Pan-Commonwealth Forum, 9-12 September 2019, Edinburgh, Scotland.

The Opportunities and Challenges for Developing ICT-Based Science Learning and Teaching in Ghana

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Abstract

Africa's transition to an innovation-led, knowledge-based economy could drive the continent's economic growth and lift millions out of poverty and there is opportunity to increase the number of skilled professionals across the chemistry, biology and physics disciplines. However not enough students enrol in science subjects in Higher Education in Ghana, with proportions admitted to public universities well short of the Government's 60% target. Significant barriers for all young people include the lack of practical scientific equipment in schools, and barriers to young women include prevailing socio-cultural attitudes, a lack of female role models and unsupportive educational environments.

To address these constraints The Open University UK and the Centre for National Distance Learning and Open Schooling (CENDLOS) Ghana, under the guidance of the Ministry of Education, Ghana are developing a project in the programme OpenSTEM Africa (OSA) to support work already begun by CENDLOS to bring ICT-based learning and teaching to Senior High Schools through their pioneering iBox and iCampus. OpenSTEM Africa is a framework for improving science education in Africa, with the co-development of appropriate learning and teaching materials including curriculum-relevant interactive onscreen science experiments, gender sensitive teaching and learning materials, female role modelling, and a school teacher and teacher leadership programme that will support the delivery and sustainability of improved ICT-based science education which is scalable to national level.

We are still near the beginning of this collaboration and we would like to present interactively to participants at PCF9 on both the opportunities and the obstacles with a short demonstration of the potential interactivity while also collectively interrogating some of the challenges of a shift to ICT-based teaching and learning.

Introduction

The African Union' Commission's Science, Technology and Innovation (STI) Strategy for Africa 2024 recognises that Africa's transition to an innovation-led knowledge-based economy will drive the continent's economic growth and ultimately lift millions out of poverty (African Union Commission, 2014). Universal primary education, and since 2015, the focus via the Sustainable Development Goals (SDG) on lower secondary education presents a timely opportunity to address this need, as more children are transitioning to secondary education (World Bank 2018),and accessing science education. The SDG objectives to achieve gender equality and a quality education for all also frame the need, matched in government policies across Africa, to improve opportunities for all young people, especially girls, to study science subjects and takes up STI-related careers.

Nevertheless, in Ghana there remain concerns at policy level that nationally across Senior High schools (SHS), there is much lower enrolment (11.7% in 2016-17) in elective science subjects than in other specialist options and that fewer students enrol in science subjects at tertiary level (Ministry of Education (MoE) 2018). In Ghana, only 33% of students in tertiary education in 2016 were studying science subjects, well short of the Government of Ghana's 60% target (MoE 2018). With increasing secondary-level student numbers in Ghana, particularly since education at SHS was made free in 2017 and a double-track system introduced in 2018 to cope with the increased numbers, teaching is under-resourced, with serious shortages of qualified science and maths teachers. Moreover the pressures on school infrastructure have increased, in particular on the already low level of access to science laboratories. There are needs for improvement at Senior High School level articulated in the new MoE *Ghana Education Strategic Plan 2018-30*, including the need to improve the quality of teaching and learning materials for example by improving the student text book ratio from its current national aggregate of 0.5; the need to address the "inadequacy of computers and inadequate integration of ICT in teaching and learning at SHS" (MoE 2018 p,36); the need to improve the quality of teaching, and to improve learning outcomes in STEM subjects, especially for girls. There are still significant barriers in Ghana to women and girls' full participation in science subjects, such as socio-cultural attitudes, lack of female role models, and unsupportive educational environments (Ministry of Gender, Children and Social Protection 2015). Global evidence also suggests that lack of practical scientific equipment in schools and few opportunities for 'hands on' work can negatively impact on girls' achievement in science (UNESCO, 2017). In Ghana there is recognition that at all levels up to and including tertiary education there is a lack of access to practical activities in the sciences, with an urgent need for well-equipped modern science laboratories (MoE 2018)

OpenSTEM Africa

OpenSTEM Africa is a new collaboration begun in Ghana as a partnership between The Centre for National Distance Learning and Open Schooling (CENDLOS) and the Open University UK, under the guidance of the Ministry of Education, and a collaboration which it is hoped can be augmented with other collaborations in countries across Africa to address the constraints facing science education. OpenSTEM Africa is conceptualised as a framework for improving science education in Africa, with the aim of supporting the next generation of African scientists, especially women and girls. At the heart of this framework is the co-development of locally appropriate and gender-sensitive teaching and learning materials, including females as role models where possible, and a school leadership programme that will support the sustainability of improved science education.

