CONTINUOUS PROFESSIONAL DEVELOPMENT
(CPD) FOR SCIENCE TEACHERS

OpenSTEM Africa

SUPPORTING 21ST CENTURY SKILLS AND VALUES

Acknowledgements

Ministry of Education

The Ministry of Education, Ghana, for their oversight, support and guidance which has been essential in ensuring that OpenSTEM Africa aligns with and complements other education initiatives and programmes.

CENDLOS
CENTRE FOR NATIONAL DISTANCE LEARNING AND OPEN SCHOOLING
Nexus of virtual learning

CENDLOS, Ghana, for their collaboration and innovation in providing essential avenues for OpenSTEM Africa to reach learners and teachers.

Ghana Education Service (GES)

Ghana Education Service, and the expert SHS science teachers, for their expertise in producing materials that are rooted in the Ghanaian school context, accessible and useful to learners and teachers.

OpenSTEM Africa

For information on OpenSTEM Africa see: www.open.ac.uk/ido

OPITO

OPITO for their generous support, which has made OpenSTEM Africa and the development of the Virtual Laboratory and these materials possible.

Contents

OpenSTEM Africa: Ghana

The overarching aim of OpenSTEM Africa, Ghana, is to make a contribution to Government of Ghana/Ministry of Education policy to the effective teaching of practical science.

Effected by:

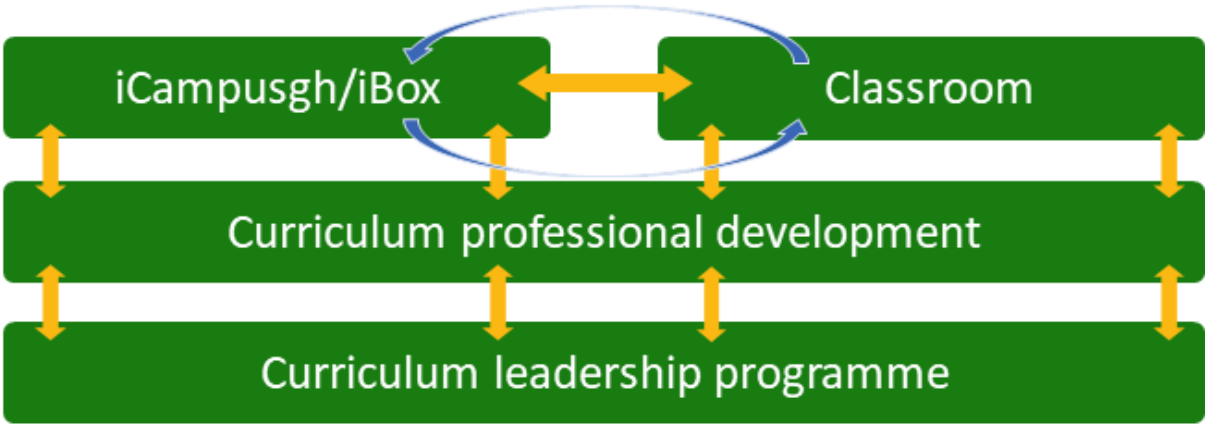
1. **Virtual Lab:** onscreen interactive science instruments using real data and with examples of science lessons, to improve the experiential teaching and learning of science in Senior High Schools, helping develop girls' and boys' practical science study skills, and building on the iCampusgh/iBox model developed by CENDLOS.

Underpinned by:

2. **Continuous Professional Development (CPD) for science teachers:** which develops confidence, skills and strategies to enable improved teaching and learning in the sciences, with a particular focus on ICT-based practical sciences, and which supports them in meeting the aspirations of the SHS elective science curriculum (Physics, Chemistry and Biology).

Embedded in Senior High Schools through:

3. **Curriculum Leadership Programme:** for Heads of Department/Heads of Subject, which enables them to effectively implement short- and long-term strategies to improve teaching and learning in the sciences, with a particular focus on ICT based practical science in their school.



The school-based professional development and leadership programmes will help more teachers use ICT-based science resources more and more effectively, with more learners. The support for school leaders' facilitates the development of a sustainable community of practice in science within the school, led by the Head of Department/Subject Lead and with the support of the Headmaster/Headmistress, in line with National Teaching Council Guidelines.

