CONTINUOUS PROFESSIONAL DEVELOPMENT (CPD) FOR SCIENCE TEACHERS

OpenSTEM Africa

# ORGANISING PRACTICAL WORK

# Acknowledgements

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

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:

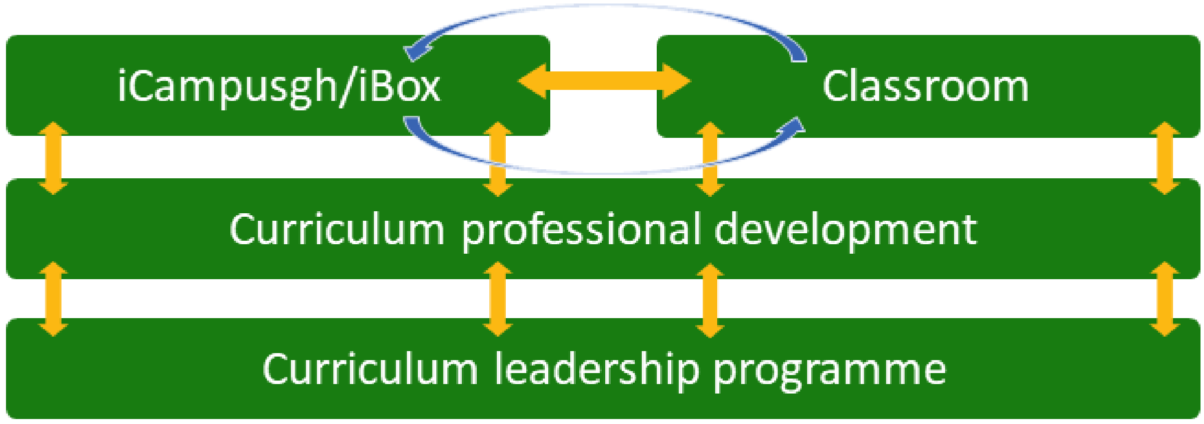
1. **Virtual Lab:** onscreen interactive science instruments using real data and with examples of science lessons, to improve the experiential teaching and learning of science in Senior High Schools, helping develop girls' and boys' practical science study skills, and building on the iCampusgh/iBox model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

# Organising practical work

## Introduction

As an SHS science teacher, you already understand the importance of practical work in the elective sciences. This unit will support you in planning your practical work for your science classes. As with the other units in this series, there are links to the OpenSTEM Africa Virtual Laboratory to enable you and your classes to link to on-screen, online experiments.

By the end of this unit you will:

1. have considered the different purposes that practical work can serve
2. planned different types of practical work
3. have worked with your HoD/HoS and colleagues together to plan how to integrate the OpenSTEM Science applications into your teaching.

## Profile dimension of practical work

As you know practical and experimental skills are one of the three profile dimensions in the SHS elective sciences syllabuses, which are:

1. Knowledge and Understanding
2. Application of Knowledge
3. Practical and Experimental Skills

As it says in all the syllabuses:

> *"The Practical and Experimental Skills involve the demonstration of the inquiry processes in science and refer to skills in planning and designing of experiments, observation, manipulation, classification, drawing, measurement, interpretation, recording, reporting, and conduct in the laboratory/field."*
>
> (Teaching Syllabus for Physics, 2010)

Practical work is an important part of learning about science, learning how to *do* science and learning to be a scientist. Practical work in the sciences involves students finding out, learning and verifying through observation and experiment, using skills and methods that are used by scientists in the real world. Practical work provides the opportunity to develop a range of higher-order skills, such as problem solving, creativity, analysis, evaluation and collaborative working, as well as being able to develop an understanding of key concepts through experiential learning ('learning by doing').

Again, as you will know, in the introduction to each of the elective science syllabuses (Biology, Chemistry, Physics), the SHS syllabuses state:

> *"A suggestion that will help your students acquire the habit of analytical thinking and the capacity for applying their knowledge to problems 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."*
>
> (Teaching Syllabus for Biology, 2010)

Practical work is therefore at the heart of the elective sciences and working as a department to provide practical lessons meaningful experiences for students is an important – and sometimes challenging – aspect of your work.

