Evidence-informed science practice

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5 March 2019

EVIDENCE FOR LEARNING

Acknowledgement of Country

We acknowledge Traditional Owners of Country throughout Australia.

We pay our respects to Aboriginal and Torres Strait Islander Elders past, present, and emerging.

Outline of webinar

Seven recommendations for teaching science:

1. Preconceptions
2. Self-regulation
3. Modelling
4. Memory
5. Practical work
6. The language of science
7. Feedback


QUIZ

Quiz

The current state of the evidence base suggests that…

1. Feedback on how students complete a task is more effective than general praise (True or False)
2. Metacognition and self-regulation cannot be taught rather it is found within the innate ability of the student (True or False)
3. Feedback for students is most effective when targeted to (select the three most effective):

   a) self, task, process and self-regulation (e.g. self is most effective and self-regulation is least effective)
   b) self-regulation, process, task and self
   c) self, self-regulation, process and task
   d) process, self, task, self-regulation

Seven recommendations for science teaching

1. **Preconceptions**: Build on the ideas that students bring to lessons.
2. **Self-regulation**: Help students direct their own learning.
3. **Modelling**: Use models to support understanding.
4. **Memory**: Support students to retain and retrieve knowledge.
5. **Practical work**: Use practical work purposefully and as part of a learning sequence.
6. **The language of science**: Develop scientific vocabulary and support students to read and write about science.
7. **Feedback**: Use structured feedback to move on students thinking.

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E4L

Preconceptions: Build on the ideas that students bring to lessons

- Cognitive conflict is an effective way of moving on students’ thinking and helping them reconstruct their existing ideas.
- Misconceptions can be difficult to shift, but doing so can lead to big gains in learning, particularly for threshold concepts. Diagnostic questions and small group discussions can be useful for identifying misconceptions.
- Changing thinking takes time and students need to revisit ideas and be shown different examples to develop their thinking.

How to identify student misconceptions

Diagnostic questions – multiple choice questions with the incorrect options carefully designed to uncover common misconceptions.

Which of the following parts of an animals' body are made of cells?

a) The muscles, but not the brain

b) The brain, but not the muscles

c) Both the muscles and brain

d) Neither the brain nor the muscles

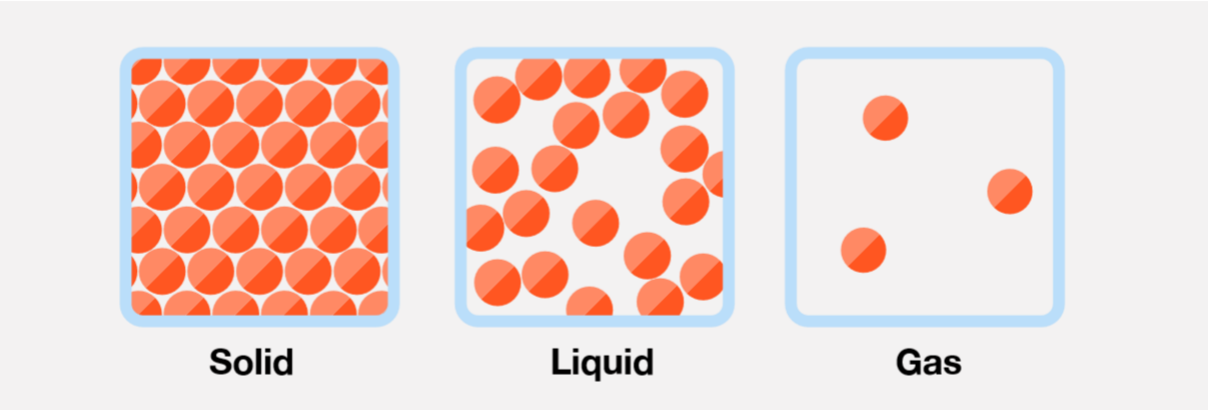
How to identify student misconceptions

Class and small group discussions

- Misconceptions can be uncovered through dialogue.
- Ask students to write down or discuss what they know about a topic.
- A list of students' ideas can be kept throughout the topic and revisited to show students how their thinking has changed over the course of several lessons.

