Purposeful practical work in **primary science**

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Contents

1. Executive summary

Practical work is a distinctive feature of science teaching, but its role in primary science is not always clear, with teachers uncertain about how to use it most effectively to support learning. This study viewed practical work from a uniquely primary perspective, to consider its use in science lessons with young children.

Drawing on a scoping literature review examining 195 documents, 231 responses to a stakeholder survey and 34 teacher interviews, this research makes three key contributions to the field: a new definition, a prioritisation of purposes and a model for pedagogy.

In the scoping literature review, we found that many authors were either not explicit with their definition of practical work, or they relied on a view based in the secondary school laboratory which did not take account of the foundational sensory learning experiences of younger children. We present a new definition for practical work in primary school science, that emphasises the importance of children communicating about their 'hands-on' (sensory experiences), 'minds-on' (science thinking) interactions with the world around them.

Definition of practical work in primary science

Children observe, manipulate, communicate and connect their science thinking through sensory learning experiences with physical objects and phenomena.

Collating 10 possible purposes for practical work in primary science from the literature, we asked teachers and other stakeholders to rank their importance and likelihood in a nationwide survey. The majority of respondents classified all purposes as important, but with some slightly less likely to happen regularly in classroom learning.

The interviews provided insights into the barriers and enablers for practical work, for example, with availability of resources and confidence of teachers in their science pedagogy influencing how often practical work took place.

In the survey and interviews, teachers were enthusiastic about practical science and considered practical work to be an essential part of primary science teaching and learning.

We found a wide range of possible purposes for practical work in primary science, but propose that a 'core' purpose should always be selected, so that the intended science learning is explicit and focused. This will help teachers to assess whether the practical work has been effective.

Purposes of practical work

The Purposes Framework (Figure 1, page 4) supports teachers to identify why practical work would be undertaken.

1. Firstly, practical work engages children, supporting their interest and attention within the lesson.
2. Secondly, practical work addresses one or both of two core purposes for children's learning in science:
   i. developing the children's science **practices** e.g. measuring skills, understanding of different approaches to enquiry and the scientific method for planning, doing or reviewing,
   ii. developing the **concepts** of science, e.g. vocabulary, scientific ideas or content of biology, chemistry or physics.
3. Thirdly, practical work supports a longer-term aim of helping children to understand science as a discipline, recognising how science is related to their lives and how important it is to them as global citizens.
4. Finally, the Framework acknowledges science as a part of a broader education entitlement, where practical work contributes to children's development of social skills and cross-curricular learning.

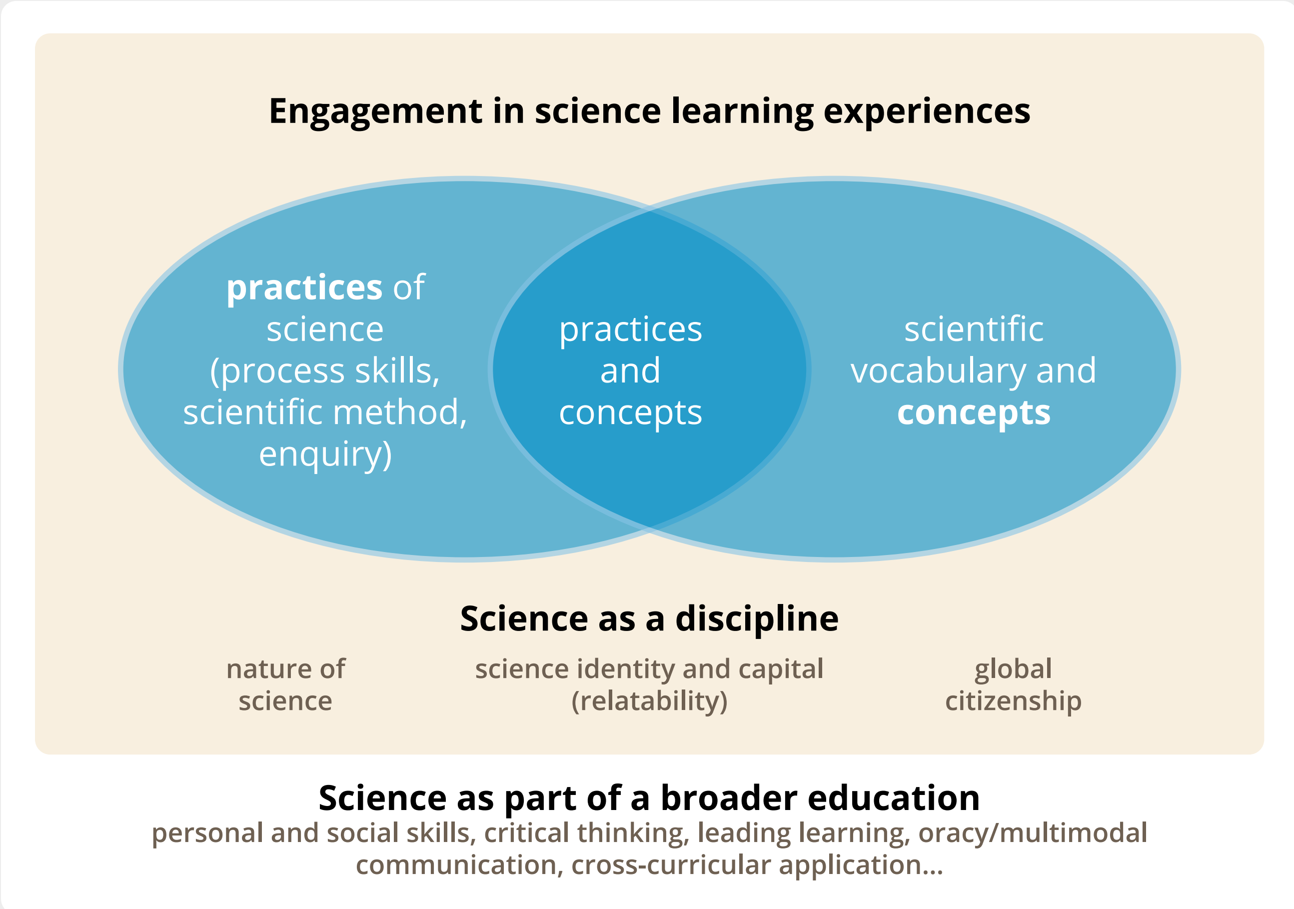


Figure 1. The Purposes Framework: a framework for prioritising the purposes for practical work in primary science, with core purposes in white text

Pedagogy for practical work

Building on the work of Abrahams and Millar (2008) and others, this research also proposes a model for teaching and learning (pedagogy) that supports teachers to plan for and curate practical science learning experiences in a primary context (Figure 2, page 5). From the child's perspective, three features of effective practical work are defined within the model, each coming together to inspire embodied learning experiences within primary science. The features for children's learning are:

- 'Hands-on' sensory engagement, where children explore and observe real objects and scientific phenomena.
- 'Minds-on' cognitive engagement, where children make connections with their science learning and prior real-world experiences.
- Multimodal communication, where children describe and explain their sensory experiences in words and gestures, with the support of peers and adults.

From the teacher's perspective, we propose three essential elements when planning for effective practical work, represented in the Pedagogy Model (Figure 2). These draw on the Purposes Framework, informing the teacher's role during planning and within the classroom. The elements for teachers to consider are:

1. purposefully setting up practical work with a defined core purpose,
2. explicitly connecting practical work to science learning, and
3. adapting feedback to children and scaffolding support throughout the activity.

This pedagogical model can be used to consider and to plan for how teaching practical work can happen. It explains the types of experiences that will be happening for the child and what the teacher's role is to structure this.

