education

Department:
Education
PROVINCE OF KWAZULU-NATAL

FET
Just-in-Time Training Workshop
2019: No. 3

Participants' Handout

Physical Sciences

Endorsed by:

Jika iMfundo
what I do matters

Improving Learning Outcomes in Physical Sciences

Workshop Purpose

This workshop has been designed to help HODs and lead teachers develop tools that will help teachers to develop activities and homework questions for learners to help them develop conceptual thinking in different topics of Physics and Chemistry. The content focus of this workshop is on Electricity and Magnetism. Links to Electrochemistry are also explored in Session 3.

Rationale for the focus on Conceptual Thinking

The diagnostic report on the 2018 NSC for Physical Sciences identified learners' ability to answer questions that required conceptual thinking as an area of weakness. The report encourages teachers to develop activities and questions for learners to do in class and for homework regularly so that these learners will be better prepared for future examinations.

Methodology of the Workshop

In this workshop, we will take time to developing learning activities and assessment questions for topics to be taught in term 3 in Grades 10 - 12.

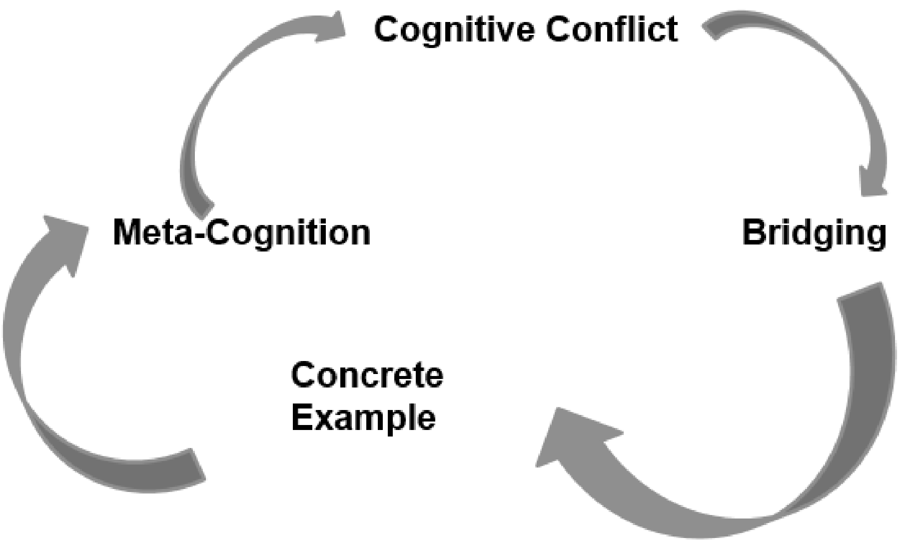
Session 1: A framework to promote conceptual thinking

Introduction **10 min**

One of the most successful interventions in improving learners' ability to answer exam questions that target higher order, abstract concepts was originally conducted by Michael Shayer and Philip Adey in the 1990s in the UK. They designed a programme called CASE (Cognitive acceleration through Science Education). In a long term longitudinal study learners who were part of the programme improved their thinking compared to similar learners who were not part of the intervention. The value of this intervention is not only in the specific activities but in the general approach to teaching Science – especially content that has lots of abstract mathematical concepts in it – as it explicitly focuses on the development of thinking skills. The thinking skills approach used in CASE has been adopted in many countries and similar results have been reported. In this session we will explore the thinking skills approach as a useful framework for teaching Science content.

The Thinking Skills Approach

There are four distinct features of a thinking skills lesson as shown in the graphic below.



It is important to understand the type of activities and questioning that needs to be included in each stage. A summary of these is given below. Activity 1 is designed to demonstrate these stages explicitly.

Concrete Examples

Young children learn by playing. Before they develop ideas they need to interact with concrete objects. Unfortunately, many people rush through this concrete stage of learning.

Even older learners need to have the chance to touch and interact with objects. The interactions with Science activities can create curiosity and “Wow!” or “Ah ha!” moments. These learning experiences are powerful hooks to motivate and consolidate learning.