Develop students' thinking through cognitive conflict and discussion

- *Cognitive conflict* is an effective way of moving on students' thinking and helping them reconstruct their existing ideas.
- Students make unexpected observations which challenge their misconceptions and restructure thinking to accommodate new evidence.
- An example is to show that air in a blocked syringe can be compressed into a smaller volume (for examples using a 100cm^3 syringe and showing that the air can be compressed to 50cm^3) but that a liquid and solid can not.



Allow enough time to challenge misconceptions and change thinking

- Some misconceptions can take time to shift, so it is important to use formative assessment to check that thinking has changed in the long-term.
- Many misconceptions link to threshold concepts. Threshold concepts are likely to be:
  - Transformative – they result in a change in perception of a subject and may involve a shift in values and attitudes.
  - Irreversible – the resulting change is unlikely to be forgotten.
  - Integrative – they expose a previously hidden interrelatedness between other concepts within a discipline.
  - Potentially troublesome – students may have difficulty coping with the new perspective that is offered.

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Metacognition and self-regulation

High impact, very low cost, based on extensive evidence

Average cost	Evidence security	Months' impact
$ (1 of 5)	4 of 5 locks	+7

Metacognition and self-regulation approaches have consistently high levels of impact.

1.2
Understand how students learn

Demonstrate knowledge and understanding of research into how students learn and the implications for teaching.

1.5
Differentiate teaching to meet the specific learning needs of students across the full range of abilities

Demonstrate knowledge and understanding of strategies for differentiating teaching to meet the specific learning needs of students across the full range of abilities.

evidenceforlearning.org.au/toolkit/metacognition-and-self-regulation

Metacognition and self-regulation

- How would you define metacognition and self-regulation?
- Do you think that they are helpful skills for students to have?
- Enter your answer in the chat box.

Self-regulation: Helping students direct their own learning

The ability of students to direct their own learning is often called self-regulation and includes three parts:

- **cognition** – students' understanding about strategies they can use to learn. For example strategies for solving equations or planning controlled experiments.
- **metacognition** – learners monitor and purposely direct their learning e.g. checking our memorisation technique was accurate or selecting the most appropriate cognitive strategy for the task we are undertaking;
- **motivation** – students' motivation to learn, including their self-beliefs and interest in topics. For example, students motivating themselves to undertake a tricky task for homework.

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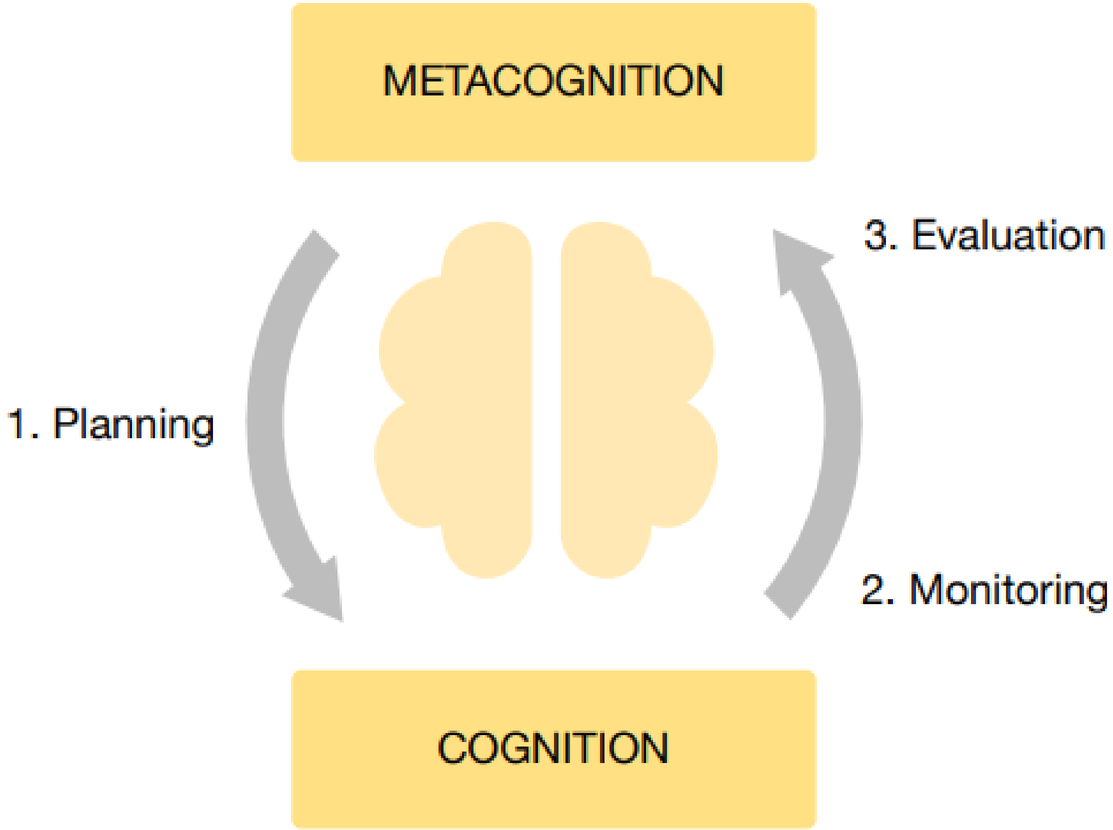
Metacognition and self-regulation

