Insight

Susie d'Espagnac shares how she helps prepare student teachers to embed routines into practical science lessons

Five evidence-based strategies to plan and implement practical science lessons

Science is a practical discipline with experimentation as part of its identity, essential for nurturing a life-long interest in the subject. It has been suggested that learning science without practical work is like learning English without books (Gatsby Foundation, 2017). However, there seems to be a worrying decline in the frequency of hands-on practical science lessons in secondary schools, with some sources reporting as little as 26% of science lessons involving practical work (Hamlyn *et al.*, 2023). Equipping our science teachers with the knowledge, skills and confidence to run effective practical lessons could go some way towards helping reverse this trend. Ensuring science lessons run smoothly through effective use of routines is a good place to start.

Presented here are five evidence-based strategies (summarised in Figure 1) that can be embedded as routine into the planning and implementation of any practical science lesson before teachers even utter the words '*OK, off you go!*'

Strategy 1: Purpose and organisation

The purpose of the practical work being carried out must be clear to teachers and pupils (Toplis and Allen, 2012; Hodson, 2014; Gatsby Foundation, 2017). Depending on the key stage (KS), the content and the nature of the practical work itself, the purpose may be entirely different. For example, the purpose of a KS3 (age 11–14) lesson using microscopes could be centred around identifying the difference between plant and animal cells, while the purpose of a KS4 (age 14–16) lesson using microscopes could be to calculate the length of a cell. The practical element (using a microscope) is the same, but the purpose is different and requires different instructional input, organisation and resources. Pupils cannot be expected to arrive at a scientific theory or concept through simply taking part in practical work. So considering the purpose of practical work during mid- to long-term planning will ensure that pupils are given sufficient theoretical input before and after carrying out the task (Toplis and Allen, 2012; Ofsted, 2021). When it comes to teaching the lesson itself, organisation is also key. Depending on the purpose of the practical work, this could include (but is not limited to):

- teachers preparing pupil pairings or groupings in advance;
- setting and displaying a time limit;
- generating example data to fall back on;
- printing resources such as a table of results or axes for a graph;
- laying out equipment in stations rather than all in one place;
- allocating variables to different groups.

'Learning science without practical work is like learning English without books.'

For example, when carrying out an investigation into how temperature affects rate of reaction, do all pupils need to test all temperatures, or could the class be split into five sections, each testing one temperature, and the results collated at the end? By considering

Figure 1 The five evidence-based strategies that can be embedded as routine into the planning and implementation of any practical science lesson

purpose and organisation as the first part of a practical routine, teachers can alleviate some of the subsequent pitfalls. These might include pupils wasting time sorting out their own groups, not being able to discuss results because of lack of collected data, and spending 15 minutes ensuring everyone has a pencil and ruler to draw graph axes with appropriate scales (of course, if the purpose of the practical is data interpretation, their graph-drawing skills will become the focus).

Communicating the purpose of the practical work to the pupils will help prioritise what needs to be shared, and manage cognitive load for them (Holman and Yeomans, 2018). For example, if pupils know the purpose is to identify products of electrolysis, limit the amount of information they need to process by setting up the equipment as a whole class and completing each step together, rather than all pupils following methods independently, before allowing them to individually watch the reaction in progress to observe results. This minimises the scramble for equipment and allows the teacher to deal with questions that affect the whole class such as '*Does the black wire have to go in the black socket?*' This is also reliant on appropriate mid- to long-term planning and a clear awareness of where the practical work sits in the scheme of learning.

Strategy 2: Explicit instruction

The next part of the routine considers how the practical task will be introduced and carried out. Explicit instruction does not mean lecturing, but planning and communicating how pupils will be instructed to carry out the practical work is key. Explicit instruction can range from highly structured and teacher-led (such as demonstrating a method) to guided pupil inquiry (such as following a method) (Vorholzer, von Aufschnaiter and Boone, 2020). Simply giving pupils a method to read and setting them off is often not sufficient, but giving pupils a set time to read the method in silence followed by structured dialogue and questioning might allow for better engagement with the task and opportunity to uncover and address misconceptions before they begin the practical task. If the purpose is for pupils to write their own method, consider how this might be scaffolded, for example by explaining and showing how different pieces of equipment are used, emphasising and explaining key terminology, and ensuring theoretical knowledge is sufficient beforehand.

Strategy 3: Modelling

In this context, modelling refers to the act of modelling a physical or mental process, rather than use of conceptual models such as the particle model.

Modelling often goes hand in hand with the explicit instruction phase and is one of the most valuable tools in the science teacher's toolkit. Practical science experiments are full of fiddly equipment with complicated names, and often even the simplest of tasks can lead to mayhem if not properly modelled. Take the KS3 experiment of the collapsing can as an example: simple pieces of equipment and a fairly simple process, but pupils often struggle with the act of inverting the hot can using tongs. By modelling how to hold the equipment and how to carry out the inversion, and then having pupils practise this process with a cold, empty can, teachers can minimise the risk of disruption and health and safety issues when they carry out the real thing. Modelling physical and mental processes helps pupils develop metacognitive skills (Holman and Yeomans, 2018), and embedding this as part of a practical routine will help reduce misunderstanding and promote independence.