- At upper secondary level it is designed to address the lack of practical science activities via access to OpenSTEM Africa (OSA) engagements through which teachers and students can work with curriculum-relevant onscreen science experiments and simulations using real data.
- It is designed to develop Open Education Resources (OERs) to support teachers with the appropriate pedagogy to improve the quality of their science teaching, including developing their skills in teaching practical science, using the onscreen experiments in their lessons.
- It is designed to address constraints in teachers' knowledge of both the subject and the appropriate pedagogy to teach it by co-developing and embedding locally appropriate and freely available in-service professional development Open Educational Resources (OERs). This includes teacher capacity and confidence to lead on technology-based learning.
- It is also designed to support school leaders, in particular subject leaders such as heads of science and ICT to lead the long-term development of their staff, in order to identify and respond to the key challenges to improve science education in schools.

The Open University has been awarded three years' funding from OPITO to pilot OpenSTEM Africa in Ghana, working with CENDLOS to develop work already begun in this area and to trial and test new initiatives. The overall objective, assuming Ministry of Education affirmation, is for scale-up to national level.

The Open University UK

The Open University (OU) UK is a distance learning tertiary level institution which during its 50 years of existence has developed technology-based learning in its remit to meet the needs of its students. Across those 50 years it has pioneered distance learning in tertiary-level science subjects in ways which were previously not thought to be possible, e.g. by supplying home-based students with practical science equipment to carry out their own experiments; by pioneering the use of DVD demonstrations of laboratory experiments, and more recently by developing interactive onscreen science engagement for students through its OpenScience Laboratory (OSL) https://learn5.open.ac.uk/course/view.php?id=2

The OSL allows access to interactive practical science activities to students anywhere in the world at any time that the internet is available, and OSL features investigations based on on-screen instruments, remote access experiments and virtual scenarios using real data.

The OU has also long-standing expertise in approaches to school-level education through the qualifications in education it offers both at undergraduate and postgraduate level aimed at all those working with school-age children and young people. Further, it has a long history of working in teacher education, including its own distance learning PGCE and Masters in Education qualifications. These are augmented by collaboration with teacher education institutions and the co-creation of digital and print-based open-access materials across Africa and Asia, through programmes such as the Teacher Education in sub-Sahara Africa programme (TESSA) http://www.tessafrica.net and its sister programme TESS-India www.tess-india.edu.in as well as its work in developing the use of technology in learning in programmes such as English in Action (EIA) in Bangladesh http://www.eiabd.com/

CENDLOS, Ghana

CENDLOS is a Government of Ghana Ministry of Education agency, constituted in 2012 with support from the Commonwealth of Learning to develop alternative approaches to pre-tertiary education in order to increase access to learning and to make learning more relevant for young people. It champions alternative approaches, and in particular technology-based learning. Since 2016, it has been introducing technology-based approaches to SHS teaching and learning through a Ghanaian-developed system known as the iBox as part of a wide-ranging Government of Ghana Secondary Education Improvement Project (SEIP) to support what the government describes as 'low-performing' schools in 'underserved districts'. So far 148 SHS are benefiting from the project in districts across Ghana.

The iBox device acts as a local file server. It contains a quad core processor and the current versions have 2 terabytes of local storage. The iBox is installed into the ICT laboratory in each school as a heavy-duty box fixed inside a custom-made cage on a wall as shown in Figure 1.