We approach any learning task or opportunity with some metacognitive knowledge about:

- Knowledge of *ourselves* as learners – our own abilities and attitudes.
- Knowledge of *strategies* – what strategies are effective and available.
- Knowledge of the *task* – the particular type of activity.
- Metacognitive regulation – planning how to undertake a task, working on it while monitoring the strategy and evaluating the overall success.



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Model your thinking to help students develop metacognitive and cognitive knowledge

Show your students how you think. You can provide a useful example for students by making your thinking processes explicit.

You can do this by working through problems in front of the class, talking through how you are approaching the problem, the kinds of strategies you are trying and why you've chosen them and how you are monitoring if they are successful.

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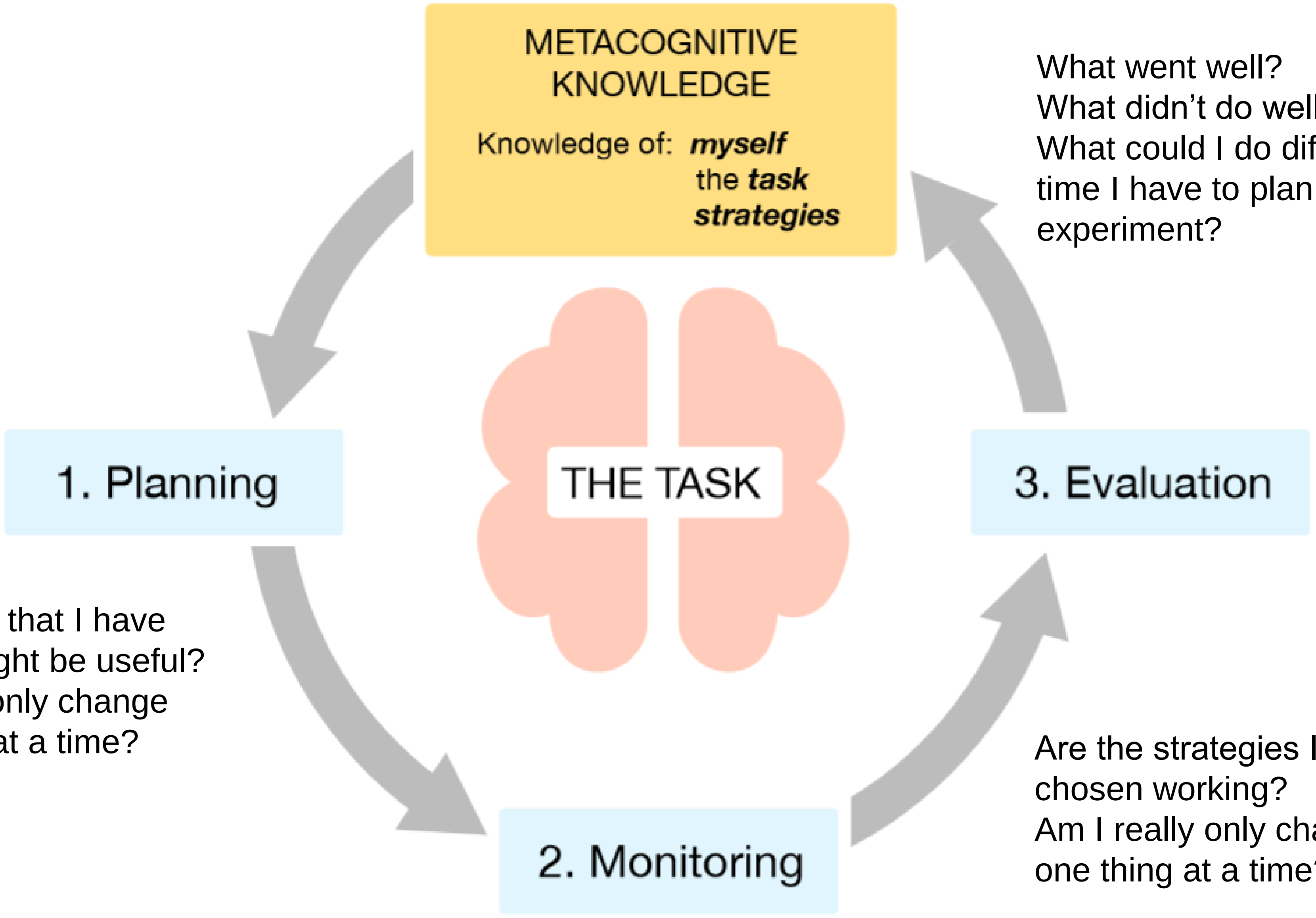
Explicitly teach students how to plan, monitor and evaluate their learning