## Purposes of practical work

Different types of practical work and particular experiments will meet different objectives, but the benefits of practical work include:

1. Skill development of the manipulation involved in the handling of scientific objects and tools for accomplishing specific tasks.
2. Skills in the development of hypotheses.
3. Creativity and flexibility: the ability to modify and adapt when difficulties arise.
4. Perseverance: the ability to continuously pursue an idea until results are achieved.
5. Use of the all the senses to make accurate observations.
6. Skills in accuracy for reading and making observations.
7. Skills in handling information and the interpretation of data.
8. Skills in making inferences and predictions to extrapolate and/or derive conclusions.
9. Respect for the scientific conclusions others have arrived at.
10. Skills in critical review and reflection for improvement and development.

(Adapted from introductions to the SHS syllabuses)

### Activity 1: Discussion with colleagues: Practicals

Think of a practical experiment that you undertook either at school or at university and which you really enjoyed. Which of the purposes listed above did it include?

Discuss with colleagues who also teach your science subject what for you are the main opportunities and the main challenges to the practical work you carry out in your own teaching.

# Types of practical work

## Demonstrations

There are multiple examples across the SHS elective science syllabuses where the teacher is asked to demonstrate an experiment. This may be for reasons of safety, because of the complexity of the experiment or because it uses specialist equipment or expensive reagents. A practical demonstration is a good opportunity to use questioning to engage students and draw out explanations (see CPD Unit *Effective questioning*: https://www.open.edu/openlearncreate/Teacher_units).

As well as planning questions, the things to consider in any investigation include:

1. Ensuring the safety of the class (e.g. as set out in Chemistry SHS 1 Section 1 Unit 3).
2. Making sure that everyone can see properly.
3. Ways of involving students in the experiment to take readings or record results.

## Class practicals

As you know, there are multiple examples across the SHS elective science syllabuses where the objective is for the students to carry out an experiment.

If enough equipment is available, it is good for students to have every possible experience of doing experiments in pairs or in a small group (see CPD Unit *Collaborative learning*). The things to consider when planning class practicals include:

- ensuring the safety of the class (e.g. as set out in Chemistry SHS 1 Section 1 Unit 3)
- how to give the instructions
- how to organise the distribution of equipment, particularly chemicals
- what students will need to record and how they will do so
- how you will organise the pairs or groups (including ensuring that gender is considered).

## Activity 2: Organising a practical

Work with your Head of Department/Head of Subject and colleagues on how best to organise practicals in your department. Take the following Chemistry example and think how it could work in your school, or adapt the example to Physics or Biology.

## Teaching analysis:

### Organisation of the lesson

***Apparatus:***

- test tubes
- Bunsen burner (when there is the need to heat a reaction)
- washed bottle
- distilled water
- precipitating reagents and unknown solutions.

## Activity 2: Organising a practical (continued)

### *What the teacher needs to do:*

1. Perform the practical to understand the outcome <u>before</u> students come in.
2. Plan for the structured practical: The teacher should make ready all the materials and apparatus to be used for the practical. This can easily be done by considering the class size and setting up stations for the number of groups. The apparatus should be sufficient for the number of groups.
3. Plan safety precautions for before and during the practical.
4. Decide beforehand who would be the best student group leaders, based on your experience of those students who demonstrate responsibility and understanding.
5. Ensure you have a fair weighting of male and female group leaders.

### *When the students arrive:*

6. (Depending on the class size), divide students into small groups, specifying a student leader for each group and ensuring that there are an equal number of female and male leaders to the groups.
7. Run a two-minute safety quiz to remind students of all the relevant safety information needed for this experiment (referring back to Chemistry SHS 1 Section 1 Unit 3).
8. Ensure every group responds and is engaged.
9. Distribute any relevant safety equipment (e.g. goggles, gloves, protective clothing) via the student leaders and ensure that it is in place and functioning before beginning the practical.
10. Distribute (via the student leaders) a list of instructions that students must follow (written/typed) for the practical.
11. Distribute the chemicals, via the student leaders, to help ensure the safety of everyone in the class.
12. Give the time limit for the practical to be done.
13. Make room for extra chemicals to be used in case the practical has to be repeated or a particular group makes a mistake in the process of performing the practical and will need additional chemicals.

As the students engage with the practical work:

14. Every five minutes during the practical, write an open question on the board, following the sequence of the practical (your open questions would typically begin with 'What… ?' or 'How… ?')
15. Explain that each group must decide on a collective answer to the open question and also be prepared to explain how and why they arrived at their responses.

### *Advice to the teacher*

Solutions should be freshly prepared.

## Activity 3: Rotating (circus) practical

Work with your Head of Department/Head of Subject and colleagues on how best to organise practicals in your department. Take the following Chemistry example and think how it could work in your school, or adapt the example to Physics or Biology.