While this sort of interaction is taking place, teachers need to guide learners to talk about what they see and experience. The development of vocabulary about Science concepts needs to be linked to objects that illustrate a concept. Based on a concrete scenario teachers need to ask learners to solve a problem or explain what they are observing. You can even ask learners to develop questions they would like to find answers to.

Meta-cognition

The second stage takes time to develop but even younger learners can become experts at this process. Here we ask learners to explain their thinking. We say we think about our thinking. In this stage the answer to a problem is not the most important objective but the explanation of how someone arrived at the answer is. The most powerful thing about meta-cognition is that people arrive at the same answer in different ways. So in this stage of a lesson we need to teach learners to listen carefully to other people’s ideas.

Cognitive Conflict

The third stage of the thinking process requires a teacher or another learner to challenge an idea presented during meta-cognition. If possible, the source of cognitive conflict needs to be illustrated by a concrete example.

Bridging

The fourth stage asks learners to confirm their ideas but looking for other examples that they come across in their daily lives. Although bridging is about applying an idea to a different context and is a higher order thinking skill, it does link learners back to a concrete example and so consolidates their ideas.

Activity 1: Candle Investigation 40 min

A candle is something very familiar to most people. But not many people have taken time to observe what happens when a candle burns.

Instructions:

1. Observe the candle you have been given. Discuss what you see and make a few notes in the space below:

2. Light the wick of the candle and melt some wax onto the small paper plate. Stick the base of the candle onto the hot wax so that the candle can stand upright.

3. Carefully watch the candle burning. Discuss what you see and make a few notes in the space below:

4. In your discussion what Science terminology did you use?

5. When a candle burns are there chemical or physical changes?
Explain your thinking steps that helped you decide.

To guide you think about the following questions:

- What are the reactants?
- What are the products?
- Are the properties of the products different to the properties of the reactants?
- Has there been a change in energy?

6. Hold a glass or ceramic plate above the candle flame.

- What do you observe?
- Can you explain your observation?
- Does your observation provide evidence for you to rethink your answer to question 5?

7. Look carefully at the base of the wick. A liquid forms there while the candle is burning. A learner seeing this liquid suggest that this is water, a product formed in the chemical reaction. How do you respond to the learner? If possible back up your answer with evidence and show why water is a product of this chemical reaction.

8. Blow out the candle (but not the match!) Quickly bring the burning match in the smoke trail of the candle but keep it a few centimetres away from the candle. Watch what happens. Can you explain your observations?

9. Can you identify any other chemical or physical changes taking place while the candle is burning? Draw a flow diagram to show all the processes taking place to illustrate your thinking.

10. Identify two other chemical and physical changes you see around you.

Reflect on the activity you have completed and link the questions / activities to the stages of the Thinking Skills framework. Here's a summary of the key words:

- **Meta-cogniti**on – thinking about thinking.
- **Cognitive conflic**t – an idea that seems to oppose the evidence.
- **Bridging** – application of a concept to other contexts.

In pairs identify the key steps of the Thinking Skills framework that can assist teachers to support learners in developing their conceptual thinking.

Activity 2: Electric fields simulation 20 min

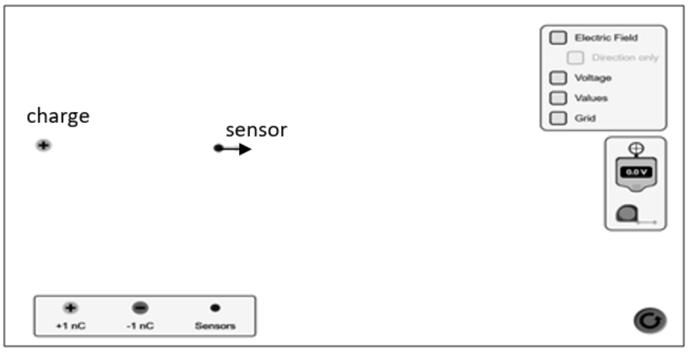
In the previous activity we used a very simple concrete tool to encourage higher order thinking. It is not always possible to find a concrete starting point but simulations can assist us. The emphasis in this activity is not on the software or technology but on developing questions that will promote meta-cognition & cognitive conflict.