What went well?
What didn't do well?
What could I do differently next time I have to plan an experiment?

Are there strategies that I have used before that might be useful?
How will I ensure I only change one variable/factor at a time?

Are the strategies I've chosen working?
Am I really only changing one thing at a time?

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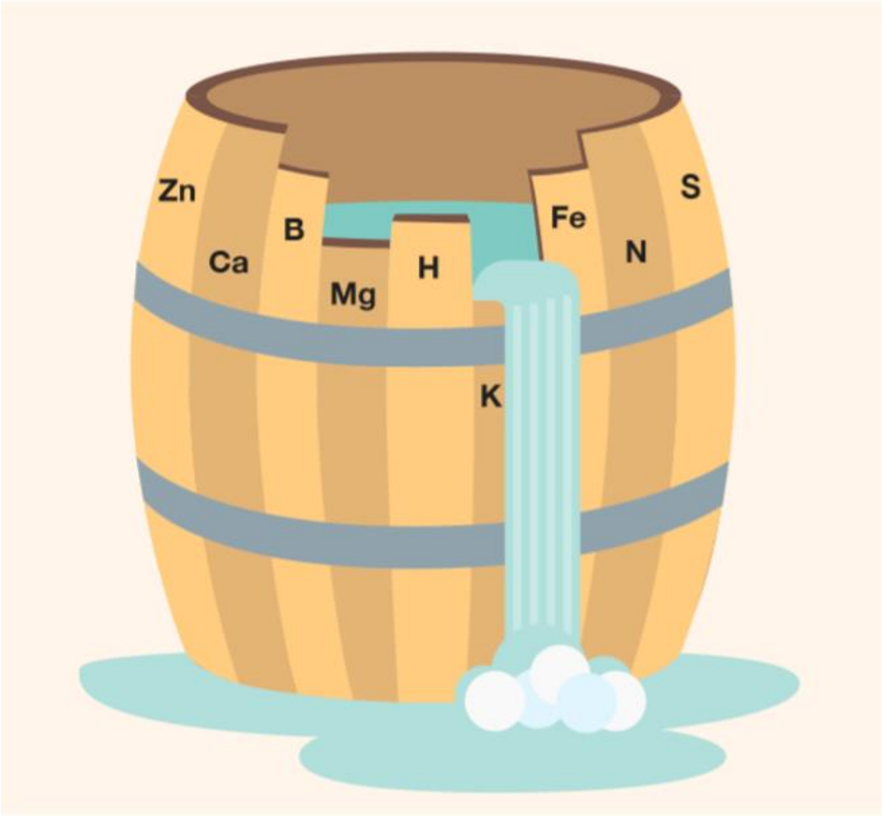
Modelling: Use models to support understanding