CPD programme for SHS science teachers

This CPD programme for SHS science teachers is designed by experienced Senior High School science teachers working with Heads of Science and SHS curriculum and Science Resource Centre developers, representing a wide range of Senior High Schools in Ghana. They are working with representatives from the Ministry of Education, CENDLOS, GES, the University of Ghana and from The Open University (UK) on OpenSTEM Africa: Ghana.

Improving teaching and learning in the sciences at SHS level is part of the Government of Ghana's *Education Strategic Plan (2018–30)* to enable increasing numbers of SHS students to specialise in the sciences at tertiary level and then move into STEM careers. Government of Ghana policy points to the importance of in-service training for teachers for acquiring new skills and keeping abreast of new developments. The National Teacher Standards for Ghana (MoE/NTC) set out the importance of teachers continuing to learn as they teach and the importance of the school as the location of that learning. Ghanaian research suggests that continuous professional development (CPD) taking place within the school is more motivating, more coherent, more sustainable and likely to be more effective in the long term This is the "growth approach in which teachers are given the opportunity to try new opinions, gain new perspectives, and extend their professional capabilities in order to understand and find solutions to problems in their individual schools" (Asare et al., 2012).

SHS science teachers, particularly those specialising in the elective sciences are already experts in their field. This programme is to enable them to work directly with their Head of Science, or Heads of Physics/Biology/Chemistry alongside their departmental colleagues to further develop the expertise of the whole department in teaching SHS sciences, with a particular focus on ICT-based teaching and learning and to help build a community of practice among science teachers in the school.

Supporting 21st century skills and values

Introduction

The 21st Century is going to be characterised across Africa by fast rates of change. The population of sub-Saharan Africa is predicted to grow significantly throughout the 21st century, with most recent predictions that the population could triple or quadruple by 2100, from approximately 1.07 billion to somewhere between 3 billion and 4.5 billion (UN 2019). This means that life is bound to change. There are going to be rapid advances in technology: environmental change and demographic change. Ways of working with technology are increasingly impacting on all aspects of life and mean that we are preparing students for a world of adult life, citizenship and employment which could be very different from the world of their parents and grandparents. The impact of environmental change is not yet fully understood but will also certainly mean that they will be more unexpected events, which will require new responses.

"The AU Agenda 2063 recognizes Science, Technology and Innovation (STI) as multi-functional tools and an enabler for achieving continental development goals. The Agenda, further, emphasizes that Africa's sustained growth, competitiveness and economic transformation requires sustained investment in new technologies and continuous innovation in areas such as agriculture, clean energy, education and health"

(African Union, 2014)

Ghana is a country rich in natural resources and with an improving economy. The progress of young people into tertiary education – developing expertise in science, technology, engineering and mathematics (STEM) studied at university – or for some students, the skills developed through tertiary-level technology, vocational, education and training (TVET) are considered core to the economic future of the country (MoE 2018).

By the end of this unit you will:

- better appreciate the importance of developing students' enthusiasm for science, technology and innovation, and their sense of what will be important to their own lives in terms of values and skills
- understand better the strategies at the core of the SHS syllabus for your science subject and be more confident in using them for your own teaching
- have made links between the ideas in this unit and some of the other OpenSTEM Africa CPD units, particularly the units on *Linking Science to everyday life*, *Collaborative learning* and *Using ICT to support learning*
- have continued to develop your skills in using ICT in teaching and learning, via the final section of this unit.

The CPD units can be found at: https://www.open.edu/openlearncreate/CPD_units

What are 21st century skills and values?

Given the context set out in the introduction, what skills and values do young people need to develop in order to lead full and productive lives in the 21st Century? A group of SHS expert teachers working together in Accra identified the following, focusing on both necessary skills and on the issues these skills would be needed to address.

Personal skills:

- perseverance (survival skills)
- resilience (survival skills)
- confidence
- creativity and resourcefulness
- multitasking
- security awareness

Academic skills:

- problem solving
- manipulating information
- creativity.

Social skills:

- communication
- teamwork
- leadership
- staying safe.