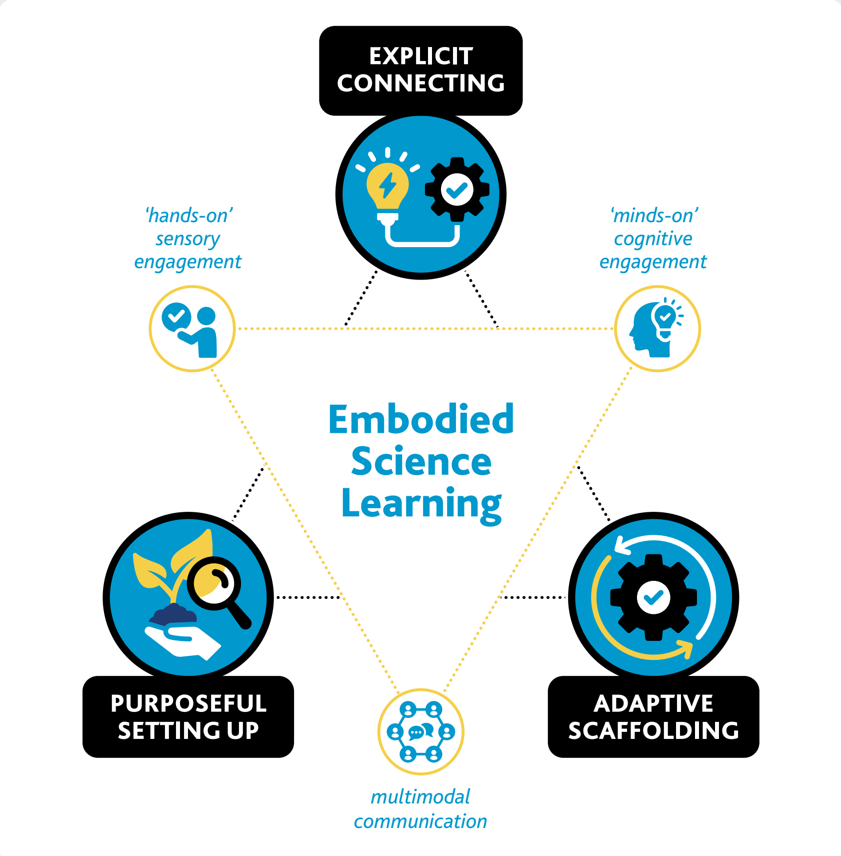


Figure 2. The Pedagogy Model: a pedagogical model for practical work in primary science, with mechanisms to stimulate children's learning (yellow triangle) supported by the teacher curating the learning experiences

Call to Action

The literature, survey and interview responses all promoted practical work as a defining feature of primary science teaching, that supports children's engagement and learning in science. In this guidance, we further explain the Purposes Framework and the Pedagogy Model, providing examples of practical work from classrooms across the four UK nations.

We call on all involved in primary science education across the four UK nations and internationally to use this guidance to promote and exemplify purposeful practical work for the effective teaching of primary science practices and concepts.

Stimulate professional discussions for the development of practical work in primary science:

- **Teachers:** think about your last/next practical activity and identify its core purpose(s), how effective was the practical work at meeting these aim(s)?
- **Science leads and school leaders:** how confident are colleagues with using practical work to teach science practices and/or science concepts?
- **Professional development leads and initial teacher educators:** do examples of practical work included in your programme support 'hands-on', 'minds-on' communication?
- **Policy-makers and resource developers:** how explicit are purposes for practical work in your guidance?

2. Introduction

Practical work is what makes science distinctive as a school subject; it can engage children in, and beyond, their science lessons, sparking interest in the world around them and supporting their science learning. Much has been written about the role of practical work, but very little of this has been from a uniquely primary perspective.

In this study, we wanted to consider both the guidance that has come before, but also the viewpoints of those currently teaching young children in a primary school context.

The place and purpose of practical work in primary school science across the UK has become increasingly confused in recent years, with conflicting priorities, curriculum overload and pandemic legacies (e.g. Ofsted, 2023, Bianchi et al., 2021) all leading to uncertainty about what to do in class. Clarity around purposeful use of practical work in primary science is needed, to support teachers and educators to use it as an effective tool for engaging young science learners.

In this study, we examined evidence from international research and the latest guidance from each nation of the UK, together with asking teachers and other stakeholders about their current experiences in the classroom. By considering how theory related to current practice, we aimed to find out how purposeful and effective practical work is understood and enacted in primary school science in the UK.

3. Research study outline

This Nuffield Foundation funded research study ran from April 2023 to March 2025, with the aim of answering the following:

Research question:
How is purposeful and effective practical work understood and enacted in primary school science in the UK?

The research began with a literature review, to consider pre-existing work in this field. This was followed by a nationwide stakeholder survey and teacher interviews to consider current practice in primary science practical work. An Advisory Group, of teachers and educators representing each of the four nations of the UK, were consulted throughout the study. A summary of the phases of research is provided in Table 1, with further detail about the methodology in the Appendices.

Table 1: Overview of research (see Appendices 2-4 for further details)

Research phase	Research sub-question	Methods and data
Phase 1: Scoping review April – September 2023 onwards	How does the academic and grey literature define and describe the purpose and effectiveness of practical work for primary school science?	Keyword search of academic journal databases, together with collection of curricula and policy documents for each UK nation. The literature was revisited at regular intervals to include new publications. A total of 195 documents were analysed to identify practical work definitions, purposes and empirical outcomes.
Phase 2: Sector wide survey September 2023 – February 2024	How do stakeholders in each of the four UK nations define and describe the purpose and effectiveness of practical work for primary school science?	An online survey was constructed to find out about perspectives of teachers and others working in the education sector. It was shared widely on social media and at primary science events. Responses from 231 anonymous stakeholders were analysed using descriptive statistics and thematic coding.
Phase 3: Teacher interviews February – October 2024	How do teachers enact practical work in primary school science across each of the four nations in the UK?	Practising teachers who had completed the survey and gave permission for an online interview were invited to share their experiences and examples of practical work in the classroom. 34 interviews took place and anonymous transcripts were coded to identify themes around purposes, enablers, barriers and examples of practical work.
Phase 4: Guidance report and dissemination November 2024 – March 2025	What recommendations can be put forward to strengthen and develop policy and practice for practical work in primary school science in the UK?	Findings from above were collated. The research team discussed emerging guidance with the Advisory Group and educators at a range of primary science events in order to refine wording.

4. Findings

4a. What do we mean by practical work?

Practical work is frequently described as an 'essential' part of learning science (Gatsby, 2017), it is part of what makes science distinct from other subjects. In the literature, research studies often did not explicitly define what they meant by practical work, but where definitions were in place, these generally include mention of 'real objects' and some sort of direct interaction, a 'hands-on' manipulation, for example:

> *Practical work—activities in which the students manipulate and observe real objects and materials.* (Abrahams & Millar, 2008, p.1945)
>
> *Learning activities in which students observe, investigate and develop an understanding of the world around them, through direct, often hands-on experience of phenomena or manipulating real objects and materials.* (SCORE, 2013, p.2)
>
> *Any type of science teaching and learning activity in which students, working either individually or in small groups, are required to manipulate and/or observe real objects and materials (e.g. carrying out a titration or observing the results of a pH test).* (Abrahams et al., 2014, p.264)
>
> *Practical work may consist of: sensory experiences, observation and illustration activities, practical exercises and investigations or investigative activities, where we could include experimental work.* (Pereira et al., 2020, p.66)
>
> *Practical work is defined here as any planned teaching and learning activity that involves, at some point, the students in observing or manipulating real objects and materials.* (Ofsted, 2021)
>
> *Experiences in which students engage in various hands-on activities or investigations involving scientific equipment or apparatus, inclusive of laboratory work and experiments.* (Wei et al., 2022, p.950)

Figure 3. Practical work definition wordle using key words from definitions in 71 texts

'Hands-on' manipulation is a recurrent theme, but it is also frequently expressed in terms of secondary school laboratory-style practical work, thus we saw a need to create a definition that encapsulates a more primary perspective. A primary-age specific definition makes the foundational sensory learning experiences more explicit, together with the need for young children to communicate with others about their interactions with the world around them. The call for practical work to be 'minds-on' as well as 'hands on' reverberates through the literature from Millar and Abrahams (2009) onwards, where activities become 'minds-on' when children make links between the practical work and their understanding of science. This essential connection of sensory experiences ('hands-on') and science thinking ('minds-on') is contained and re-emphasised within the new definition of what it means to do practical work.

