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School-based Gifted Education: Fostering higher-order thinking skills of scientifically gifted/ more able students through differentiated inquiry-based learning activities (Secondary) (New)

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1. Developing evidence-based reasoning in students
2. Designing simple investigative tasks for senior form students

Part I

Instructional model POE -
Developing evidence-based reasoning in students

I would like to ask a few questions before I go into my topic of the day

Q1: Teaching about the position of carbon in the metal reactivity series. What would you choose to do?

1. Using deduction with their prior knowlege: Which metal can be extracted through carbon reduction and which cannot?
2. Asking students to figure out the relative position themselves ***if they are interested.***
3. Not teaching it because it is difficult for students to deduce the position with the knowledge they have.

Q2: What do you think learning science should look like?

1. learn science (understand scientific concepts)
2. learn to do science (engaging in scientific inquiry)
3. learn about science (understanding nature of science)
4. all of the above

<u>Let's reflect:</u> ***Which category does majority of our science lessons fall into?***

Overview of the lesson idea to teach about position of carbon in metal reactivity series

Engaging prior ideas

- Make prediction about whether magnesium can burn under carbon dioxide.

Constructing evidence-based claim

- Formulate arguments using evidence cards that support/ refute the feasibility of the reaction.
- Observe the reaction and collect more data to revise their arguments

Explaining the underlying scientific principles

- Infer the chemical equation
- Discuss the relative position of carbon in the reactivity series

Stage 1: Engage prior ideas

Students generally think:

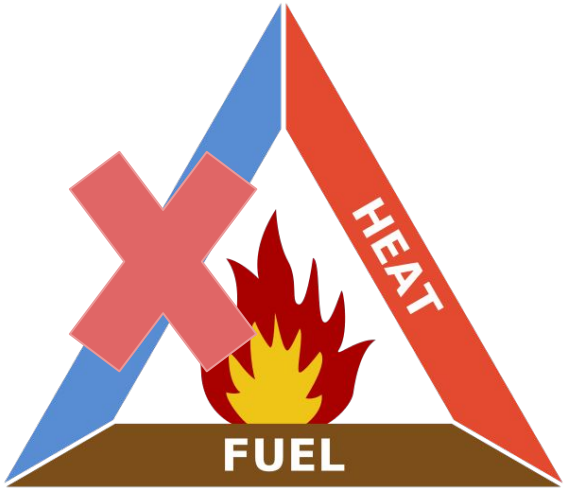
- carbon dioxide can put out fire because it displaces oxygen.
- without oxygen, burning is not possible (Fire Triangle)

What will happen when a burning splint is placed in CO_2? Why?

What did you observe?

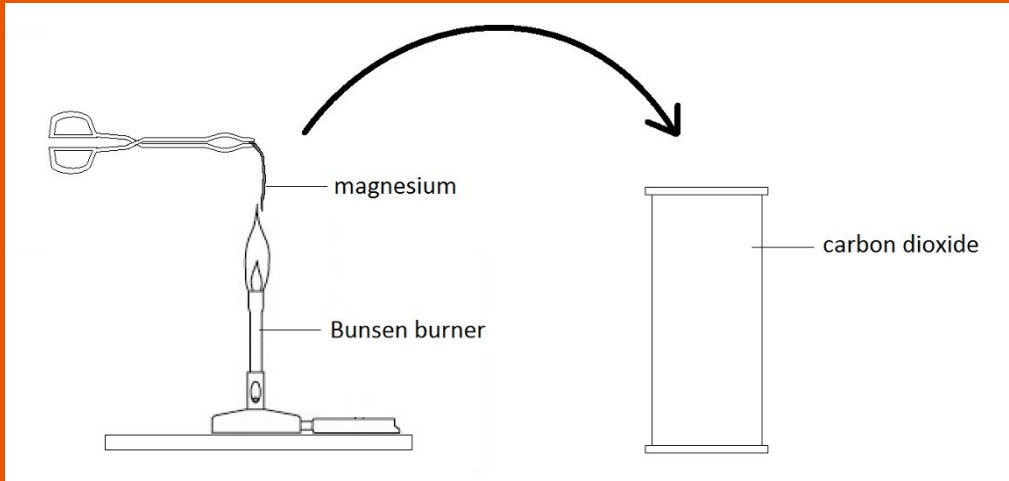
The CO_2 will extinguish the burning splint. But why?