21st century skills for students:

- using ICT (the teacher also needs ICT skills to support the students)
- being assertive/confident
- creative
- problem solving (links to analytical stills)
- manipulating information
- agricultural skills
- multitasking
- communication skills (links to confidence and agency and sense of security)
- networking
- teamwork
- analytical skills (links to problem solving)
- predicting/anticipating.

Values:

- environmental consciousness/awareness
- entrepreneurship
- valuing the contribution of all
- valuing self-esteem
- adaptability.

Environmental awareness:

- biology – pollution, industry, renewable energy
- environmental chemistry
- chemistry and industry biogas renewability
- climate change
- nuclear physics/nuclear power
- species under threat (e.g., frogs, Ghanaian flora threatened by non-native plants).

Issues in Ghana:

- air pollution in cities
- illegal diversion of running water, polluting rivers 'galamsey', pollution in water bodies
- plastic waste.

Activity 1: Identifying 21st century skills and values

Working as a departmental group, under the guidance of your HoD/HoS, critically review the suggestions above and add any other skills or values that you would add, based on your own experiences within the context of your own school.

From the lists above, pick out five skills or values that you think are priorities for your students in your school or which are local to where your students live.

21st century skills in the elective science syllabuses

The Introduction to the SHS science syllabuses emphasises a number of skills and values that the syllabuses aim to develop.

Biology

- Develop scientific approach to solving personal and societal (environmental, economic and health) problems.
- Recognise the value of biology to society and use it responsibly.
- Develop a sense of curiosity, creativity and a critical mind.

Chemistry

- Create awareness that chemical reactions and their applications have significant implications for society and the environment.
- Develop the ability to relate chemistry in school, to the chemistry in modern and traditional industries, or real-world situations
- Use facts, patterns, concepts and principles to solve personal, social and environmental problems.

Physics

- Develop in students desirable attitudes and values such as precision, honesty, objectivity, accuracy, perseverance, flexibility, curiosity and creativity.
- Enable the Ghanaian society function effectively in a scientific and technological era, where many utilities require basic physics knowledge, skills and appropriate attitudes for operations.

Key themes which emerge from these are problem-solving, creativity and critical thinking skills, alongside person skills such as curiosity, honesty and perseverance. These are framed in the context of environmental and technological changes and highlight the relevance of science in understanding the social and economic world.

Developing 21st century skills in Science lessons

Activity 2: Focus on your own learning

As a graduate and a professional you will have developed your own 21st century skills.

Within your department, under the guidance of your HoD/HoS and if possible, in a cross sub-subject group, first reflect as individuals on how and when you have developed skills in problem solving, critical thinking and being creative.

When did you develop those skills?
Where?
Individually or collectively?
When studying by yourself or with friends?
In professional teams?
With guidance?

Brainstorm your ideas as a team on a large piece of paper or a whiteboard or chalkboard.

Finally, as a group, highlight any of the opportunities that you have collectively agreed that could be translated into classroom practice. There will be chance to develop these ideas in the rest of this unit.

In order to understand how these skills might be developed, it is helpful to consider the science topics covered in the syllabus and the pedagogical approaches that could maximise learning opportunities to develop these values. But first, focus on your own learning.

Focusing on subject matter

Sometimes the syllabus content provides opportunities for students to engage directly with relevant issues. For example:

Chemistry

The section in SHS3 on 'Chemistry, Industry and Environment', and particularly Unit 4 on 'Environmental Pollution' provides opportunities to raise awareness of environmental issues and how science can both cause problems and contribute to solutions. Information can be presented in creative ways and debates and discussions used to highlight controversial issues where economic benefits and the wider needs of society might clash.

Physics

In Mechanics (Section 2) particularly in SHS 2, students have to know about renewable forms of energy. This provides opportunities to critically review the alternatives in different local contexts and hence develop thinking kills and an awareness of the impact of technology on local communities. Students can be encouraged to present information in creative ways and work in groups to gather information from a variety of sources.

Biology

Section 3 'Humans and their Environment' in SHS2 has a unit (Unit 4) on Health and Hygiene. This provides general opportunities to debate the importance of personal and community hygiene, sanitation, immunisation and vaccination. It also gives the opportunity for students to engage with some of the current debates taking place during the COVID-19 pandemic, and to critically review the arguments, for example, for and against wearing masks; how to communicate information about effective infection control; and in the event of shortages of equipment, who should benefit?