Definition of practical work in primary science

Children observe, manipulate, communicate and connect their science thinking through sensory learning experiences with physical objects and phenomena.

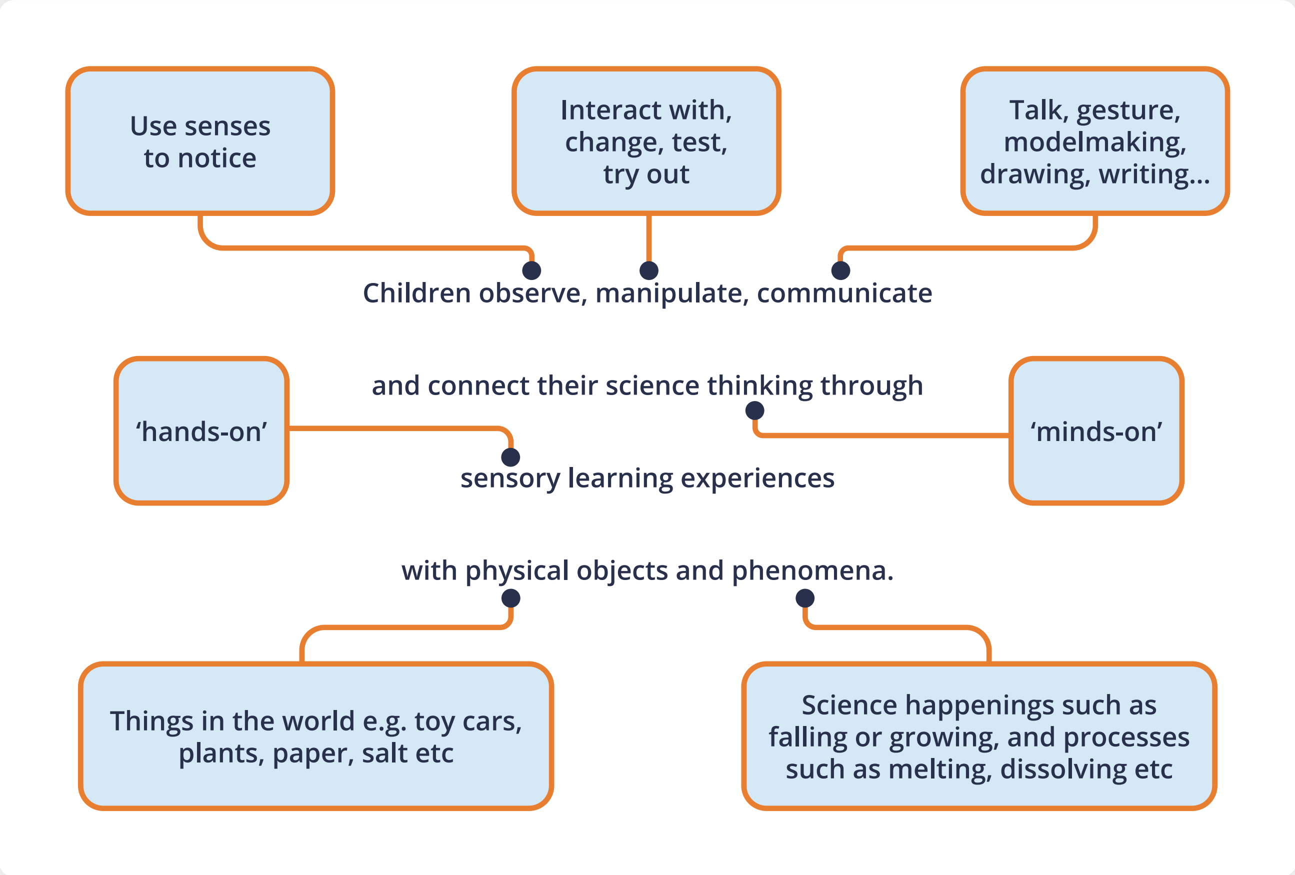


Figure 4. Explanation of definition keywords

We see practical work as a sensory, embodied experience. 'Hands-on' and 'minds-on' are not separate parts of the lesson; the sensing, thinking and communicating are all part of the same experience. For example, interacting with materials helps to build foundational concepts such as hard and soft, dry and wet, push and pull (Tang et al., 2022).

This new definition describes what practical work is, not why we do it, which will be discussed below. But before we move onto the purposes of practical work, an important distinction to support the planning of lessons is to note that **not all practical work is enquiry**. An enquiry is taking place when children are trying to answer a question, for example, they might be trying to find out how many invertebrates can be found in the forest school area, or whether changing the size of a parachute affects the time it takes to fall. These are practical activities, that are also enquiries, but sometimes enquiry questions lead to research using secondary sources like books, the internet or an expert. Other times, practical work might not be focused on answering an enquiry question, for example, when demonstrating the water cycle or digestion (Figure 5, plus more examples are given when we discuss purposes below). It is also useful to note that 'inquiry-based science education' (IBSE) is an internationally recognised child-centred teaching approach, and whilst it often involves practical work, IBSE is a broader pedagogy. This study is focused more tightly on the practical activities, whether as part of an enquiry or not.

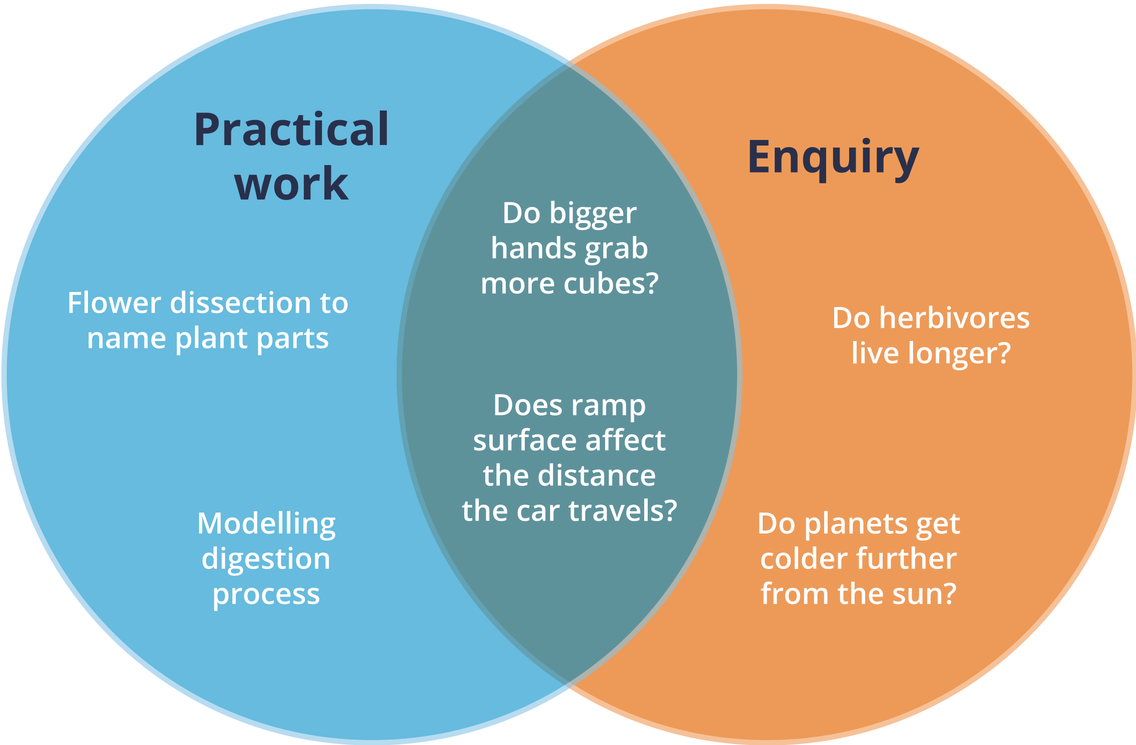


Figure 5. Practical vs Enquiry: not all practical work is enquiry and not all enquiry is practical

4b. Why do practical work?