In a rotating class practical, students in groups move from one experiment to the next at 'stations' in the classroom. As long as safety instructions are carefully followed, this can help to ensure that students in a large class can view in detail, and at close range, several practical experiments within one lesson.

The experiments should be related to one another, and instructions should be brief.

4–6 student leaders (female and male) should be chosen to run 4–6 experiments, with each student leader running the experiment twice. There should be two starting points for the student observers in the room, each one for half the class. This will ensure safety, with the teacher able to monitor all the stations. It will also ensure that there is less of a problem with crowding and much more likelihood the all the students can see what is going on. The student leaders will also get a second chance at the experiment if the first attempt goes wrong!

Similar questions at each experiment will help students gradually build their understanding of a key concept, e.g. particle theory of matter or adaptation. Some of the stations could include a card sort or problem to solve, rather than an experiment. This is good way of organising practical work if there isn't sufficient equipment for every group to do the same experiment.

This would need a lot of pre-lesson planning until this way of doing practical work becomes well understood.

## Practical work in groups and pairs

### Activity 4: Chemistry

Using SHS 1 Section 1 Introduction to Chemistry, Unit 3: Basic safety laboratory practices, prepare a set of laboratory scenarios and write each one on a paper or card.

The scenarios should describe a laboratory incident or issue which highlights the knowledge set out in the syllabus. They could include situations in which a small fire developed, where someone spilt acid on their skin or in their eyes, where something happened as a result of chemicals being stored erroneously, a significant spillage etc. Prepare a few copies of each scenario.

1. divide your class into groups of 3–4 and give them 2–3 scenarios
2. ask them to say what should be done in the event of your chosen scenario happening, and how it could be prevented in the future
3. get one set of feedback on each scenario
4. finish by asking them individually to answer a set of questions which cover the content of the syllabus.

### Activity 5: Biology

Using SHS 1 Section 2 Cell Biology, Unit 5: Movement of substances into and out of cells, put the class into pairs and ask them to:

1. Write down the characteristics of diffusion, osmosis and active transport. These could include definitions, whether they are active or passive, examples, e.g. root hair cells, etc. Write these on small pieces of paper or card.
2. Take it in turns to place them onto a 3-circle Venn diagram.
3. Once finished, compare each other's attempts.
4. Find and discuss the similarities and differences.
5. Decide on a final group answer.

### Activity 6: Biology

Using SHS 1 Section 2 Unit 3: Specialised Eukaryotic cells, put the class into pairs and ask them to:

1. Decide upon a specialised cell (animal or plant). Prepare a poster to present your ideas to the class or display on the wall. In your groups, decide upon some success criteria:

- What you want it to look like (relevant to its purpose).
- What things need to be included.

2. Once you have decided upon these criteria, share the jobs out evenly between the group members, decide the order they need to be completed and how long you think each will take.

## Activity 7: Physics

Using SHS 2 Section 2 Thermal Physics, Unit 1: Heat transfer, divide the class into groups.

- Ask them to measure the rate of cooling of hot water and test various forms of insulation. Award a small prize for the group that keeps it warm for the longest.
- Alternatively, give each group a cup of water with ice. The challenge is to keep it cool for as long as possible – the winner is the group whose cup is the coolest at the end of the lesson!

## Investigations

In an investigation, students plan, carry out and analyse their own experiment. They may have freedom to choose what they investigate, or the teacher may limit the materials available or specify a topic to investigate. The teacher has the role of facilitator rather than teacher. They will usually give students guidance on ‘the scientific method’ or carrying out a ‘fair test’. Investigations can help students experience what it is like to be a ‘real’ scientist. Investigations are highly motivating when the answer is genuinely unknown. For example, which is the most cost-effective brand of bleach (requires titration)? Or which shops issue the strongest shopping bags (linked to work on forces or materials)?

The SHS syllabus suggests students should experience planning and carrying out an investigation.

The example given below is an experiment from the Chemistry syllabus and is one that all students will do. It has just been framed differently to encourage students to practise thinking in a scientific way. The same approach could be adopted with popular Physics and Biology experiments. For example:

- investigate the effects of the minerals on plants by using water culture (hydroponics)
- investigate the factors which affect the strength of an electromagnet.

# Chemistry

## Classroom example 1

Mrs Ahadzie has access to the OpenSTEM Africa Virtual Laboratory because the school she works in has an iBox. Via her Head of Science and working with the Head of ICT she has been able to arrange for a class to take place in the ICT lab. She prepares for this lesson with her class beforehand, by demonstrating to them an experiment which will form the basis of an investigation which each student in the class will be able to carry out in a small group in the Virtual Lab.