Which component of the fire triangle is cut off?



Claim:

Then, what will happen when burning Mg is placed into CO_2?



Constructing evidence-based claim

1. Discussing evidence for their initial argumentation
2. Tools to support - argumentation grid for students to match which evidence support the idea that magnesium burn in CO_2, which does not and which evidence is irrelevant
3. Watch the teacher demonstration to make direct observation that add new idea about the evidence and revise their initial thought

What is your claim?

When a piece of burning magnesium is placed in a jar of carbon dioxide gas,

the magnesium keeps burning 👍

the magnesium stops burning 👎

discussing evidence for their initial argumentation

Why do you claim Mg will burn in Co2 or not burn in CO2? Explain briefly.

discussing evidence for their initial argumentation

Select 2 or 3 cards which provide the strongest argument for your prediction. Explain why they support your prediction (claim)

Tools to support - argumentation grid for students to match which evidence support the idea that magnesium burn in CO_2, which does not and which evidence is irrelevant

① Fire needs oxygen to burn.	② Magnesium is a reactive metal.	③ When carbon burns in oxygen, it forms carbon dioxide.
④ Magnesium burns with a bright white flame.	⑤ When you drop a lit match into a gas jar of carbon dioxide, the lit match will go out.	⑥ Magnesium gets very hot when it burns.
⑦ Carbon does not react with magnesium oxide.	⑧ Carbon reacts with copper oxide to form carbon dioxide and copper.	⑨ Some fire extinguishers use carbon dioxide to put out fires.

Let's do the demo! I want you to notice what you observe carefully!

https://www.youtube.com/shorts/aBzHJDHzCEM

Watch the teacher demonstration to make direct observation that add new idea about the evidence and revise their initial thought

Evidence (Observations)

What did you observe when burning Mg was placed into Co_2?

→ Write down in your worksheet as they may be evidence to support your claim!

Watch the teacher demonstration to make direct observation that add new idea about the evidence and revise their initial thought

Evidence: Write an argument for what you saw.

Include the following evidence:

- Your inference of what the black solids and white solids are.
- A balance chemical equation - give it a try.

New evidence - observations

- When burning magnesium is placed in a jar of carbon dioxide, some black solids and white solids formed.
- Magnesium burns strongly in carbon dioxide.
- No silvery solid is left at the end of the reaction.

Reasoning: Displacement reaction...

- What can you deduce about the reactivity of C and Mg if Mg can react with CO_2?

Do you think such argumentation practice can mirror scientific practice? Why?

Does this argumentation practice mirror scientific practice?

- How scientific knowledge is generated?
- Isn't it through examining evidence and discussion?
- Do you think students will enjoy this way of discussion more than lecturing?

Role of teacher: Not tell the answer, but facilitate student thinking and making scientific thinking accessible to all students.

Explaining and consolidating the underlying scientific principles

- Teacher acts as a facilitator throughout the lesson
- After the evidence based learning, we can add ***an extension: anchor activity*** to allow students to apply what they have learnt in other unfamiliar situation
- Students compose a short essay to summarise what they have learnt

Anchor activity

When burning sodium is put into a gas jar of carbon dioxide. Peter and Mary argue for what might happen.

Peter: The fire will go out because there is no oxygen present.

Mary: The sodium will burn in carbon dioxide because sodium is a very reactive metal.

Who do you agree with? Write an argument to explain your idea.

Your argument should include:

- Claim (who do you agree with?) (~1-2 sentences)
- Evidence (support your claim with evidence. This include data from the activity of burning magnesium in carbon dioxide. Data should be appropriate (relate to your point) and sufficient (fully explain your claim) (~3-4 sentences)
- Reasoning (demonstrate why your evidence supports your claim using chemical principles) (~3-4 sentences)

Student Samples

I agree with Mary. I think sodium will burn in carbon dioxide because sodium is a very reactive metal. From the activity of burning magnesium in carbon dioxide, we saw that when burning magnesium was placed in carbon dioxide, the very bright white light was still there, it didn't go out and even started to burn more vigorously. The reason for this is that magnesium is more reactive than carbon. So, it can steal oxygen from carbon and continue burning, as oxygen is needed for something to burn. Sodium is more reactive than magnesium. Meaning that it is even more reactive than carbon. Therefore, it can steal oxygen from carbon and continue burning.