A large number of different possible purposes for practical work can be found in the literature (Appendix 2), with many authors providing differing lists, for example:

> *Practical work motivates students, teaches them laboratory skills, improves their learning of science, gives them insight into scientific methods and develops scientific reasoning, such as objectivity and open-mindedness.* (Vinko et al., 2020, p.11)
>
> *Develop their knowledge of the natural world and their understanding of some of the main ideas, theories and models that science uses to explain it.* (Millar & Abrahams, 2009, p.61)

When extracting purposes from the literature, we found a wide range of differing points that may be relevant to primary science teaching, for example:

> *Generating ideas and questions and fostering a* ***feel for phenomena****.* (Stylianidou et al., 2018, p.7)
>
> *Avenue for the development of specific* ***knowledge and understanding*** *of science.* (Omilani et al., 2019, p.760)
>
> *Understanding of the* ***scientific approach*** *to enquiry (e.g. design an investigation, process the data to draw conclusions, evaluate).* (Millar & Abrahams, 2009, p.61)
>
> ***Skills*** *associated with observation, measurement and the accurate recording of data' (Kennedy 2014, p287), 'can only be acquired by* ***practice****.* (Park & Abrahams, 2016, p.2528)
>
> *To generate* ***interest and enthusiasm****...to aid students in remembering things.* (Bangoy, 2022, p.100)
>
> *Exciting practical work increases their interest in* ***science-related careers*** *and helps bring home to them the relevance of what they are studying.* (Royal Society, 2014, p.47)
>
> ***Scientific literacy****... contributing to the formation of better-informed individuals, and able to apply critical thinking.* (Oliveira & Bonito, 2023, p.18)
>
> *Physical manipulatives are less demanding on language proficiency, they provide a level of* ***access to language learners*** *who are learning science and the language of instruction at the same time.* (Tang et al., 2022, p.182)

In order to consider which purposes were most relevant to primary science teaching, we compiled a 'long list' that drew on the range proposed in the literature exemplified above (Appendix 2). To find out which of the purposes in the literature were important in the current context, the list was shared with stakeholders in a nationwide survey (Appendix 3). The 'long list' of 10 purposes was worded concisely, with some examples, to help with clarity within the survey:

1. Experience scientific phenomena e.g. real world sensory interactions
2. Be engaged and motivated e.g. children being interested in learning and doing science
3. Lead their own learning e.g. children asking their own questions and making decisions
4. Develop understanding of the scientific method e.g. plan, do, review
5. Develop scientific skills e.g. observe, gather and measure data using equipment
6. Developing understanding of what it means to do science and be a scientist
7. Learn and use scientific vocabulary
8. Developing conceptual understanding e.g. deepen and apply scientific knowledge
9. Develop personal and social skills e.g. oracy, collaboration, perseverance
10. Relate science learning to their own world and cross-curricula context

To avoid unnecessarily limiting the opinions of participants, more than one option could be selected for each category, leading to the interesting outcome that the majority of the possible outcomes were found to be 'most' or 'somewhat' important (Figure 6).

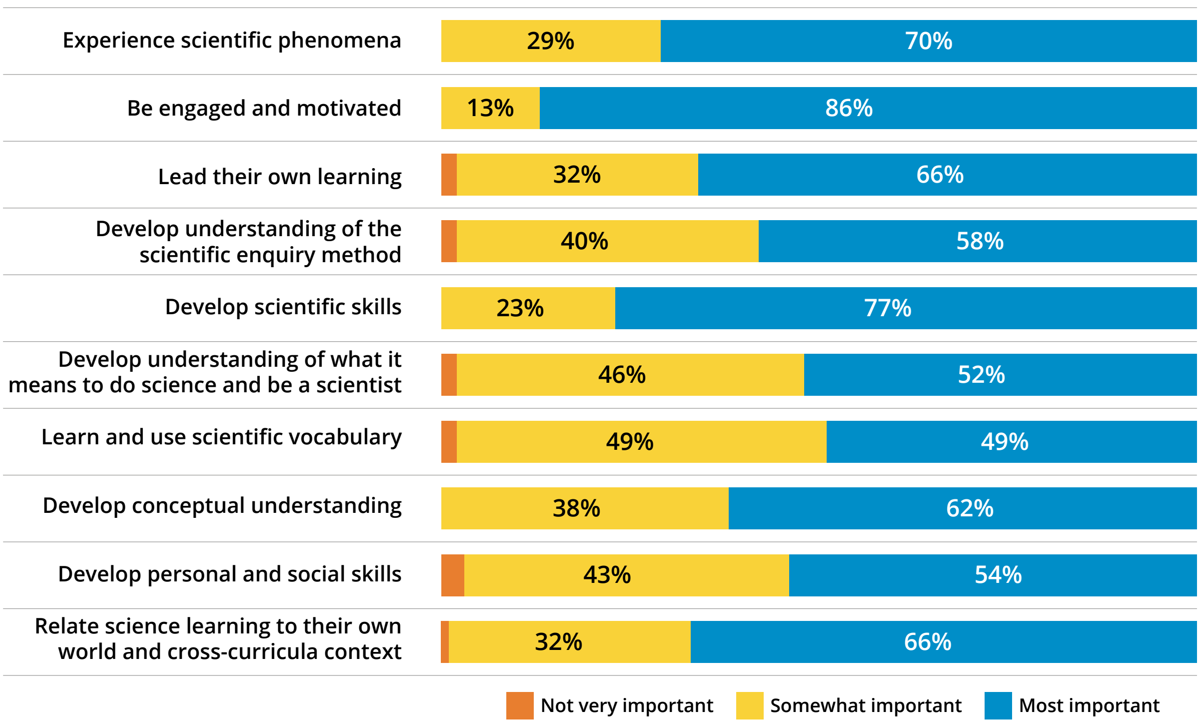


Figure 6. Survey graph 1: how important each purpose is perceived to be

Examples provided by teachers in the survey (before seeing our list of 10) also pointed towards a wide range of purposes, for example:

> *To give children experiences within the context of real life problem solving and understanding the world around us through asking questions.* (Survey participant 50 from England)
>
> *...They need to be doing practical science to develop their curiosity and sense of wonder using all their senses.* (Survey participant 91 from England)
>
> *It is also used to develop their problem solving skills, by giving them opportunities to lead their own learning and plan their own investigations from scratch when they are given a goal to achieve.* (Survey participant 4 from Wales)
>
> *...Hands-on activities allow students to practice important skills like observation, measurement, prediction, experimentation, and drawing conclusions. These skills form the foundation for future scientific learning. ...Through practicals, students learn about important science processes like fair testing, controlling variables, modelling, etc. This develops their understanding of the scientific method.* (Survey participant 14 from Scotland)