Instructions

Use the Phet simulation: Charges and fields

https://phet.colorado.edu/en/simulation/charges-and-fields

The screenshot below shows a sensor a distance away from a positive charge and the arrow next to the sensor shows the Electric Field Strength (E).



A simulation like this one encourages “play”. Unstructured play can be rewarding for some learners as they will make their own discoveries. But other learners may need more explicit guidance. In both these scenarios conceptual thinking is best developed by asking questions about relationships between the variables identified in the simulation.

Instructions

1. What changes would you like to make to:
   - The sensor(s)
   - The charge(s)
2. What did you observe when making changes to:
   - The sensor(s)
   - The charge(s)
3. Based on your observations what relationships exist between the charge, distance and the Electric Field Strength (E). Explain your thinking.
4. Is the electric field strength inversely proportional to the distance?
5. Reflect on questions that promote meta-cognition or cognitive conflict.

Session 2: Electrodynamics

Introduction

The topic of Electrodynamics combines the concepts of electric fields, magnetic fields and force. Although we can see evidence of this theory in action, it is does involve abstract concepts that many learners struggle with. It is important to see the development of the concepts starting in the Senior Phase through to Grade 12. The activities in this session trace a developmental pathway from the magnetic effect of current through to electric machines.

Activity 1: Magnetic Effect **45 min**

The discovery of the relationship between a moving charge (current) and a magnetic field was a major breakthrough in the development of scientific knowledge. However it does pose a challenge in teaching because the current and associated field are in two different dimensions that are perpendicular to each other. One way to help develop learners' conceptual thinking on this topic is by drawing diagrams.

Instructions

1. Complete the diagrams showing a cross section of a straight conductor, where the current direction is out of the plane of the page and into the page.
   Use the right hand rule to show the direction of the magnetic field around the conductor.

Current direction: **Current direction:**
Out of the page **Into the page**

Thinking Questions

- How does the strength of the magnetic field change as you increase the distance from the conductor?
- Does your diagram illustrate this relationship?

2. Draw a diagram to show a longitudinal view through a straight conductor and indicate the magnetic field associated with the conductor. Show the direction of current using an arrow pointing to the top of the page.

3. Draw a diagram to show what happens to a straight conductor (show in longitudinal view) is bent into a single loop.

Thinking Questions

- Is the magnetic flux uniform?
- Does the view you have drawn represent a North or South pole?

4. Draw a diagram to show the direction of current through a coil (side view) and the magnetic field surrounding the coil.

Thinking Questions

- Is the magnetic flux uniform?
- Explain how you decided which end of the coil is a North pole?

Discussion

What activities or questions could you include in developing conceptual understanding of the magnetic effect of a current?

Activity 2: Electromagnetic Induction **45 min**

Use the Phet simulation: Faraday's Law
https://phet.colorado.edu/en/simulation/faradays-law

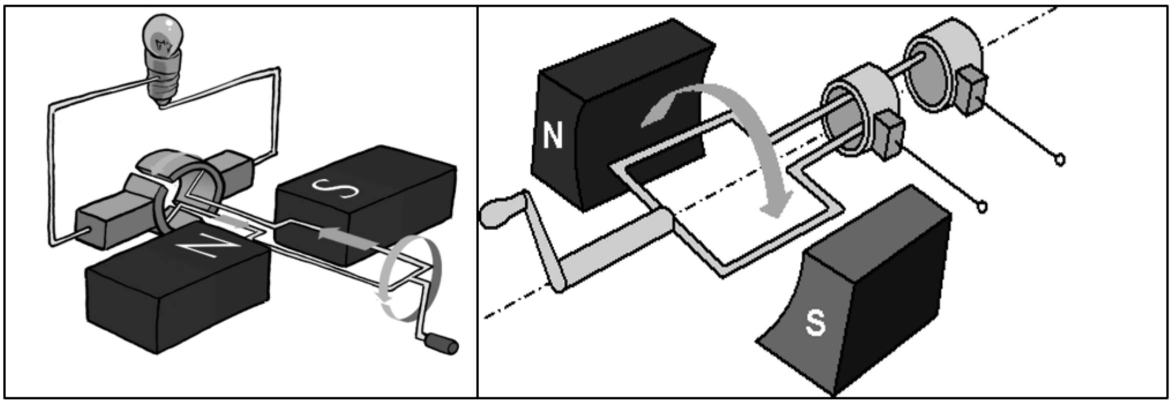
Design a guide for using this simulation to develop the concepts required for learners to have a good understanding of electromagnetic induction.