Student Samples

I agree with Mary. The reactivity of sodium is why sodium continues to burn. Using the data from putting burning magnesium in carbon dioxide, burning magnesium will continue to burn with a bright white flame and produce a black solid and white powder.

At high temperature, magnesium atoms in the metal combine with oxygen atoms in carbon dioxide. A chemical reaction produces white powder and black solid, which are magnesium oxide and carbon respectively.

Since Sodium has a higher reactivity than magnesium, due to sodium atom having one outermost shell electron only, while magnesium atom have two outermost electrons, sodium atom has a higher tendency to lose electrons than magnesium atom.

Therefore, if magnesium can keep burning in carbon dioxide. Sodium also can,

Student Samples

I agree with Mary that sodium will burn in carbon dioxide because sodium is a very reactive metal. Since sodium is more reactive than Mg, when Na atom reacts with oxygen atom to form NaO leaving carbon behind to support burning as carbon doesn't react with NaO.

Because Na is a very reactive metal. Na break CO_2 into carbon and oxygen and helps burning.

Summary - Evidence based learning is better than traditional learning approach

Evidence-based learning:

- prevents rote-learning
- students can use their prior knowledge and try to connect to the new knowledge in an easier way
- students enjoy the process more - more minds on and can be hands on as well

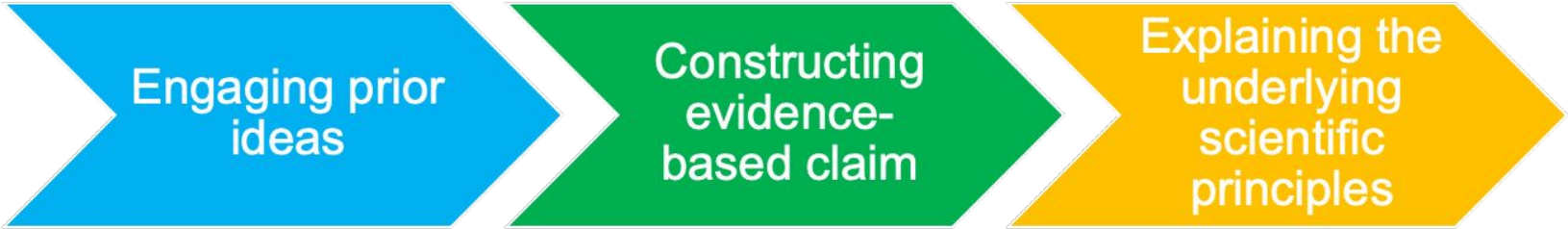
Part II

Designing simple investigative tasks for senior form students

Teaching Rate Law (e.g. order of reaction) (usually):

Introduce different concepts like order, how to use data method, graphical method, etc

→ ***rarely use investigative study (esp in S6)***
→ ***more lecture based learning***


Engaging prior ideas
Constructing evidence-based claim
Explaining the underlying scientific principles

1. **<u>Engaging prior ideas:</u>**
   - Ask students prior knowledge: how rate of reaction is affect by surface area, concentration, pressure and presence of catalyst
   - Demonstrate iodine clock reaction using Landolt method to arouse students' curiosity
   - Pose a question: how concentration of each reactant affect the rate quantitatively?

We use a microscale approach to investigate the iodine clock reaction

Why do the experiment in a microscale way?

- Reduce preparation time and time of experiment.
- Reduce ‘noise’ of the experiment (e.g. refilled chemicals, breaking of glasswares, washing apparatus…)
- More time to do the experiments repeatedly.
- More time for discussion and learning from peers

Why use the Landolt's method of iodine clock reaction?