Models are an essential part of developing and sharing scientific knowledge. They have been around for as long as scientists have been explaining their ideas to one another.

Models are critical as science often involves working with phenomena and concepts that are inaccessible to our everyday senses.



Modelling: Use models to support understanding

Models that teaches often use include:

- Three dimensional models – plastic ball and stick model of an organic molecule.
- Verbal and written models – analogies such as water flow for electric current.
- Mathematical models – equations of motion and chemical formulae.
- Visuals – graphs, diagrams and animations.
- Computer models – simulations of population growth.

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Memory: support students to retain and retrieve knowledge

- Long-term memory – store of knowledge.
- Working memory – information that is being actively processed is held – it's where the thinking happens.
- Working memory can hold around seven 'bits' of information and only keeps them for about 20 seconds unless they are refreshed by rehearsal.

Where's the evidence?

Cognitive science has recently led to significant breakthroughs in understanding the different functions and processes of the brain, but applying laboratory data to classroom practice is not straightforward. Research does support:

- cognitive load theory, although it is less clear how much information pupils can hold in their working memory;
- spaced review, which has the most evidence from classroom studies of the strategies discussed in this section, with effects noted across different contexts; and
- retrieval practice and elaborative interrogation, which have a number of studies with positive effects.

Pay attention to cognitive load

Any task that exceeds the limit of the working memory will result in cognitive overload and this increases the possibility that the content may be misunderstood and not effectively encoded in the long term memory.

A key way of preventing cognitive overload is to help students commit important and frequently used pieces of information to their long-term memory.

Pay attention to cognitive load

Spaced review – involves revisiting a topic after a ‘forgetting gap’ and strengthens long-term memory. A simple way to manage this is to build in review time, including reviewing learning from the previous lesson at the start of the next one or over longer periods (at the end of each week, month or topic).