Here are some suggestions to help you:

- Identify three or four key words that learners need to know based on a previous section
- Formulate a question or design an activity that uses these words in a way that you can check that learners have the required prior knowledge
- Pose a question or state a problem that requires learners to test their thinking using the simulation given. There should be more than one way of finding the answer or even multiple answers.
- Ask two questions about the activity that will encourage learners to explain their thinking (meta-cognition) and one question that will challenge or contradict their thinking (cognitive conflict).
- Help learners think about how the ideas they have discovered in the simulation can be applied to other scenarios.

Activity 3: Electric Machines **40 min**

Carefully examine the diagrams below:



1. Identify the components of these two machines.

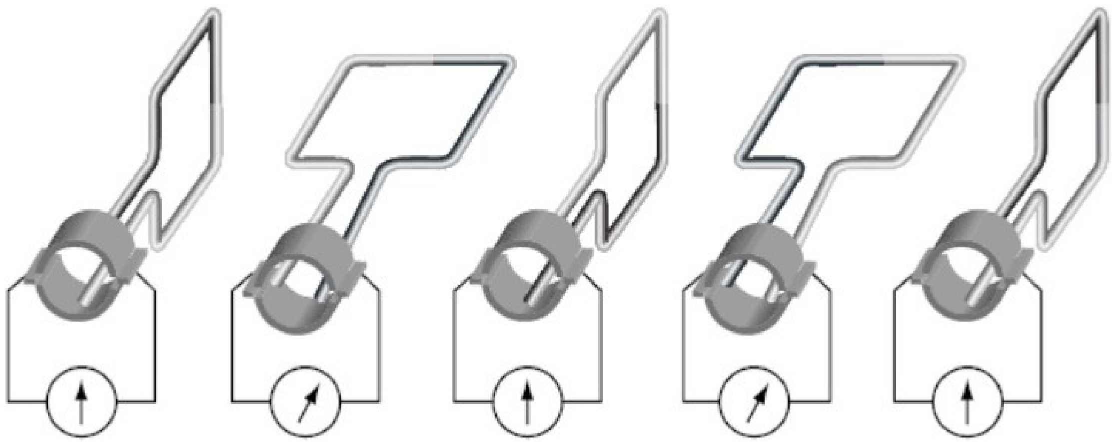
2. Tabulate differences and similarities between the machines.

3. How are these machines different to motors?

Useful Video demonstration from Edison Tech Centre:

https://www.youtube.com/watch?v=UL_ryxub-RA

Look at the diagram below, showing the armature in different positions



- Explain why the needle on the meter is changing as the armature is moving in the magnetic field.
- Draw a sketch graph to show how the induced emf changes during each rotation if the brushes are connected to a split ring commutator.
- How would your graph be different if the split ring commutator was replaced with slip rings?