Reflection point

Can you think of any more topics in your specialist subject that relate directly to wider issues which will impact on students' lives?

The way science is taught also provides opportunities for students to develop a wide range of skills and values that will be relevant in their everyday lives as they move into adulthood. For example, in the introduction to the SHS elective science syllabuses, the explanation in column 4 for the Teaching and Learning activities is:

"The major purpose of teaching and learning is to make students able to apply their knowledge in dealing with issues both in and out of school. A suggestion that will help your students acquire the habit of analytical thinking and the general capacity for problem solving is to begin each lesson with a practical problem. Select a practical problem for each lesson. The selection must be made such that students can use knowledge gained in the previous lesson and other types of information not specifically taught in class. At the beginning of a lesson, state the problem, or write the problem on the board. Let students analyse the problem, suggest solutions, etc., criticise solutions offered, justify solutions and evaluate the worth of possible solutions. The learning of any skill considered important must start early."

(Adapted from the introduction to the Biology, Chemistry and Physics SHS syllabuses)

Classroom example 1

Mrs Adu teaches Chemistry to SHS3 students and they are studying the unit on Environmental Pollution (SHS3 Section 1, Unit 4). Mrs Adu knows that the chemical industry contributes significantly to Ghana's economy – for example with the oil industry, mining, soap or salt making, and brewing etc. Several of the class are interested in careers in the chemical industry and Mrs Adu knows that it is important that she encourages them, while reminding all of the class of the general concerns about the pollution caused by various types of industrial process.

She decides to work with the class to consider aspects of environmental pollution which are important in or around the location of the school. For example bauxite mining is a key industry in the region and while the community benefits from the employment opportunities this offers, they are aware that issues such as deforestation, wastewater disposal and soil contamination have led to health issues in local population.

She specifies the task to the class – to work in groups to make a presentation which sets out a specific environmental issue and then suggests realistic solutions, including chemical solutions to the issue.

She brainstorms with her class on what the key environmental issues in their locality are. There are some general ones such as air pollution in the urban areas, plastic waste, and sanitation, and then there are some which are specific to industries which have factories and plants in their area.

She then leads a class discussion to three to five judging criteria. One agreement is that the presentations should be short three-minute presentations using no more than three pieces of paper or three PowerPoint slides. This is to ensure that the presentations do not take up too much class time and that each presentation is powerful and to the point. Each group in the class also divides up their tasks so that each member of the group can work on their presentation for homework. The presentations and the judging take place within one lesson.

Classroom example 2

Mr Boampong teaches Biology SHS3 in a Senior High School in a rural area. When studying Section 3 Biology and Industry, he uses the same kind of approach as Mrs Adu does with her chemistry class. He divides his class into groups of four or five and asks each group to consider a different question which is important to the agriculture of the area. The basic format of the question is:

"Explain the biological principles by which XXXXXXX can respectively increase the productivity of crops".

XXXXXXXX could be fertiliser, pesticide, selective breeding, irrigation or reduction in water contamination etc.

He asks each group to prepare a three-minute presentation on their topic.

Classroom example 3

Mrs Ackom is teaching Physic SHS2. She decides to set her class research tasks in which groups have to research the uses in real life of the photoelectric effect, electromagnetism, lasers, and cathode rays across several weeks.

Using the same kinds of approach as Mrs Adu with her chemistry class and Mr Boampong with his Biology class, she divides her class into groups and gives each group a timeframe of three weeks to devise a three-minute presentation based on their collective group research.

In this way, she knows her students are making connections between their SHS study and life outside the classroom, and hopefully are also considering the relevance of physics to their own careers and future interests. The three-minute presentations are not too disruptive of class time and ensure that the class keeps up with the pressure of completing the syllabus for the year.

Activity 3: Analysing teaching

Working with your HoD/HoS as a subject group, read the extract from the syllabus (explanation of column 4) and the classroom examples above.

- In what ways do Mrs Adu's, Mr Boampong's and Mrs Ackom's lessons reflect the objectives of the syllabus?
- Go back to the skills you identified in Activity 1 and highlight any skills that students are able to develop and practise during Mrs Adu's, Mr Boampong's or Mrs Ackom's lessons.
- Choose a topic that you will be teaching in the next few weeks and work together with your HoD/HoS to devise a lesson which uses approaches that will support students in developing some of the skills that you identified in Activity 1.