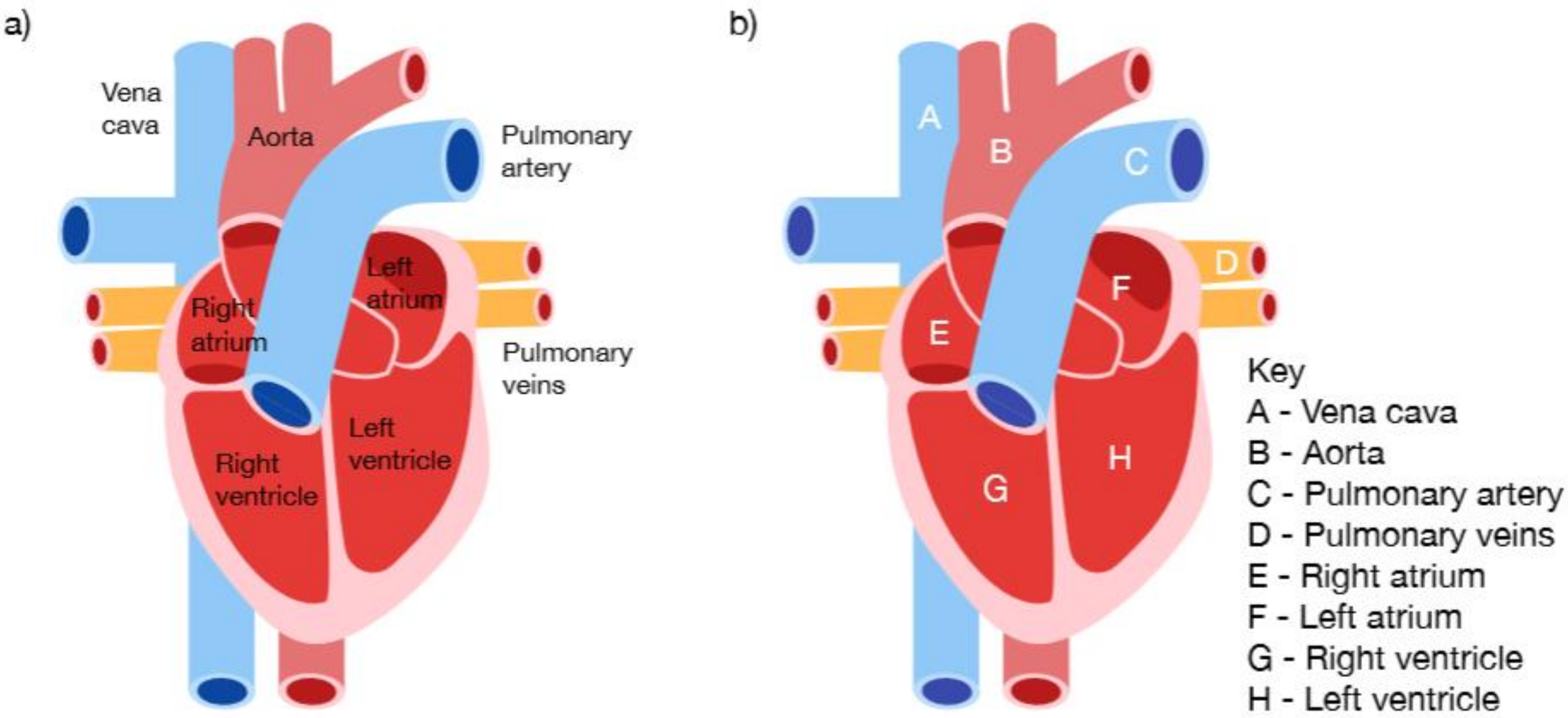
Retrieval practice – involves retrieving something you have learnt in the past and bringing it back to mind.

Avoid split attention by ensuring students do not need to refer to multiple sources to complete a task.

Pay attention to cognitive load

Do you find diagram a) or b) easier to understand?

Type your answer into the chat box.



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Practical work: use practical work purposely and as part of a learning sequence

Purposes of practical science:

- to teach the principles of scientific enquiry;
- to improve understanding of theory through practical experience;
- to teach specific practical skills such as measurement and observation, that may be useful in future study or employment;
- to develop higher level skills and attributes such as communication, teamwork and perseverance and;
- to motivate and engage students.

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E4L

Practical work: use practical work purposely and as part of a learning sequence

What knowledge and skills will students need before they can get the most out of the practical?

You will need to plan how their practical skills develop in the same way as you plan the development of their knowledge.

Students need to be ‘*minds on’* as well as ‘*hands on*’.

Practical work: use practical work purposely and as part of a learning sequence

	Assessing if a practical activity is 'hands on'	Assessing if a practical activity is 'minds on'
Do the students do what is intended?	Students do what was intended with the objects and materials provided, and make the intended observations.	During the activity, students think about what they are doing and observing, using the ideas intended in the activity.
Do the students learn what is intended?	Students can later recall and describe what they did in the activity and what they observed.	Students can later discuss the activity using the ideas it was aiming to discuss.

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Practical work: use practical work purposely and as part of a learning sequence

Use practical work to develop scientific reasoning.

Use a variety of approaches to practical science:

- Virtual experiments can support real experiments.
- Open-ended projects in science show several benefits including learning science ideas, attitudes towards pursuing science carers and skill development.

Carefully select the vocabulary to teach and focus on the most tricky words

Be aware of the vocabulary demands of a topic and make a conscious choice about the words that you are going to teach and when to introduce them.

Focus on the words that students really need to understand and make sure they understand them well.