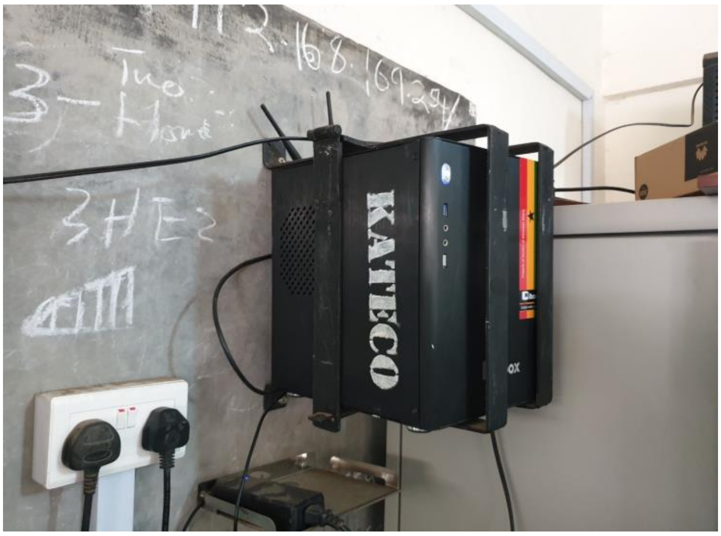

Figure 1. An iBox *in situ* in a Senior High School in Accra, Ghana.

The iBox does not rely on access to the internet to function. It can accommodate up to 100 hard-wired or wi-fi enabled users at a time, though the reach depends to a certain extent on precisely where it is located and the configuration of rooms around it. Its advantages are that a school needs only laptops, desktops, tablets or smartphones to access the content, obviating the need for an expensive or unreliable connection to the internet. The iBox as a local server gives complete control over content and it is only the materials created and installed under the direction of CENDLOS which are loaded. This does mean that adding and updating materials involves physical access to the machine. So far, this is being carried out on an annual basis. CENDLOS is also developing web-based access to iBox content via iCampus https://icampusgh.com/contact.html . However this would entail access to the internet for users and is not yet functional. Access to the materials whether located on the iBox or on the iCampus website is restricted and necessitates log in credentials.

Content for the iBox: the work of CENDLOS

In terms of creating content for the iBox and iCampus CENDLOS has been working since 2016 to develop materials in the core SHS subjects of mathematics, english language, integrated science and social studies. It has also begun to develop materials in the elective sciences (e.g. agriculture, physics, chemistry, biology), in all cases drawing on the expertise of curriculum developers, SHS subject leaders and university academics to create curriculum-relevant SHS science lessons. The lessons are primarily aimed at the students, though the lesson notes at the beginning are equally appropriate for the teacher.

CENDLOS has developed a lesson template for each hour-length lesson it creates for the iBox, which follows a format of

- Lesson notes
- Lesson video (about 30 minutes in length)
- An interactive activity
- A moodle quiz

In other words, CENDLOS has a tried and tested format for its content and a high level of expertise in matching content to curriculum needs. For every SHS subject for which it is creating digital content (for example the core subject of integrated science) it has constituted a team of up to 6 curriculum experts who work to develop content across 50 lessons. CENDLOS has an in-house technical team which has addressed all aspects of developing the digital materials already created. CENDLOS has also engaged with training head teachers and teachers in the use of these iBox materials, using a cascade model. And as previously indicated CENDLOS engages with the practicalities of installing the iBoxes in the SEIP schools and in maintaining them.

Nevertheless CENDLOS and the OU are pleased to be collaborating to further develop this work, in order to address the following challenges and develop the following opportunities

Challenges

The greatest challenge faced by CENDLOS at this moment is the limited take up of the iBox materials. In other words in schools where there is an iBox with materials available to support learning and teaching, then students and teachers are not using them to the extent which was envisaged. This was identified in an informal report by the World Bank, which noted,

> The iBoxes deliver pre-prepared video lessons, student exercises and content assessment to SHS students and teachers. However, the independent verification indicates that the technology is not being adequately used by students and teachers in many schools that still lack the infrastructure (computer labs) to access the content. The current policy prohibiting cell phones and/or tablets further prevents students from accessing the iCampus on their personal devices. (World Bank 2017 p,3)

We believe in fact that there are several potential reasons why this low take-up could be occurring, including those stated above:

- A need to for easier/more extended access to an ICT lab.
- Government/school/parental concerns over the use of mobile phones to access ICT-based teaching and learning.
- Students needing to develop skills and confidence in accessing technology-based learning.
- Science teachers needing to develop skills and confidence in accessing technology-based learning.
- Science teachers/science subject leaders/head teachers needing long-term school-based professional development to widen their range of support for science pedagogies.
- Some development of the iBox materials needed to make them more interactive, more attractive and more relevant to students and teachers, especially girls.