> *...Most scientists are engaged in practical activity, if not personally then as part of a research community; by doing practical activity children experience some aspects of what it is like to work like a scientist and get a feel for that way of life.* (Survey participant 26 from England)
>
> *Practical work allows children to think and consider the concepts and apply their understanding. It is not about teachers telling children scientific concepts, the children need to engage with the knowledge in a practical way to think about it and understand it. When taught well, practical work allows children to be creative and critical thinkers to have ideas and know how to investigate. Engaging in practical work within science allows children to think scientifically...* (Survey participant 82 from England)
>
> *Practical work allows children to develop their social skills by having to work collaboratively with their peers, learning how to work well as part of a pair or team, take turns and solve conflict.* (Survey participant 6 from Northern Ireland)

The wide range of purposes listed in the literature, the survey and interview responses indicates a strong rationale for embedding practical work in primary science learning. Large-scale studies that promote practical work such as 'Thinking, Doing, Talking Science' (Hanley et al. 2020), provide evidence of impact on children's attitudes and learning in science, albeit as part of a wider programme. Studies focusing more narrowly on the role of practical work provide evidence of impact (e.g. Leuchter et al. 2014; Polikoff et al. 2018, further details in Appendix 2). The high 'importance' noted by survey respondents also suggests the value of practical work, with it seen as being able to lead to many outcomes. However, this also raises questions around what is possible in a busy primary school classroom: can we really do all of this, can a practical activity really fulfil all of these purposes at the same time?

With primary teachers largely responsible for teaching all of the subjects to the children in their class, then perhaps it is not so surprising that all purposes are important. However, the key question here is: **which are the most important reasons for doing practical work in primary science and how might they be achieved?**

We propose that to make practical work more manageable, **core purpose(s)** should be selected and prioritised for the lesson. A core purpose could be related to the **practices of science**, where learning is focused on process skills like measuring or developing an understanding of the scientific method or different approaches to enquiry. This will still take place within the science topic, linked to the appropriate substantive content, but the focus is on developing science practices. Alternatively, a core purpose could be to develop knowledge and understanding of the content of science, where learning focuses on using scientific vocabulary and building ideas towards key **scientific concepts**. Within an enquiry, it is sometimes possible to address both core purposes of practical work (Figure 7), for example in a car ramps investigation: children are applying the science practice of using results to draw conclusions, at the same time as applying the science concept of friction to explain how some surfaces slowed the toy car's movement. Further examples are briefly listed in Table 2 below, with case study examples to follow later in this section.

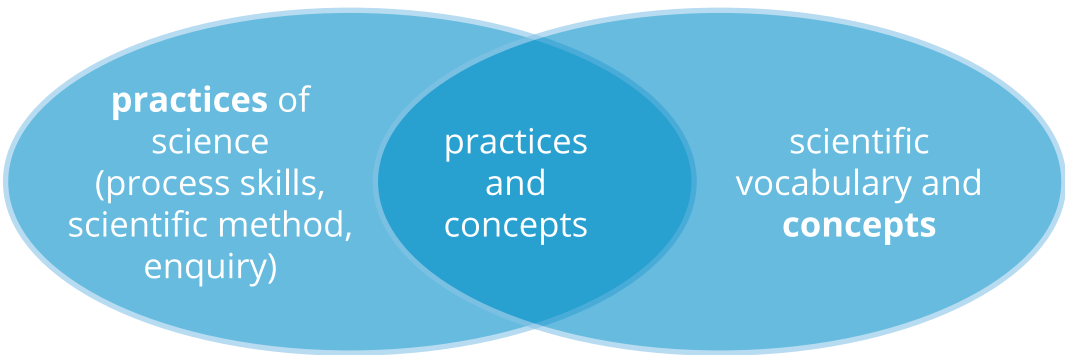


Figure 7. Core purposes for practical work in primary science

Table 2: Examples from participants mapped onto core purposes (practices, concepts or both)

Core purpose: to develop **science practices** e.g. process skills like measuring, understanding of scientific method or different approaches to enquiry	**Core purpose:** to develop science vocabulary and **concepts**	**Both core purposes:** to develop practices and apply concepts
Practices focus examples: • Measuring plants • Datalogging temperature • Planning an investigation to compare paper planes or whether longer arms throw further	**Concepts focus examples:** • Naming the materials that objects are made from • Dissecting flowers to identify the parts of a plant • Modelling digestion process • Light travelling (e.g. periscopes)	**Practices and concepts examples:** • Testing 'best' material for a gym mat • Microhabitat survey • Drawing conclusions based on car ramp results • Making a bulb light by making a complete electric circuit

Selecting a core purpose for the practical activity, makes it easier to manage the lesson and decide whether it has been effective, such as if the children have learnt what was intended. For example, if the children were able to control variables in their catapult testing, name parts of a plant when dissecting flowers or apply their knowledge of friction when drawing conclusions about car ramps.

The core purposes are lesson learning outcomes that may be the focus for individual practical activities, but there are also longer-term purposes that build over time. Developing an understanding of science as a discipline is a long-term goal for primary science lessons. For children to relate to science as a discipline, they need to develop an awareness of the nature of science, that science is a way of working based on evidence, that they can identify with and use to take their place in the world as a global citizen. This links to the Science Capital Teaching Approach (Nag Chowdhuri et al., 2021), with practical activities being one way to develop this feeling that science is 'for them', something that they can take part in. This is not a single activity or lesson outcome, this is something that is built over time. It may also be considered at the science lead or whole school level, for example, with science events that relate practical work to careers and the children's local environment.

Science is also part of a broader curriculum, with practical work supporting the development of group work skills, oracy and cross-curricular application. These purposes are not the only reason for selecting a practical activity, but they provide additional benefits that are important to recognise in the primary school context, especially in nations where interdisciplinary learning is a key curricula priority. We have collated these differing purposes into a framework (Figure 1) with the core purposes in white text, science as a discipline as a longer term aim and opportunities for learning through science listed as part of a broader education.