Session 3: Electrochemistry

Introduction

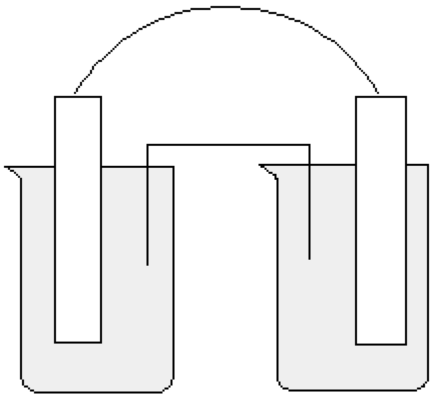
In this session we investigate the relationship between chemical reactions and electricity. When introducing the two types of electrochemical cells is useful to compare them to generators and motors. Galvanic cells use chemical reactions to produce electric energy (similar to generators) while electrolytic cells use electric energy to produce chemical reactions (similar to motors). By highlighting the links between the electrochemical cells and making the converse relationship explicit helps learners organise these concepts better and gives them the ability to apply converse thinking to solve problems.

A key concept that links Physics and Chemistry is potential difference and its relationship to energy. The Table of Standard Reduction Potentials gives relevant data about the potential of different half cells compared to the Standard Hydrogen Electrode (Reference Cell). This table is often misinterpreted and used in a procedural routine. It would be better to develop activities that promote thinking rather than routines. However, it is also important to give learners tools to help them remember key concepts and definitions

Activity 1 Galvanic Cells 30 min

Instructions

- Work in groups of 3 or 4
- Identify the key concepts learners require before starting this topic
- Identify the concepts involved in this topic by referring to CAPS or the tracker and planner for Term 3.
- Draw a concept map to show how the concepts link together.
- Design a short activity that makes use of the diagram below:



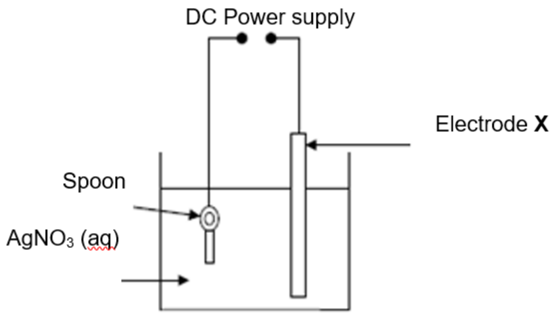
  - Include question to stimulate discussion of terminology
  - A problem that needs to be solved
  - Two questions that encourage meta-cognition
  - A question the engages learners in cognitive conflict
- Record your activity on a piece of flip chart paper
- Be ready to present your ideas to other participants.

Activity 2 Electrolytic Cells **30 min**

Electrolysis is used in many different industries. Electrolytic cells may look different but they all operate on the same principle. In this activity you will examine an exam question and identify the core concepts learners need to know to be able to answer the questions.

Question 7

The diagram below represents a simplified electrolytic cell used to electroplate a tin spoon with silver. The spoon is continuously rotated in a saturated solution of silver nitrate during the process of electroplating.



7.1 Which electrode is connected to the positive terminal of the power supply? (2)

7.2 Why does the solution conduct electricity? (2)

7.3 What would you observe happening to electrode X if the cell operated for more than 30 minutes? (2)

7.4 Write down the half reaction, including the state symbols, that occurs at the spoon. (2)

If the voltage of the DC supply is increased to 1V, bubbles of hydrogen gas appear on the tin spoon. Water is reduced to form the hydrogen gas.

7.5 Write down the equation of the half reaction that produces the hydrogen gas (2)

7.6 What other substance is involved in this reaction? (2)

Electrode X is made of silver but also contains some zinc impurities.

7.7 By making specific reference to the E° values in the standard electrode potential table, explain why it can be said that the spoon will still only be coated with silver and not zinc. (4)

7.8 At the end of the experiment, where would one find the impurities? (2)

Memo Question 7

7.1 Electrode X✓✓

7.2 The solution is an electrolyte. There are positive (cations) and negative (anions) ions in the solution that can move freely. ✓✓

7.3 Electrode X would decrease in size✓✓

7.4 $Ag^+(aq) + e^- \rightarrow Ag(s)$ ✓✓

7.5 $H_2O\ (l) + 2e^- \rightarrow H_2\ (g) + OH^-(aq)$ ✓✓

7.6 Ag in electrode X ✓✓

7.7 Zinc is a strong reducing agent with an E^0 value of -0,76V✓ compared to copper which has an E^0 value of +0,34V. ✓At the low voltage this cell needs to operate at there is insufficient electrical energy✓ to cause zinc to form ions or deposit onto the tin spoon. ✓