'Modelling … is one of the most valuable tools in the science teacher's toolkit.'

Explicit instruction and modelling are closely linked. Using these strategies in what has been coined a 'slow practical' (Boxer, 2020), where each step is taken slowly with clear instruction and modelling and completed as a whole class, can ensure that all pupils have a firm understanding of each stage of the experiment while the teacher maintains a calm and structured environment.

Strategy 4: Safety and risk management

This is arguably one of the most important parts of the routine and one that absolutely cannot be skipped. Most pupils know they should use safety precautions such as protective eyewear, tie back long hair and stand up when handling chemicals, but how much of this is a regurgitation of commonly heard phrases rather than an understanding of managing risk? If a pupil suggests wearing goggles for building parallel circuits, they have not understood the nature of the practical work and have not understood the risk. The 'working scientifically' aspect of the science National Curriculum in England states that pupils should be given the opportunity to consider health and safety aspects when carrying out practical work, so try to elicit this from pupils before explicitly telling them.

This will also promote self-regulation, build on pupils' existing knowledge and allow misconceptions to be addressed as they arise (Holman and Yeomans, 2018). The teacher remains responsible for health and safety in a science lesson, so must ensure all pupils follow the safety rules.

Strategy 5: Assessment

The final strategy, and the one that brings everything together, is assessment. Throughout the entire process of setting up a practical science activity, effective use of assessment should be a key part of the routine. Assessment at this stage is not necessarily about checking understanding of scientific content, but more about checking pupils' understanding of the task they are about to carry out. Ways of embedding assessment into a practical routine include (but are not limited to):

- use of mini whiteboards to check whole-class understanding of an aspect of the practical such as identifying variables;
- use of cold-calling for low-stakes recall of facts such as the volume of acid required for titration;
- use of collaborative questioning strategies such as think–pair–share (Lyman, 1981) to generate discussion and feedback on an aspect of the practical such as risk management;
- giving instructions (for example reading a method) followed by a mini-quiz and peer/self-assessment.

If pupils cannot clearly demonstrate that they have understood the practical task they are about to do, they should not embark on it. Don't be afraid to revisit aspects of the routine through questioning, and adapt instructions until it is clear pupils are adequately prepared.

Conclusion

We must not restrict the need for pupils to experience science and how it is carried out; they must *do* science as well as learn about it and how it is done (Hodson, 2014), and part of carrying out successful and purposeful practical work comes from embedding routines in practice. Routine mid- to long-term planning helps consider the context of a practical in the scheme of learning, but having a basic routine to rely on during a practical lesson will make adapting on the spot more manageable and help teachers consider how each part of a practical experiment might need to be scaffolded for pupils with SEND. Developing, practising and embedding a routine for teaching practical work in lessons, before pupils even pick up a piece of equipment, will not only save time and effort in the long run but will increase teacher confidence and hopefully bring more practical work back into science lessons.

REFERENCES

Boxer, A. (2020) Practicals; Why you should take them slow. *Education in Chemistry*. https://edu.rsc.org/ideas/practicals-why-you-should-take-them-slow/4012186.article

Gatsby Foundation (2017) *Good Practical Science*. www.gatsby.org.uk/app/uploads/sites/2/2025/07/good-practical-science-report.pdf

Hamlyn, B., Brownstein, L., Shepherd, A., Stammers, J. and Lemon, C. (2023) *Science Education Tracker 2023*. London: The Royal Society. https://royalsociety.org/news-resources/projects/science-education-tracker

Hodson, D. (2014) Learning science, learning about science, doing science: different goals demand different learning methods. *International Journal of Science Education*, **36**(15), 2534–2553.

Holman, J. and Yeomans, E. (2018) *Improving Secondary Science Guidance Report*. Education Endowment Foundation. https://educationendowmentfoundation.org.uk/education-evidence/guidance-reports/science-ks3-ks4

Lyman, F. (1981) The responsive classroom discussion. In *Mainstreaming Digest*, ed. Anderson, A. S. pp.109–113. College Park, MD: University of Maryland College of Education.

Ofsted (2021) *Research Review Series: Science*. www.gov.uk/government/publications/research-review-series-science/research-review-series-science#fn:165

Toplis, R. and Allen, M. (2012) 'I do and I understand?' Practical work and laboratory use in United Kingdom schools. *Eurasia Journal of Mathematics, Science and Technology Education*, **8**(1), 3–9.

Vorholzer, A., von Aufschnaiter, C. and Boone, W. J. (2020) Fostering upper secondary students' ability to engage in practices of scientific investigation: a comparative analysis of an explicit and an implicit instructional approach. *Research in Science Education*, **50**(1), 333–359.

Susie d'Espagnac
Assistant Professor in Science Education at the University of Sussex
Sc2003@sussex.ac.uk