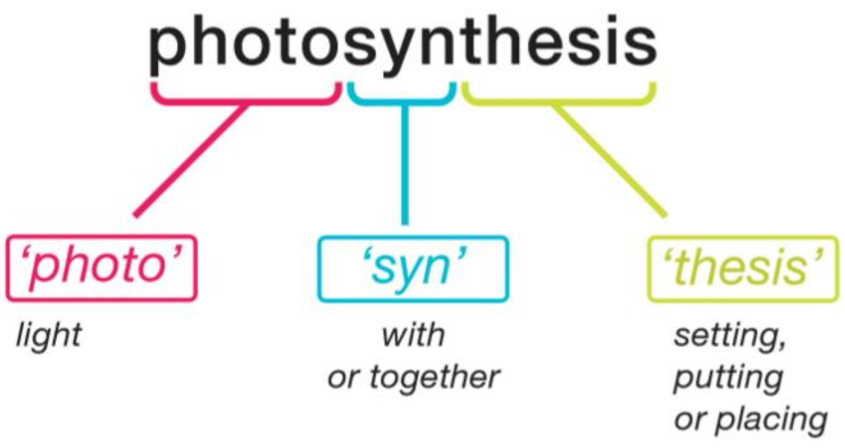
Less is more; a deep understanding of fewer words is better than understanding lots of words at surface level.

Show the links between words and their composite parts

Support students to understand the meaning of root words and how to use prefixes and suffixes to change the meaning of root words.

Teach students to segment and manipulate words according to their morphemes (unit parts) so that new words with similar morphemes are more easily recognised and understood. This is an efficient way of expanding vocabulary.

Figure 8: Teaching the morphemes that make up the word 'photosynthesis'



Putting together with light

Support students to develop their scientific writing skills

Good writing needs a strong sense of purpose and audience: ‘*Why am I writing this, and who is it for?’*

Frameworks can be helpful to support early writing and to teach students strategies they can use over time. The framework can be withdrawn as students become more confident writers.

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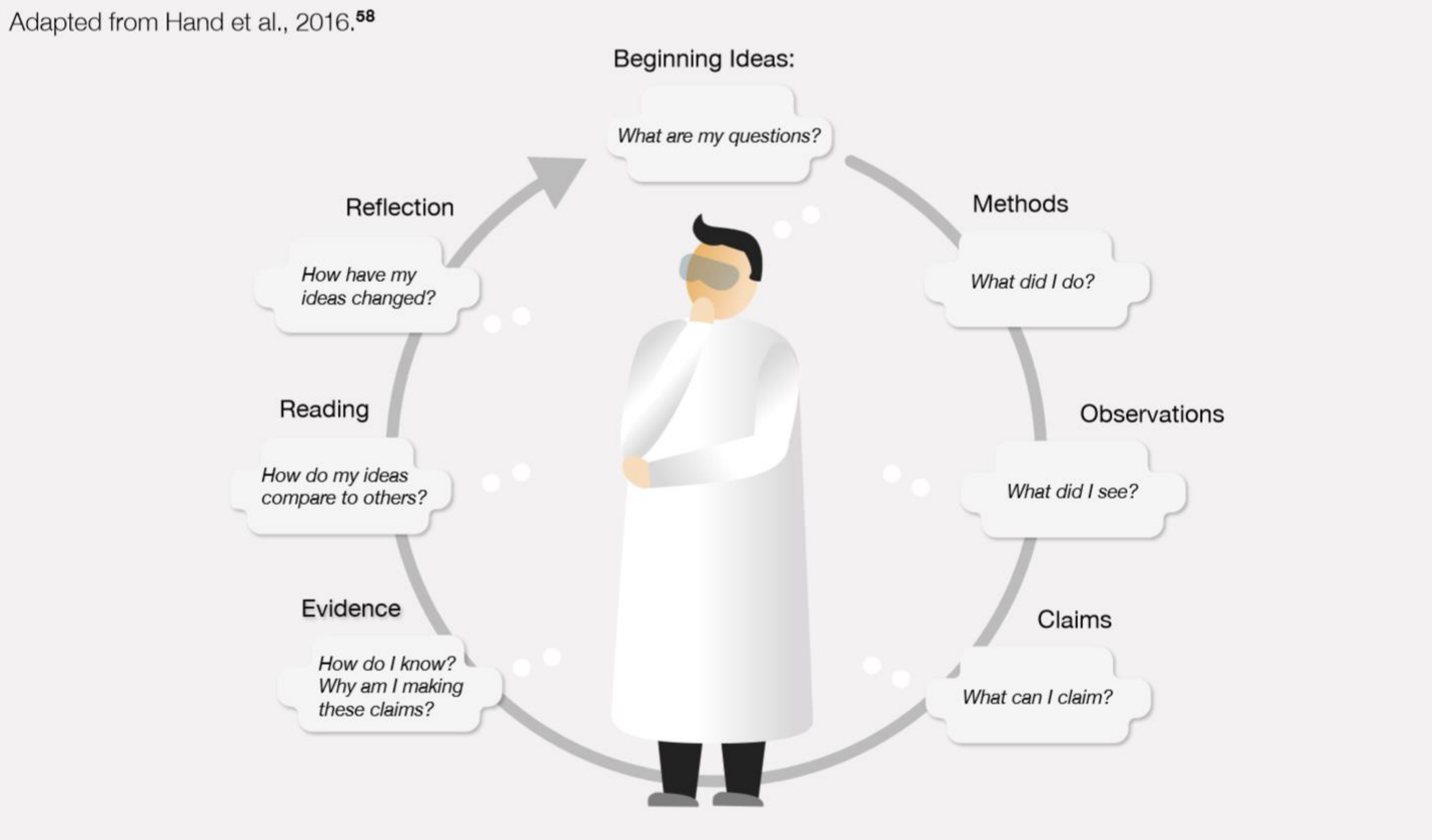
A scientific writing template