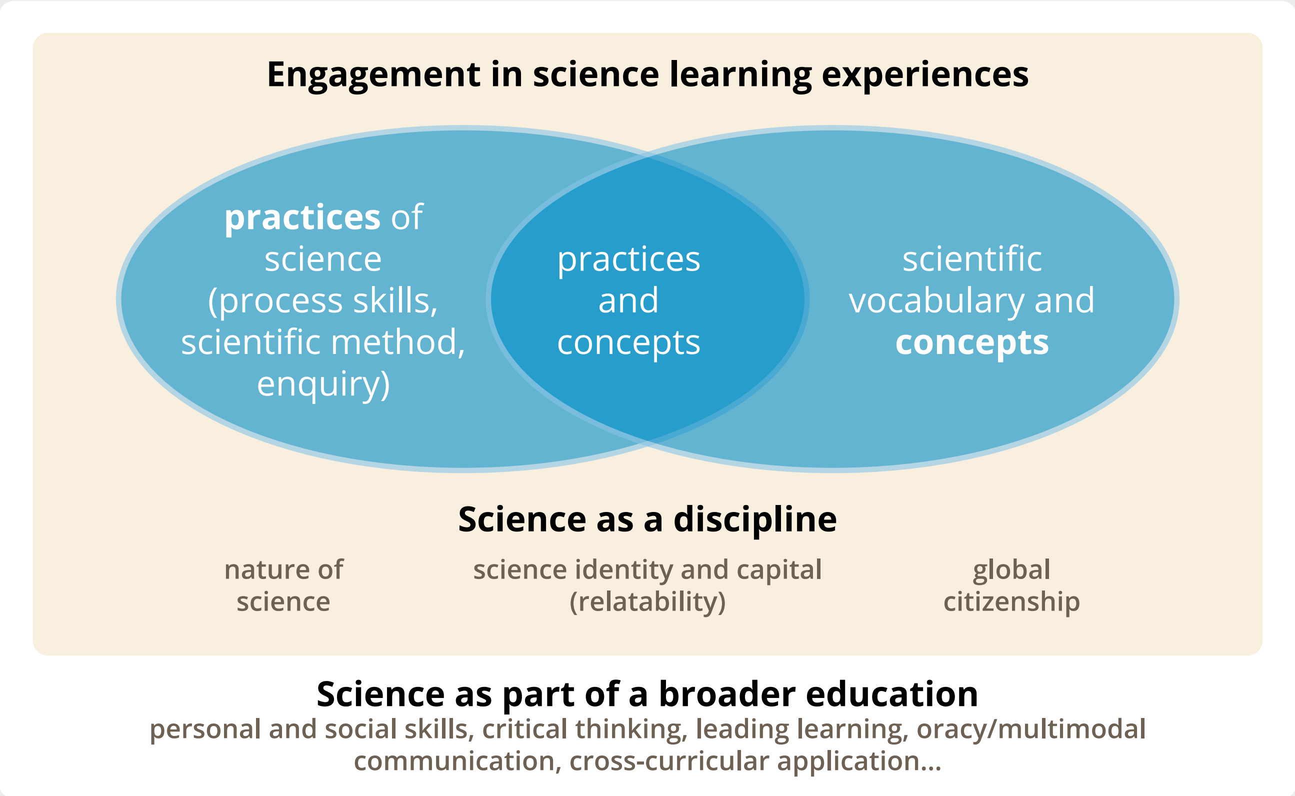


Figure 1. The Purposes Framework: a framework for prioritising the purposes for practical work in primary science, with core purposes in white text

In Figure 1, 'Engagement in science learning experiences' is listed above the core purposes, as a way of showing that it may be the first thing to happen, the way into the learning experience for the child. We see this more as a mechanism for learning, a means to gain attention towards the core purpose of the activity. Attending to the phenomena is needed to be able to learn about the phenomena, practical work helps to secure that attention, to engage the child in the science learning.

Examples from the interviews have been selected to exemplify the core purposes further in the following case studies.

Case study 1
Concept core purpose: modelling the digestion process

We started with some bread (food), cut it into smaller pieces (incisors), into a bowl (mouth), added water (saliva), mashed it (molars), into a plastic bag (stomach) with orange juice (stomach acid) and food colouring (digestive enzymes), then into the leg of old pair of tights (small and large intestine) to squeeze out the nutrients and water, before being expelled out of a hole in the toe end (anus). The kids absolutely loved it. Some children who don't like the touchy stuff just mashed, others were confident to squeeze and make the tights have a 'poo'. And even now in June, if I talk to them about the digestive system model, they remember what they did, they can talk about the process and they understand it. It was for the children to physically see what the digestive system does. We did this at the end of the unit, so we had talked a lot about the process, but this helped them to physically see it. It just tied everything together and they could see the process in action. It was really visual for those with less language, to understand the process.
(Interview participant 20 from England, children aged 7-9)

Commentary
The sensory engagement is evident in this example, with the 'hands-on' experience set up by the teacher with the core purpose of developing scientific vocabulary and understanding of the process of digestion.

Case study 2
Practices core purpose: body investigations

Example 1: does the tallest person always have the biggest feet?
It all started from looking at animals and their feet and how tall things were, and then we posed a question: does the tallest person always have the biggest feet? We just did it within our classroom to start with, but they were very keen to carry this on so they actually took it home and measured all of the family. We talked about how to make it a fair comparison, like did everybody take their socks and shoes off? Then they went on to pose their own question, their own prediction, and then do their own independent investigations. They looked at other body parts like: Does the person with the biggest foot have the longest big toe? I wanted them to look back on what they had done, look at those results, what do they tell us? To link to the prediction and report back on those results.
(Interview participant 5 from Wales, children aged 8-9)

Example 2: do longer arms throw further?
We've just taken part in the Great Science Share with our cluster schools. The hall was full of practical science being shown. One question was do people with longer arms throw further?

We did this as a whole class. The children predicted, and then they got going with measuring arm lengths of the children in their class, and then throwing three times working out the mean. They made a scatter graph to represent the data. The follow on for the independent application will be that the children get to pick a similar kind of pattern seeking enquiry question and follow a similar format, with each group investigating their own question. So they get a scaffold and the model of how it works, and then they go off and do that themselves.
(Interview participant 3 from Wales, children aged 9-11)

Commentary
In these examples, the conceptual context was the human body, but the core purpose was to develop scientific practices. In both examples, a guided enquiry led on to further questions and more independent investigations.

Case study 3
Both core purposes of developing practices and applying concepts: gym mat

*We had previously looked at the four ways to change the shape of solid objects (squashing, bending, twisting and stretching) and we took that into a context. Ronan loves gymnastics but can only practice safely on a mat: what properties would his mat need? We talked about the squash-ability and how we want it to return to its original shape too. Then we tested different materials to decide which one would be the best one for a gym mat. We agreed how to test (because that planning wasn't the main focus of our lesson), by pressing two fingers down and counting to 5 to see which ones squashed and which went back to their original shape. The focus was on **recording of their observations**, so putting a tick or cross each time they tested a material. We could then use these results to decide as a class which go into the 'Not squashed' basket etc. We came to a conclusion together about which one would be the **best material due to its properties**.*
(Interview participant 4 from England, children aged 6-7)

Commentary
The main activity in this lesson involved data collection, but all of the talk around it about where they might look for the 'best' mat, required the children to apply their knowledge of materials, meaning both core purposes are evident.

4c. What affects the success of practical work?

In the stakeholder survey, whilst the respondents identified most purposes as important (Figure 6), they also noted that many were less likely to happen in real life (Figure 7). Figure 7 indicates that the busy primary school classroom leads to the shaping, or potential prioritising of purposes: it seems as though teachers may be experiencing challenges in enacting practical work which addresses many of the purposes. For the interview phase of the research, we were interested in exploring the **enablers** and **barriers** of practical work, with the hope of offering clarity over why practical work may or may not be planned and delivered with particular purposes in mind.