Supporting 21st century skills and values

The following table was compiled by a group of Secondary Science teachers as they reflected on how to teach 21st century skills in Ghana. Keep this list in your staff room and add to it as you try different activities in your classroom.

Skill	How to teach this in the Ghanaian context
Perseverance	Provide encouragement such as clapping for the student **Rewards:** provide thoughtful feedback on students' work in which you encourage them and show them what they need to do to improve.
Resilience	Set realistic, challenging, but attainable goals Link challenges to rewards
Confidence	Provide opportunities to show what they can do: - Ask them to give presentations - Encourage them to take on roles in class - Have them create posters or models that can be displayed Feedback/comments in laboratory notebooks: - Ask questions - Frame comments carefully
Creativity	Make a poem or rap or mnemonic to remember an order: - Classification in biology (nine categories; students find it difficult to remember all of them) - Reactivity of metals (e.g., people say cows make a zippy invigorating liquid having carefully munched some grass)

	- Five kingdoms in living world: prokaryote, protoctista, fungi, plantae, animalia) - The order of the planets (e.g., in English the phrase: “My very eyes may just see under nine (planets)” helps students to remember their order) Drawing pictures to illustrate scientific ideas Making a model of a plant, animal, nerves, cell, electric circuit, solid, liquid and gas. Make up a story: - WASSCE biology: “describe what happens to yams and beans, imagine you are a piece of yam, imagine you are a bean…” or different things - Adaptation stories about being something: a bee visiting a flower - “Pretend you are an insect/animal and write about survival skills” - “Pretend you are a tapeworm in the gut of a human” (thick covering, flattened, able to move, reproduce, produce toxins…)
Think of alternative explanations	Physics: transfer energy to ice, but the temperature does not go up Adrenaline: bring something scary (for example locusts/model of snake) groups of children screaming, eyes dilated, extra energy, heart rate
Academic skills / thinking skills	For example, to illustrate heat transfer: Conduction: pass item from one to the other Convection: stand up and walk with it Radiation: throw it Get students to explain the analogy
Creativity / resourcefulness	Withhold information - Find equipment for an experiment - Work out how to solve a problem Set competitions with simple incentives - Give a time limit/time taken - Precision Give simple topics for them to work on a presentation or to make posters which can be displayed and peer-assessed.
Multitasking	Set open ended tasks Following practical instructions - Qualitative analysis - Food tests - Calorimetry experiments

	- Cooling curves Helping with setup of experiment
Teamwork	Group work - Doing experiments collectively, giving roles, working as a team, helping each other - Giving questions, stronger students teaching others Using seating plans to make sure student support each other
Communication	Opportunities to present Ask open ended questions which require longer answers or an explanation Write for different audiences
Leadership	Opportunities for students to take responsibility - Work as lab technicians - Undertake project work
Staying safe	Group work – encouraging people to look after each other Role modelling – teacher wears lab coat, safety glasses, gloves
Safety awareness	Awareness of others/be observant - Diabetes - Asthmatic pupils suffer in dust strong perfumes - Individual needs of students Importance of linking up with families to find information about students which may affect their ability to engage with science for example, allergies to particular animals or chemicals.
Thinking skills	Sequencing Adaptation Making models - Explaining how they work - Critically reviewing their authenticity - Working out how they can be improved

Using ICT to transform learning

National Teachers' Standards for Ghana

Examples of the Standards in action

All teachers have good technological pedagogical knowledge, knowing how to incorporate ICT into their practice to support learning.

(National Teachers' Standards, 2017)

Classroom example 4

Mrs. Adu was teaching redox titrations to a group of SHS2 Chemistry students. Previously, they had studied acid-base titrations so they were familiar with the principles of titration experiments, but not the details of those involving potassium permanganate.

She started the lesson by writing out the practical steps for an acid-base titration in the wrong order. She asked students to work individually to put the steps in the right order and then agree with a partner the right order.

Once the correct order was agreed, Mrs Adu asked the students to work in pairs go through the method and write down a reason for each step. For example, washing the pipette with water followed by the reagent that is being used in the experiment ensures that no dilution occurs from residual water droplets. This is important as titration is a very precise technique.