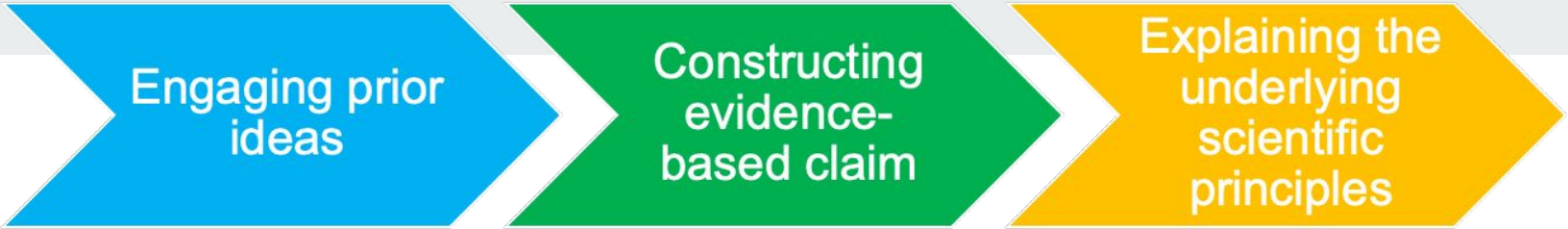
- no need addition of dilute acid
- more unfamiliar to students

$$IO_3^-(aq) + 3HSO_3^-(aq) \rightarrow I^-(aq) + 3H^+(aq) + 3SO_4^{2-}(aq)$$

$$6H^+(aq) + 5I^-(aq) + IO_3^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

$$I_2(aq) + HSO_3^-(aq) + H_2O(l) \rightarrow 2I^-(aq) + SO_4^{2-}(aq) + 3H^+(aq)$$

$$I_2(aq) + \text{starch} \rightarrow \text{dark-blue colored complex}$$

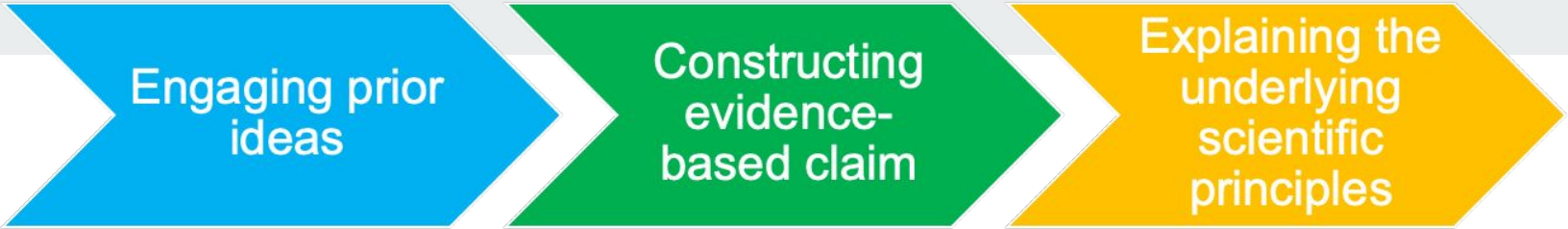


Constructing evidence-based claim

- Students read up on experimental procedures and design
- Teacher asks some reasons for procedural understanding of the experiment

  e.g.:

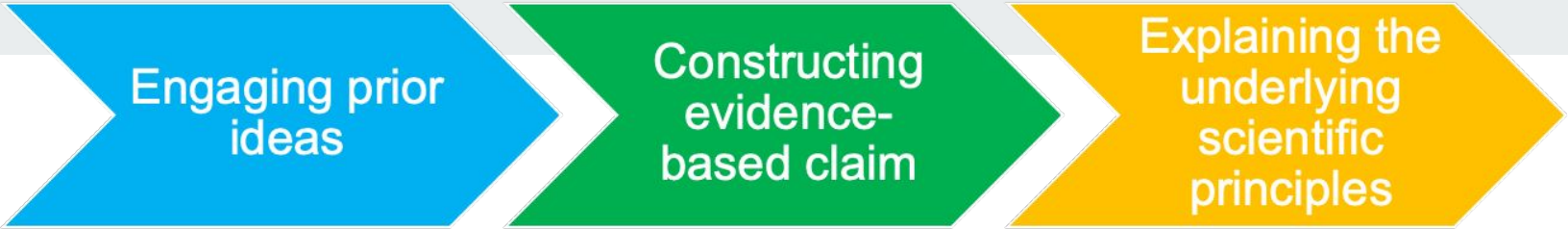
  - Why the total volume in each experiment was kept constant in the iodine clock reaction?
  - Why is it necessary to maintain a constant volume of sodium iodate when investigating the effect of sodium metabisulphite concentration on the rate of the iodine clock reaction?