7.8 The zinc impurities would remain in the solution as a precipitate. ✓✓

TABLE OF STANDARD ELECTRODE POTENTIALS

Half –reaction			E°/volt
$Li^+ + e^-$	⇌	Li	-3.05
$K^+ + e^-$	⇌	K	-2.93
$Cs^+ + e^-$	⇌	Cs	-2.92
$Ba^{2+} + 2e^-$	⇌	Ba	-2.90
$Sr^{2+} + 2e^-$	⇌	Sr	-2.89
$Ca^{2+} + 2e^-$	⇌	Ca	-2.87
$Na^+ + e^-$	⇌	Na	-2.71
$Mg^{2+} + 2e^-$	⇌	Mg	-2.37
$A\ell^{3+} + 3e^-$	⇌	$A\ell$	-1.66
$Mn^{2+} + 2e^-$	⇌	Mn	-1.18
$2H_2O + 2e^-$	⇌	$H_2(g) + 2OH^-$	-0.83
$Zn^{2+} + 2e^-$	⇌	Zn	-0.76
$Cr^{3+} + 3e^-$	⇌	Cr	-0.74
$Fe^{2+} + 2e^-$	⇌	Fe	-0.44
$Cd^{2+} + 2e^-$	⇌	Cd	-0.40
$Co^{2+} + 2e^-$	⇌	Co	-0.28
$Ni^{2+} + 2e^-$	⇌	Ni	-0.25
$Sn^{2+} + 2e^-$	⇌	Sn	-0.14
$Pb^{2+} + 2e^-$	⇌	Pb	-0.13
$Fe^{3+} + 3e^-$	⇌	Fe	-0.04
$2H^+ + 2e^-$	⇌	$H_2(g)$	0.00
$S + 2H^+ + 2e^-$	⇌	$H_2S(g)$	+0.14
$Sn^{4+} + 2e^-$	⇌	Sn^{2+}	+0.15
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2(g) + 2H_2O$	+0.17
$Cu^{2+} + 2e^-$	⇌	Cu	+0.34
$2H_2O + O_2 + 4e^-$	⇌	$4OH^-$	+0.40
$SO_2 + 4H^+ + 4e^-$	⇌	$S + 2H_2O$	+0.45
$I_2 + 2e^-$	⇌	$2I^-$	+0.54
$O_2(g) + 2H^+ + 2e^-$	⇌	H_2O_2	+0.68
$Fe^{3+} + e^-$	⇌	Fe^{2+}	+0.77
$Hg^{2+} + 2e^-$	⇌	Hg	+0.79
$NO_3^- + 2H^+ + e^-$	⇌	$NO_2(g) + H_2O$	+0.80
$Ag^+ + e^-$	⇌	Ag	+0.80
$NO_3^- + 4H^+ + 3e^-$	⇌	$NO(g) + 2H_2O$	+0.96
$Br_2 + 2e^-$	⇌	$2Br^-$	+1.09
$Pt^{2+} + 2e^-$	⇌	Pt	+1.20
$MnO_2 + 4H^+ + 2e^-$	⇌	$Mn^{2+} + 2H_2O$	+1.21
$O_2 + 4H^+ + 4e^-$	⇌	$2H_2O$	+1.23
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇌	$2Cr^{3+} + 7H_2O$	+1.33
$C\ell_2(g) + 2e^-$	⇌	$2C\ell^-$	+1.36
$Au^{3+} + 3e^-$	⇌	Au	+1.42
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	+1.51
$H_2O_2 + 2H^+ + 2e^-$	⇌	$2H_2O$	+1.77
$F_2(g) + 2e^-$	⇌	$2F^-$	+2.87

Increasing oxidising ability

Increasing reducing ability