She then gathered her students at the front of the class and demonstrated the reaction between potassium permanganate and hydrogen peroxide. She had practised in advance. As she added the purple potassium permanganate to the colourless hydrogen peroxide, it lost its colour. She kept on adding until the solution remained pink, indicating that all of the hydrogen peroxide was used up.

She then asked the class to work in pairs to devise a set of experimental instructions for a titration experiment to measure the concentration of a solution of hydrogen peroxide. She explained that hydrogen peroxide can be used as chlorine-free bleach in environmentally-friendly cleaning products and to dye hair, but that in strong concentrations it is corrosive.

In the next lesson, the students used the OpenSTEM Africa Virtual Laboratory to try out their method. The advantage of this over doing it in the laboratory is that the students were able to try out the experiment for themselves. Also if students made a mistake, it did not matter as no chemicals were wasted and there were no risks to the students. They could discover the mistakes for themselves during the experiment.

Did you notice…

- The sequencing exercise involves thinking skills
- Students practise their analytical skills by explaining the reason for each practical step.
- By understanding the reason for each step, students were more likely to be able to apply their knowledge to a new situation
- Mrs Adu allowed students to devise their own experiment, but she ensured that they

had the necessary background knowledge, by first revising the titration method in a creative way and secondly by demonstrating the colour change

By using the OpenSTEM Africa Virtual Laboratory, students could try and correct their own methods. This involves more in-depth thinking and would not have been possible in a practical situation where resources might be limited

Lesson planning using ICT

Activities 4, 5 and 6 will help you to think about the effective use of technology and how to make it transformational. Information and communication technology (ICT) provides a great opportunity to make lessons and learning more interactive, and at the same time help students engage in 21st century skills that are relevant for their studies and future professional lives. Selecting and integrating a range of ICT in your lesson requires careful consideration and thought.

Activity 4: Using ICT to transform learning

Think of a science topic that you will be teaching next week.

Imagine that you and your students could have access to any technology that you wished.

- How could you use the technology to support how you would normally teach this topic?
- How could you use technology to achieve the same learning but in different ways?
- How could you use technology to provide learning opportunities that would otherwise not be available?

As a subject or departmental group and under the guidance and support of your Head of Department, collect all your ideas for the points above on to a flip-chart and keep it as a resource to support future planning or to inform the individual coaching sessions you will be having with your HoD.

OpenSTEM Africa Virtual Lab Applications

Practical science

The practical science applications such as the virtual microscope being introduced by OpenSTEM Africa are designed to help you to teach your students practical science in the absence of other reliable equipment.

With each instrument there is an example lesson plan, demonstrating how it might be used to support science learning.

The instruments could be used to:

- introduce a topic
- deliver the main content of a lesson
- consolidate key concepts and ideas
- teach practical skills
- help students solve problems you have posed
- encourage critical thinking
- relate science to everyday life.

Working with your Head of Department, take a look at the virtual microscope and the lesson plan. Consider:

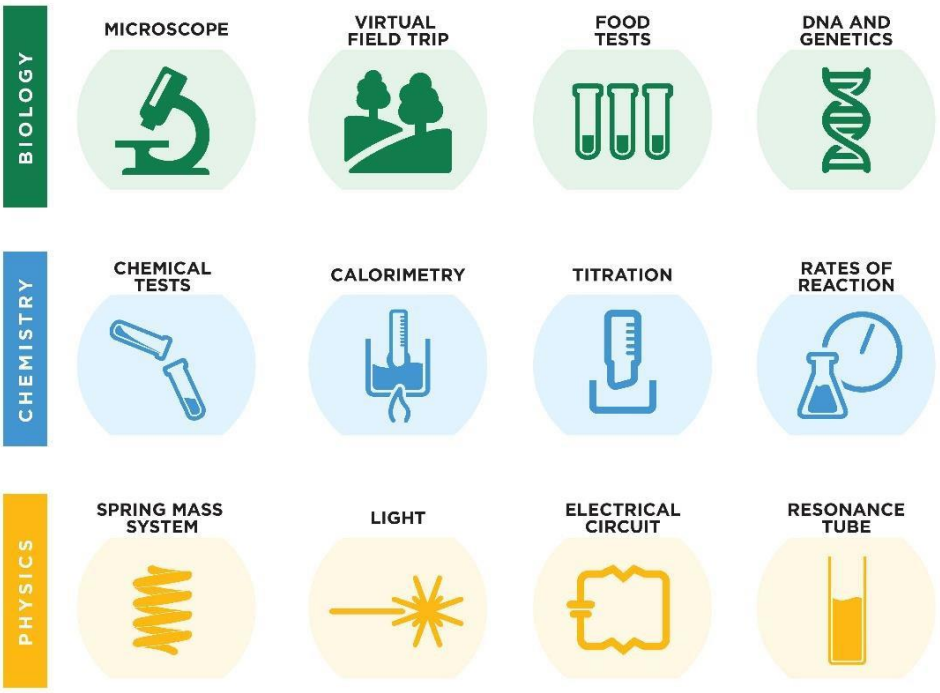
- what practical skills the students will learn
- how the application is being used
- alternative ways in which the application could be used.