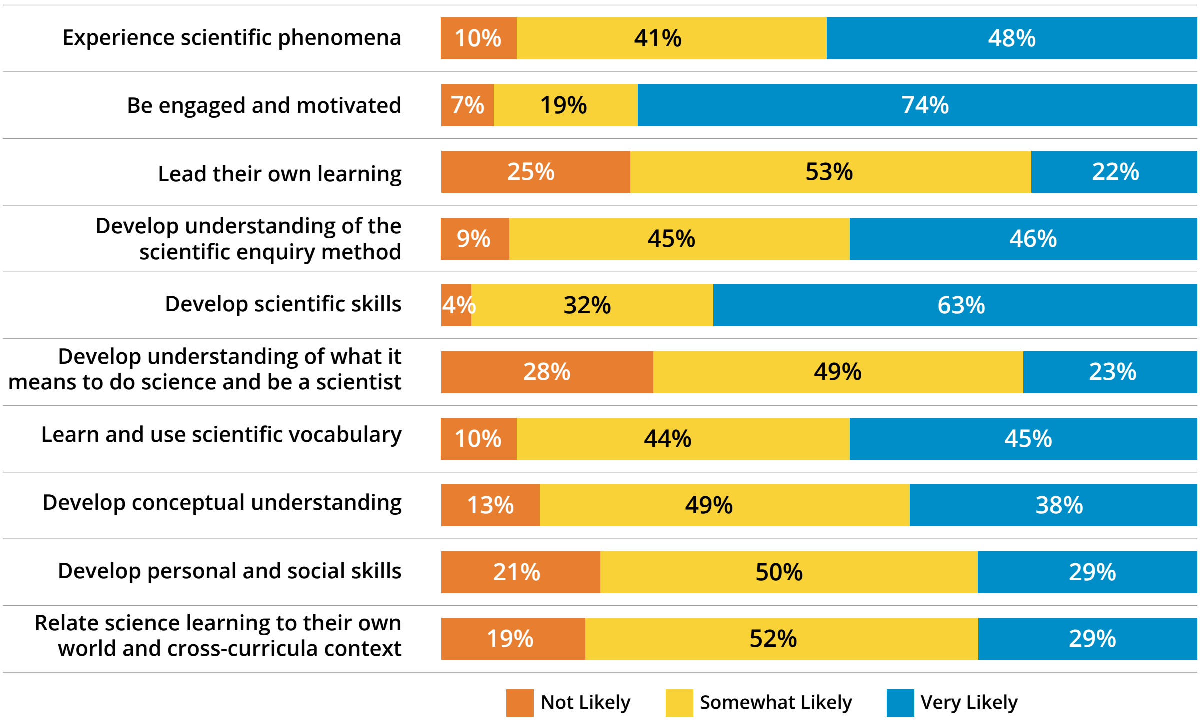


Figure 8. Survey graph 2: how likely each purpose is perceived to be

Table 3: Summary of factors affecting practical work: could be enablers (if present) or barriers (if absent)

Resources for children	• equipment and consumables • learning environment (classroom design, outdoor, enrichment)
Resources for teachers (or teaching)	• funding • teaching environment • support from other adults in class • protected planning and curriculum time • access to CPD, networks and expertise • engagement with external projects such as the Great Science Share for Schools or CREST awards, and the wider science education community
Science subject status	• science lead capability and capacity • curriculum allocation, timetabling • pressure to evidence (e.g. lesson time devoted to writing rather than practical work)
Teacher knowledge, skills and confidence	• subject matter knowledge – confidence and knowledge with science as a subject • pedagogical content knowledge – how to teach science /topics through practical work, classroom management and safety

Enablers and barriers for practical work

In the interviews, primary teachers were enthusiastic about practical work and considered it to be an essential part of primary science teaching and learning (Appendix 4). However, several factors that affect the nature and frequency of practical work in primary science were identified (Table 3), acting as enablers if they were present and barriers if they were not.

Primary schools do not always have the resources to enable children's full hands-on participation in practical work nor the resources required to develop and sustain teacher subject knowledge and confidence in order to effectively plan and teach well purposed practical work.

> *The funding has been non-existent for our Local Authority, we've lost staff. I haven't stocked my science cupboard for three years because I knew what was coming. Financially, I can't support a new curriculum with science and technology.*
> **(Interview participant 4 from Wales)**

The amount of curriculum time allocated for science, impacting the amount and nature of practical work, was a potential barrier in all nations, albeit for slightly different reasons. The cross-curricular nature of 'The World Around Us' in Northern Ireland, interdisciplinary STEM in Scotland or the 'Science and Technology' area of learning in Wales, led to variety in the amount of time spent on science. In England, the high stakes accountability measures for English and mathematics led to a lower status for science, whilst in Northern Ireland, preparation for the transfer test for post-primary grammar schools had a similar impact.

> *Lack of time for science, especially in P6 [with 9-10 year olds] when you get ready for transfer tests which focus on English and Mathematics.*
> **(Interview participant 1 from Northern Ireland)**

There is a strong desire for all primary teachers, not just those in a science subject leader role, to have some science focused professional development and planning time to develop more effective practical work.

> *What PSQM [Primary Science Quality Mark] allowed us to do is see how we could bring science more to the front, to be equal with all the other subjects, because all the subjects have the same weighting in Wales, so you didn't want anything to be left out. I'm very lucky that it was actually my senior leader that encouraged us to do the PSQM and we've been trying to encourage schools around us.*
> **(Interview participant 5 from Wales)**

Primary schools are operating on small budgets which means that opportunities for children to be able to work 'hands-on' and have direct (sensory) experiences with specialist equipment is limited. Consequently, children often work in larger groups, as opposed to working in trios or pairs during practical work which may impact their access to hands-on experiences, such as handling materials, using equipment and contributing to discussions. Furthermore, replacing basic consumables or replacing broken equipment is often an ongoing issue.

> *Making sure there is enough equipment and funding to teach science as much as we can at a primary level. They need to have things like measuring cylinders and filter funnels and all that kind of equipment and then you know, making sure that they've had hands-on experience. But a lot of the time, some of the equipment disappears or it gets broken and it's trying to make sure that it still gets replaced.*
> **(Interview participant 14 from England)**

Having easy and direct access to equipment and the time to prepare and set up practical activities is often lacking. Using outside spaces, taking advantage of enrichment initiatives, such as science week or bringing science ambassadors and role models into school was described by participants as beneficial for practical work. External funding from charities, learned societies and universities has helped some schools to build capability to innovate and to sustain practical work in primary science.

Protected planning time and after school meetings are used for formal and informal professional development. This provides time for teachers to meet and share ideas and for subject leaders to cascade and model practical work. However, there was little evidence to suggest that teachers were using this time to discuss and consider the purposes of practical work.

> *We did a 'mastery for science' and we had a 'mastery for maths'. So, I did the same for science, so everybody is aware of what is needed, and my job is also to make sure that we have all the science equipment.*
> **(Interview participant 19 from England)**
>
> *Some form of network. I think a network to bounce off is hugely important. Simple basic network where information, funding, CPD opportunities can all be shared. You know, successes, barriers, you name it. Everybody can kind of share and support one another, I think has real benefits. And I think that's where you start to build.*
> **(Interview participant 5 from Scotland)**

Teachers said that their knowledge, skills and confidence can be developed if there is the time and support for primary teachers to rehearse and to practice the practical activities that they would be introducing to children. Teachers are often nervous about teaching practical work and about behaviour management to do practical work safely.

> *Well, yeah, it's interesting to say that the teacher has hands on experience themselves, it makes me think that sometimes I often did not do the practical work.*
> **(Interview participant 4 from England)**
>
> *I would want all teachers to have not just one session of training, but a series of training events, maybe across a year. To build their confidence in knowing how they could, you know, approach practical science within the topics that they were teaching.*
> **(Interview participant 3 from England)**

There are many organisations that offer high quality support and resources to enhance practical work in primary schools. Science subject leaders named a wide range of science specific organisations, courses and online resources (listed in Appendix 1).

Effectiveness of Practical Work

When asked about the effectiveness of their example activities in the interviews, teachers often did not explicitly link to the intended purpose(s) of practical work, instead focusing on observable features within the lesson: whether the children were engaged, completing the task or taking part in the discussion.

> *Engagement. Usually for me it's visual because of the kind of lessons I do, but actual learning is often elucidated by question and answer. So you might not always have the children that you want answering questions, but I can see that they're listening and taking part that way.*
> **(Interview Participant 2 from Scotland)**
>
> *It just kind of sparked so much discussion both outside and back in the classroom. About things that they had observed.*
> **(Interview participant 5 from Scotland)**

Children's learning through practical work was also observed through their scientific talk, questioning, answering and discussions with other children and the teacher. Teachers looked to see if correct scientific vocabulary was used during an investigation and if children were able to demonstrate their understanding beyond written work.

> *I think it's listening to the discussions that come about during a practical and particularly when you listen to the conversations between peers within groups, it's a good opportunity just to stand back and see what they've taken on board from.*
> **(Interview participant 1 from England)**

When asked about other ways that teachers could assess the effectiveness of practical work, teachers were interested in whether the children could recall any prior science learning or if they could connect and apply their learning from previous lessons in different situations.