The collaboration we have begun aims to address as many of these challenges as we can, all of which have been signalled in our joint discussions, and in meetings with the Ministry of Education, the World Bank and with head teachers and staff in the SHS we have already started working with. We have already visited schools and discussed with staff the difficulty of not having a science laboratory; we have visited schools where there is a science laboratory but staff have pointed to the lack of relevant equipment or the expense of chemicals, factors which result in restricted opportunities for hands-on student engagement or teacher demonstration. Teachers in schools with iBoxes already installed have identified as a cause of concern situations where the ICT lab is wholly scheduled for use for ICT lessons and so there are challenges in making it available for teaching other subjects. There are inevitable pressures on secondary school teachers to prepare students for the SHS school leaving/tertiary education entrance examinations, the West Africa Senior School Certificate Examinations (WASSCE) and in discussion there is perceived reluctance to take on the development of new skills even if they could improve learning outcomes. An outreach team from the University of Ghana which visits schools in underserved districts each year (e.g. in the northern region) to encourage application to study sciences at tertiary level reported that schools they visited had had no previous experience of using a microscope and when the outreach team set one up, there were queues to try it out.

Opportunities

The joint objective of CENDLOS and the OU to extend the work of CENDLOS with the iBox and iCampus presents us with some exciting opportunities.

Reciprocal capacity building

We plan reciprocal visits, with CENDLOS staff travelling to the UK to work with OU staff at Milton Keynes, and vice versa for OU staff working at CENDLOS in Accra. Knowledge Exchange that brings together IT programmers from CENDLOS with the OU team responsible for the OpenScience Laboratory (STEM/KMI) will focus on developing new and contextually appropriate practices and this will benefit staff from both institutions.

Creation of digital materials

Our partnership has a strong focus on the co-design and the co-creation of materials and resources and on developing programmes which will be led by Ghanaian experts. The courses and resources we develop will be designed as digital OERs that will be freely available to all participants in Ghana. The OU's move to a 'mobile first' design for apps could be of especial benefit to teachers and school leaders in Ghana as the phone is the technology of choice, and smart phones are widely used even in the less well-resourced regions of Ghana.

On-screen interactive engagements

Our co-creation of onscreen interactive engagements will support the teaching of the practical components of the SHS elective sciences: chemistry, biology and physics. These engagements are planned to include:

- laboratory instrumentation (e.g. a digital microscope)
- virtual objects (e.g. rare hominid skulls that can be manipulated in 3D space)
- fully immersive laboratory experiences (e.g. a flame test)

Some of these planned engagements are amenable to multiple uses over the three years of SHS study. For example, in biology, a digital microscope can be used to study single-celled organisms in Year 1, the structure of plants in Year 2 and complex mammalian tissues in Year 3. The digital microscope not only recapitulates all the practical elements of a physical microscope (Figure 2), such as coarse/fine focussing, illumination control, magnification objectives, measuring graticule and stage manipulation, but because it is fully interactive, students are able to navigate to areas of interest and access explanatory text The fact that both students and teachers can regularly revisit key virtual instruments such as a digital microscope, will help to build both confidence and familiarity in the use of onscreen tools to enhance the learning and teaching of practical science.