As more instruments become available, work with your Head of Department and colleagues to develop more example lesson plans.

Activity 5: Planning to use the Science apps

Work with your HoD to plan activities across the whole department for using the Science apps. For example, you might work with a colleague to choose one of the apps to investigate, work through the exemplar lesson and discuss how it would work best in your school with your students.

OpenSTEM Africa Virtual Laboratory



The OpenSTEM Science apps in the Virtual Lab have been developed collaboratively by CENDLOS, GES and a group of SHS teachers in Ghana and The Open University (UK). They cover a range of experiments highlighted in the SHS elective science syllabuses.

Students can interact with the experiment individually at home if the internet is available, or at school if sufficient computers are available. They might benefit more from the experience if they work in twos or threes, so they can discuss the issues and work together to solve problems.

With each Science application there is at least one possible exemplar lesson. These are intended to highlight the possibilities for teaching a lesson rather than anything prescriptive. It is expected that at first you might follow the example as suggested, but you could move towards developing your own plans as you become more familiar with the apps. They have all been designed to be relevant at various points in the syllabus, or over a few weeks of work, so that there is extended opportunity for students to interact with the materials.

Lesson planning using iCampusgh/iBox

Activity 6 will help you to think about the effective use of technology and how to make it transformational.

Activity 6: Examples of using the iBox and iCampusgh

Teachers in Ghana are using the iBox and iCampusgh, which have been developed by CENDLOS, in a number of ways:

1. **Catch up** – students who have missed lessons are able to access the material at home or in the ICT lab and go through what they have missed.
2. Using the **video** lesson interactively – the teacher plays the video lesson to the class but stops the video periodically to ask questions or to set up a short discussion between the students about one of the issues raised.
3. **Flipping** – students work though the lesson on iCampusgh at home in advance of the classroom lesson. The teacher then organises a series of activities in groups or pairs designed to probe students' understanding. Through careful questioning, peer-support groups can be established and the teacher can focus on those who need the most help.
4. **Note-taking** – the teacher displays the notes and students work in pairs or groups to convert the notes into alternative formats such as poster, a mind- map or a concept map. While they work the teacher walks around asking questions and checking individuals' understanding.
5. **Teacher absence** – the teacher knows that they will be absent on a particular day so arranges for the class to access the lab and work through a designated lesson.

Classify each of the above as:

1. supporting learning as usual
2. extending learning
3. transforming learning.

Reflection point

Reflect on some of the things that you have learnt and some of the things that you would like to get better at. You should raise these with your Head of Department, who will be able to help you to think more deeply about your lessons and how they may be further improved step by step.

Summary

The intention is that this unit has provided a starting point. Hopefully the ideas provided will inspire you to try new approaches and to analyse your ideas in terms of the skills that are highlighted in the syllabus, but that are also widely accepted as being important in the 21st Century. You should aim to add to these examples and to work within your own subject area with the guidance of your head of subject and head of department to make progress together as a community of practice.

A full list of the OpenSTEM Africa CPD units can be found at:
https://www.open.edu/openlearncreate/CPD_units

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Acknowledgements

Grateful acknowledgement is made to the following sources:

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