Constructing evidence-based claim

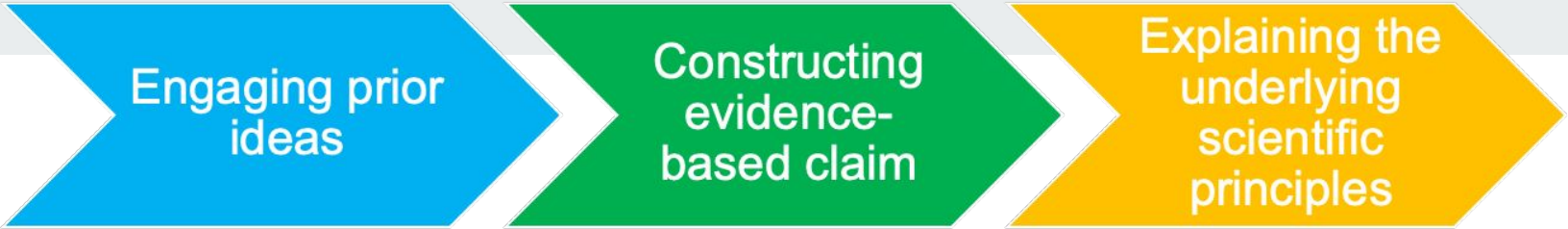
- After the discussion about experimental design, students work in groups to conduct the microscale practical work to determine the quantitative relationship between the concentration of reactants and the reaction time.

Set-up	Procedure
	1. Add 1 drop of starch solution to each of the four wells. 2. Add 8 drops of sodium iodate to each of the four wells. 3. Add 2, 4 and 6 drops of distilled water to the second, third and fourth well respectively. 4. Stir the mixture thoroughly. 5. Add 8 drops of sodium metabisulphite to the first well with stirring. 6. Record the time required when the solution turns blue/black. 7. Repeat steps 4-5 with 6, 4 and 2 drops of sodium metabisulphite in the second, third and fourth wells respectively. 8. Record the reaction time in the below table.



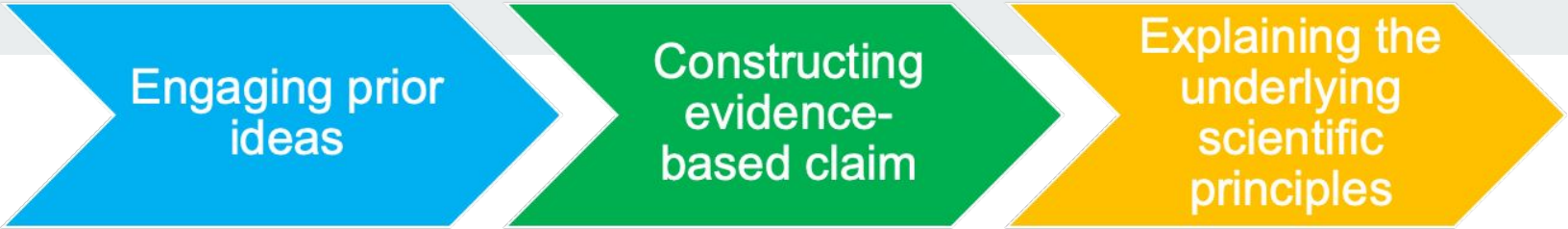
Explaining the underlying scientific principles

- Students record their findings in the provided table and use the data to deduce the relationship between the order of reaction with respect to the concentration of sodium metabisulphite
- Students are invited to present their strategies to the class on how they will calculate order of reaction = algebraic? graphical?



Using anchor activity to sustain inquiry of gifted students:

- Students extend their investigation to plan and conduct the experiment for determining the rate constant and order of reaction w.r.t. sodium iodate.



<u>Evaluating students performance:</u>

- Through a quiz/ test, summative assessment will be conducted

Summary

- engage students' prior ideas
- constructing evidence-based claim through hands-on activities/ demonstration
- scaffold student thinking through evidence cards
- sustain students' inquiry through anchor activities
- rethink and make a 'twist' of common practice for teaching science