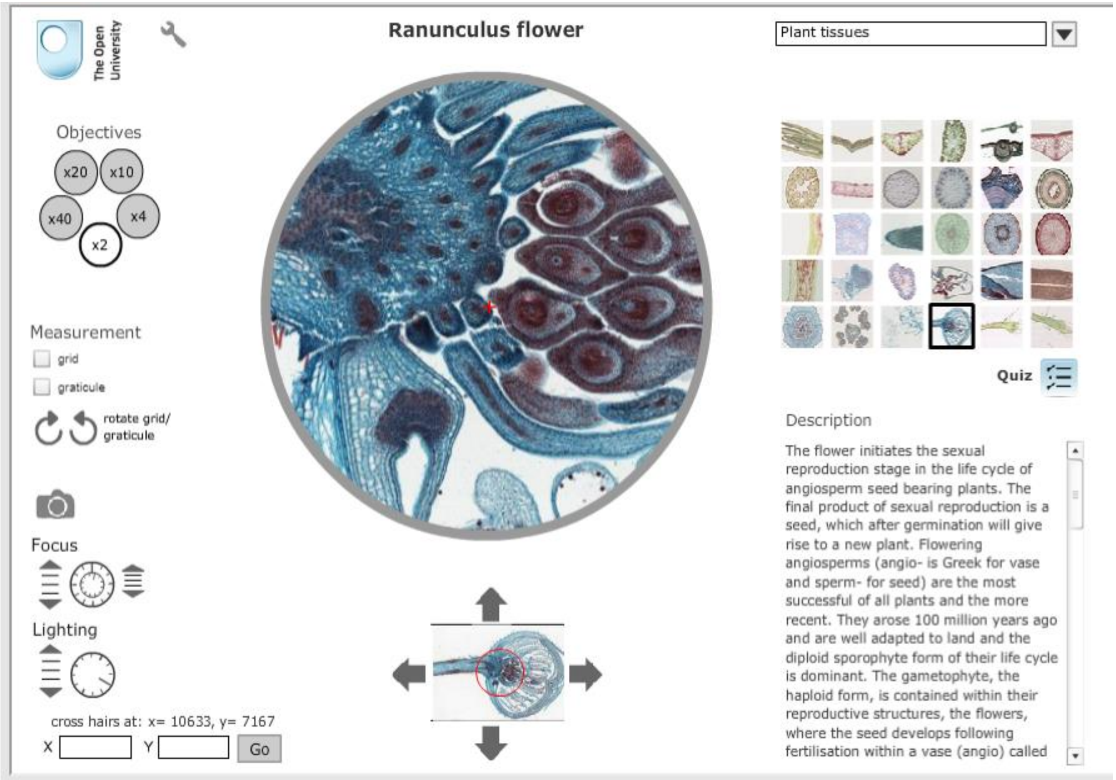

Figure 2. A screenshot showing the interface used to access the digital content of the Open University Open Science Laboratory digital microscope.

Research, monitoring and evaluation (RME): addressing the challenges

The outlining above of the challenges to developing ICT-based science learning and teaching has clear roots in the concerns raised by the MoE in its *Education Strategic Plan* 2018-2030 over the current infrastructure and resourcing of science subjects in SHS schools. As such the MoE provides a set of guidelines for evaluating change and improvement. At a finer level of detail CENDLOS itself, since development of the iBox began, has been gathering analytical data on the use of the iBox in each school and compiles evaluation data on its own training. Our RME will draw on that data.

Nevertheless for our joint work, CENDLOS and the OU are also interested in gathering data at a finer level of detail to elicit teachers' and students' lived experiences of science teaching and learning, as well as the school-level factors which affect change. This RME will include both quantitative and qualitative approaches and focuses on 'rapid analysis' research with small clusters of schools which have the iBox installed as our sample groups.

A rapid analysis (RA) is an intensive inquiry involving collaborative and iterative planning, data-generation, analysis and triangulation to quickly develop or quickly refine an understanding of a situation from multiple perspectives.

The RA intended is to develop knowledge and understanding in relation to five key areas:

1. The realities of school contexts, including the current practices, attitudes and spaces (physical and social and in terms of time) relevant to science learning and teaching
2. Teachers', subject leaders' and school heads' understandings of science learning and teaching and their understandings of what are the challenges for all their students, especially girls.
3. What schools and teachers are already doing to support the development of science learning and teaching and to understand what else could be done to support this learning.

4. The practices, attitudes and spaces (physical and social and in terms of time) in which teachers do or could engage in professional development activities.
5. How change happens in schools.

The study at school level would include observation of lessons, interview with school heads and science subject leaders, interview with teachers, focus groups with students (e.g. girl students), collaboratively drawn maps of schools and classrooms (e.g. to include science/ICT labs and science classrooms), photographs of schools, classrooms, resources and students' work. Rapid analysis lends itself both setting a baseline and a fine-grained monitoring and evaluation tool. Given the complexity of challenges around introducing and embedding the changes envisaged it seems appropriate to focus on such a fine-grained approach.

Conclusions

ICT-based science teaching and learning is not without its challenges, as both the OU and CENDLOS are well aware, but such an approach can address the needs of both learners and teachers to create relevant and engaging learning which is accessible and practicable. We look forward beginning the work of co-creation and to continuing our collaboration over a number of years.

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