementation may have long term advantages, not least in overcoming existing weaknesses in conventional delivery of practical work. It is encouraging that the possible impact of learning technologies is welcomed by lecturers though some of the students had mixed and negative reactions.

Online delivery could provide a politically and socially supported means of achieving radical change. Sub-Saharan Africa has a strong track record of using new technologies such as mobile phones to transform the way society operates - there is a readiness to change. Although enhanced use of ICT is an inevitable part of the future landscape, there are barriers to successful adoption. Practical issues such as connectivity, funding, and teacher expertise need to be addressed. Recent negative experiences of online learning need to be acknowledged and plausible solutions found. In addition, there may well be other less overt issues not revealed by this study, e.g. the possible disruption to the relationships between learners and the teacher and their students. Therefore, adoption of ICT in teaching of practical science in SSA will require re-education and vision.

There is a real opportunity that emerges from this study. Weaknesses in fixed broadband connectivity invite staff in SSA to devise practical work that is optimized for small screen delivery. This could be a ‘project’ that has valuable outputs in enhanced learning and the generation of revenue.

Acknowledgements

Special thanks to all the stakeholders who participated in this study.

Conflict of Interest

The authors declare no conflict of interest for this study

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