In order to meet the aspirations of the SHS syllabus, students need the opportunity to plan and carry out an investigation. In this example, Mrs Ahadzie's SHS 2 students plan an investigation to measure the effect of concentration on the rate of reaction.

Mrs Ahadzie wanted her students to use what they had learnt so far in Chemical Kinetics to plan their own investigation. They had already measured the effect of temperature on the rate of a reaction.

She gathered them around the front bench and demonstrated the reaction between sodium thiosulphate and hydrochloric acid.

She used the thiosulphate ($S_2O_3^{2-}$) (aq) and diluted HCl acid:

### Reaction

The reaction proceeded with the formation of a yellow precipitate of sulphur.

Mrs Ahadzie monitored the progress of the reaction by changing the concentration of the thiosulphate while maintaining the concentration of the acid.

Then she maintained the initial concentration of thiosulphate and changed the concentration of the acid.

Mrs Ahadzie gave three students a stopwatch. She mixed the chemicals together and asked those who had a stopwatch to stop it when the solution went cloudy. They all stopped it at a different time! She asked a few leading questions about how to measure how long the reaction took.

Together, they realised that if they drew an X on a piece of paper, stood the conical flask on it and looked down through the solution at the cross, then they could time how long it took for the cross to disappear. That way they always stopped the watch at the same amount of cloudiness. She explained that they would need to do the experiment several times using different concentrations of sodium thiosulphate.

Having demonstrated the experiment on rates of reaction with physical equipment, the class talked about how they would be able to carry out the investigation in the Virtual Lab. There were enough computers for them to work in threes, so Mrs Ahadzie showed them the equipment in the Virtual Lab and they discussed how to measure how long the reaction took.

In the ICT lab she divided them into groups of three and gave them a set of questions:

What is the effect of the concentration of Sodium thiosulphate on the rate of reaction between hydrochloric acid and sodium thiosulphate?

1. Can you write an equation for the reaction?
2. Why does it go cloudy?
3. How will you measure how long the reaction takes?

4. What variables will you need to keep the same?
5. How will you change the concentration of sodium thiosulphate?
6. What do you predict will happen? Why?
7. What equipment will you need?
8. What will you do in your experiment? What readings will you take?
9. Make a table in which to record your results?
10. How will you use the results to show the effect of the concentration of sodium thiosulphate?
11. What safety precautions would you take if this experiment was taking place in a real lab?

While they were working, Mrs Ahadzie went round and helped the groups. She asked probing questions to support their thinking. When she was confident that all the groups had developed a plan, they did the experiment.

***Did you notice…***

1. She made sure the students had the necessary background knowledge – in this case how to know when to stop the stopwatch or timer
2. the questions she asked were designed to structure their thinking in a logical way
3. She specifically asked them to predict what would happen – a good way to promote thinking and encourage them to draw on and consolidate their understanding
4. She did not tell them what to do with the virtual apparatus – they had to work that out – but she made sure they had experiences to draw on
5. She supported the groups while they were working to ensure they stayed on track – but did not tell them the answers.

## Problem solving

*"A suggestion that will help your students acquire the habit of analytical thinking and the capacity for applying their knowledge to problems 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 emphasis is to assist your students to develop analytical thinking and practical problem solving techniques."*

(Teaching Syllabus for Chemistry Senior High School 1–3, 2010)

### Activity 8: Chemistry

Using SHS 1 Section 2 Atomic structure, Unit 3: Periodicity:

1. Prepare several sets of cards with one element on each card for all the elements up to Calcium (20).
2. On the card, put the symbol, mass no., atomic no., melting point and boiling point, metal or non-metal, reactivity with water, and the pH of the solution formed when the oxide dissolves in water. This may sound like quite a lot of effort, and you may need to work together as a department to do it – but once you have this resource, it will be very helpful.
3. Divide your class into groups – it might be helpful to have male groups and female groups – and give each group one set of cards.
4. Ask them to lay the cards out on the table and find a way of grouping the elements together.

## Top tips for organising practical work

1. The teacher should plan and try the experiment first before the lesson.
2. Safety precautions should be taken before the lesson and during the lesson, and communicated clearly to the students.
3. Think about how to make instructions available (written on the board/ typed and printed out) before the start of the experiments (Ensure there are the right quantity for every student or group).
4. Use student monitors or leaders to assist in organising the class. Make sure your student leaders represent a gender balance in your class. Ensure that you have inducted/trained/briefed your monitors before each practical lesson.
5. Think about how students will access the equipment they need. Work out where to put equipment in order to prevent students all crowding around one place.
6. Students should have prior knowledge about the use of equipment/ apparatus before the practical lesson.
7. Lessons from students' practical work should be learnt each time in order to learn from any mistakes and to inform the teacher of their course of action the next time practical work is carried out.