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Feedback

High impact for very low cost, based on moderate evidence.

Feedback studies tend to show very high effects on learning.

Average cost: $ $ $ $ $

Evidence security: 🔒🔒🔒🔒🔒

Months' impact: +8

5.2

Provide feedback to students on their learning

Demonstrate an understanding of the purpose of providing timely and appropriate feedback to students about their learning.

1.2

Understand how students learn

Demonstrate knowledge and understanding of research into how students learn and the implications for teaching.

evidenceforlearning.org.au/toolkit/feedback/

Feedback

- How would you define feedback?
- What are the different categories of feedback you can give to students (e.g. what are the different areas feedback can focus on?)
- Enter your answer into the chat box.

Feedback: use structured feedback to move students' thinking

Student performance improves when feedback is in the form of constructive comments, and there are ways of doing this that minimise workload.

Feedback is most effective when students know how to respond and are given time to do so.

Peer assessment is useful as students often accept criticism of their work from their peers which they would not accept from their teachers.

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The four types of feedback that teachers can give

The most useful feedback is at the process and self regulation level, although sometimes it may be appropriate to give feedback at the other two levels.

Level	The question it helps students to answer	Example	Impact
Self evaluation	How good am I?	Well done, you've worked really hard this week.	Ineffective
Task	How can I get this done? How can I make this better?	Next time you do a calculation like this, try to set it out the way I showed you.	Useful
Process	How can I get better in tasks like this? What does it mean to be good in this subject?	Your understanding of Ohm's Law is good, but be careful to use the correct units.	Powerful
Self-regulation	How can I manage myself to learn better? How can I motivate myself?	Are you happy that you understand photosynthesis now? What could you do to extend your understanding further?	Powerful

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Provide feedback as comments rather than marks

Marks can demotivate students with lower achievement and can make students with higher achievement complacent; In contrast, comments show both how they can do better: ‘You can understand about homeostasis, but try to find some examples from plants as well as animals.’

Try to make quality not quantity – the smaller quantity of richer feedback is likely to do more good than a larger quantity of superficial marking.

Make sure that students can respond to your feedback

Quality feedback:

- is specific, accurate and clear
- makes connections with prior performance, or students success or failure on another part of a task
- is encouraging, helping students to identify things that are hard and require extra attention
- provides guidance to students on how to respond to their teacher’s comments
- provides concrete suggestions for improvement.

Questions?

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