### Activity 9: Making the most of practical work

Refer to the section at the front of the SHS syllabus on Practical and Experimental Skills. Try to adapt the way in which you run each practical activity you have planned to incorporate more of the skills highlighted in the syllabus.

## 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)

Activities 10, 11 and 12 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 to engage in 21st century skills that are relevant for their studies and future professional lives. Selecting and integrating a range of ICTs in your lesson requires careful consideration and thought.

### Activity 10: 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 points 1–3 onto a flip chart and keep it as a resource to support future planning or to inform the individual coaching sessions you will

# OpenSTEM Africa Virtual Lab Applications

## Practical science

The practical science apps in the OpenSTEM Africa Virtual Lab such as the calorimetry application being introduced are designed to help you to teach your students practical science in the absence of other reliable equipment.

With each application 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 one of the science apps and its related exemplar lessons. Consider:

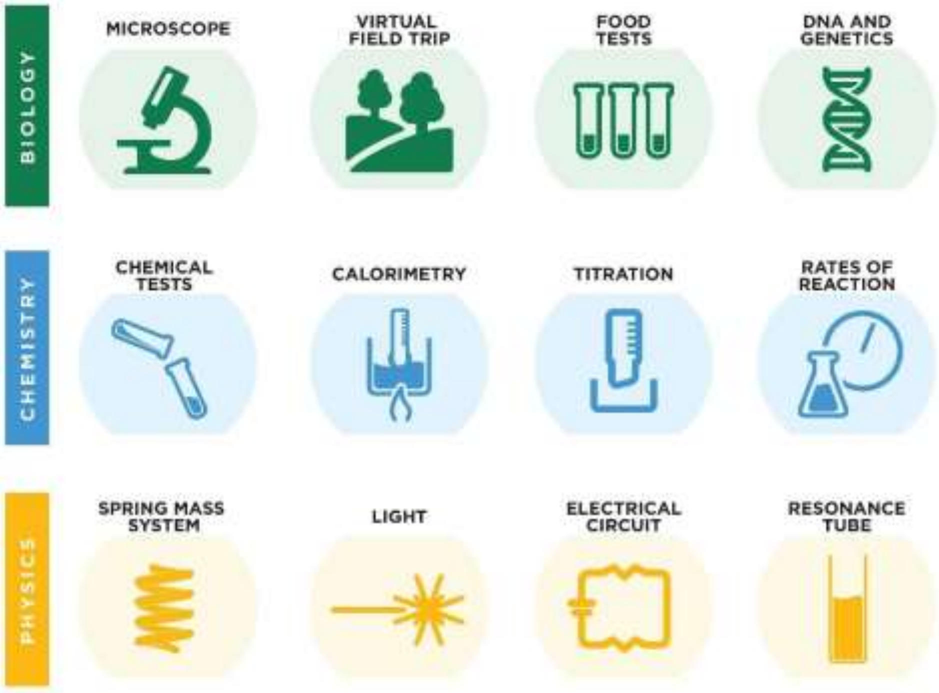
- what practical skills the students will learn
- how the engagement is being used
- alternative ways in which the engagement could be used.

As more apps in the Virtual Lab become available, work with your Head of Department and colleagues to develop more example lesson plans.

## Activity 11: 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 Lab




The OpenSTEM Science apps have been developed collaboratively by CENDLOS, GES and a group of SHS teachers in Ghana and The Open University. 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 app there is a 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 the iCampusgh and the iBox

Activity 12 will help you to think about the effective use of technology and how to make it transformational.

### Activity 12: Examples of using iCampusgh and the iBox

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

This unit has focused on practical work and highlighted some of the organisational issues that teachers face.

The SHS syllabuses are aspirational in terms of their approach to practical work, highlighting the importance of providing opportunities for genuine scientific enquiry. This does not mean that as science teachers you need to devise new experiments, but rather to think about the ways in which you introduce and organise those you usually do. By asking students to put practical instructions in the right order, or to make and explain predictions, you are introducing opportunities for thinking and problem solving. Effective questioning, and well-organised group or pair activities will also support the development of practical skills.

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

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