> *If they got the concept (adaptation). The questions that I've been asking as part of the plenary – were the children actually able to make those connections themselves. If they can explain that to each other, then they understand it.*
> **(Interview participant 1 from Northern Ireland)**

> *Recall – and even now in June, if I talk to them about the digestive system model, they remember it. They remember what they did. They can talk about the process, they understand it and they just enjoy doing it.*
> **(Interview participant 20 from England)**

Recording and capturing children's learning as a consequence of their participation in practical work was done in different ways. Recording of results in a table was commonly described, as was the use of floor books and in some cases, photographs. Floor books (scrapbooks for recording group dialogue and activities) were being used over several lessons to facilitate whole class discussions and focused collaborative talk. A science lead also explained this to give her a useful 'picture' of what was happening in science lessons in other classrooms.

> *Now I do pupil voice once a term, so I go into different classes and speak to the children. They can bring their books and their floor books, and so when I ask them what they've done we often use photos and things like that and I'm keen to get them to talk and also to get the teachers to expect them to.*
> **(Interview participant 18 from England)**

Empirical studies in primary schools rarely make specific judgements about the effectiveness of practical work. Where research has compared outcomes, it is usually a wider pedagogical approach that is being tested, rather than practical work in isolation. For example, large-scale randomised control trials in England of Thinking Doing Talking Science (Hanley et al., 2020) and Focus4TAPS (Mujtaba et al., 2022) have found a positive impact on children's outcomes for their professional development programmes that include practical work as a key teaching tool. Practical work has often been studied as part of an inquiry-based approach, for example, in Northern Ireland, Dunlop et al. (2015) found that the Community of Scientific Enquiry (CoSE) child-led approach increased engagement, confidence and oracy. Where a narrower focus on practical work has been examined, insights can be gained into effective practice. Zhang (2018) found that guided inquiry, where explanations were not 'withheld' was supportive of conceptual understanding and reasoning. Convertini et al.

(2024) observed the role of the teacher to be integral, together with the availability of objects for manipulation. Kang et al.(2024) considered embodied learning and found that movement needed to be related (congruent) to the science concept under consideration, for it to be useful in supporting learning. The importance of talk is repeatedly evidenced in the literature, for example, with Todas and Skoumios (2014) noting that without it, manipulation of materials is not linked to scientific ideas.

Neither the literature or the interview data provide us with strong conclusions regarding how to make practical work most effective for primary science. In the case of the literature, this is largely due to the embeddedness of practical work within larger approaches such as IBSE, rather than studying it in isolation, which would be difficult within the context of a complex primary school setting. In the case of the interviews, teachers were often not explicit about the main purpose(s) for their practical work examples, making it harder to then judge effectiveness. In the next section, we propose a new pedagogical model to support the use of practical work and to further consider how to make practical activities work.

5. Recommendations

5a. How to make practical activities work

Practical work was perceived to be a key feature of primary science by survey and interview respondents, but it can also be difficult to manage in a busy classroom, with multiple purposes and the range of barriers described above. In returning to examples from the literature, we pick out some key points that can help us to build a new model to support practical work pedagogy.

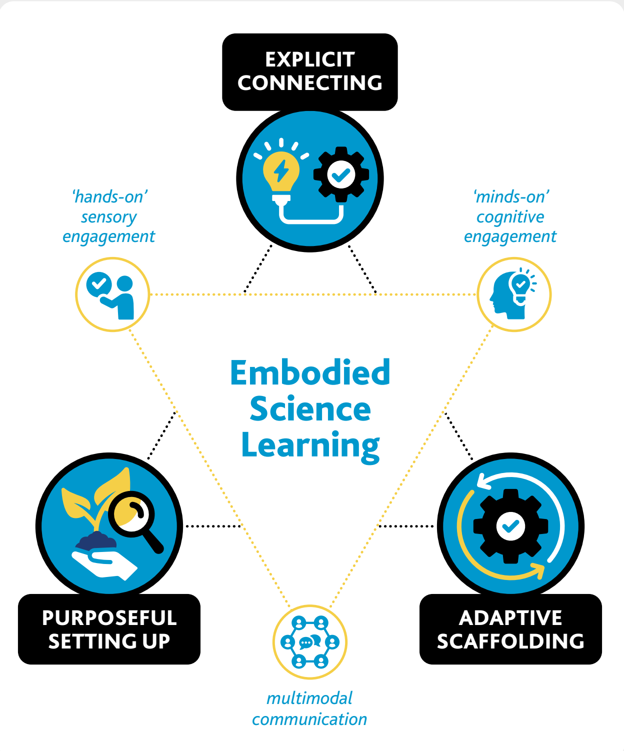


Figure 2. The Pedagogy Model: a pedagogical model for practical work in primary science, with mechanisms to stimulate children's learning (yellow triangle) supported by the teacher curating the learning experiences

Recent studies of children's experiences have taken a more **embodied learning** perspective, considering the whole sensory experience of engaging with practical work. Tang et al. (2022), from their video analysis of Swedish lessons, argue that the value of interaction with physical objects can only be realised if accompanied by verbal and or gestural communication, that could connect an utterance to an object, or mimic the movement of a physical object. In this way, **hands-on** sensory engagement and **minds-on** cognitive engagement (linking to science ideas) are not two separate activities, they are tied together through **multimodal communication** and meaning-making. Thomas Jha and Price (2022) found that UK 5-6 year olds with direct sensory experience of the phenomenon, such as running with cardboard sails or resistance parachutes, led to more accurate explanation, in words, gestures and re-enactment. It is important to note that this is not about any gesture or movement to make learning active, it is about carefully curated sensory experiences and/or body movements that correspond to the concept to be learned (Kang et al., 2024). The central triangle in the pedagogy model (Figure 2) represents the mechanisms of learning within the child, the linking of hands-on and minds-on via communication with adults and peers.

As discussed in section 4b., selecting a **core purpose** is a key pedagogical decision, guiding the curation and set up of the practical activity. Löfgren et al. (2013) studied exploratory talk in Swedish science lessons but found that practical work had 'too many aims', which may result in 'dilemmas or conflicting goals' (p.494) within the lesson, with teachers unsure what to prioritise. In a study of Dutch classroom practice, they proposed that different parts of enquiries are best related to different kinds of knowledge development (van Uum et al., 2016), sometimes focusing on conceptual understanding and sometimes addressing procedural knowledge. Clarifying the aim for the lesson, or a particular part of the process if extended over a sequence of lessons, could help to make practical work more manageable for teachers and children.

The role of the teacher in supporting practical work to be 'minds-on' (Millar & Abrahams, 2009), to scaffold 'thinking-back-and-forth' (Spaan et al., 2022) is strongly represented in studies from across the world. For example, from their study of 10-12 year old science learning in Korea, Park et al. (2016) proposed that the teacher was integral for developing phenomenon-based reasoning, **connecting** the practical activity with the conceptual knowledge in a 'teachable moment' (p.2546). In the US, Zhang (2018) found that 'withholding answers' (e.g. not discussing why it is difficult to see inside a dark box) may hinder learning, meaning that it is better for the practical activity to be explicitly linked with the science content.

Johnston (2013) noted the importance of prompt questions and adult interaction to **scaffold** the practical problem-solving in her study of 6 year olds in the UK. The large-scale European Creative Little Scientists project also described the importance of dialogue and teacher scaffolding to enable 'hands-on, minds-on exploratory engagement' (Stylianidou et al., 2014). In a Norwegian study of classroom practice, Kersting et al. (2023) argue for the children to be given more 'power to act' (p14), in the question-raising and planning stages of an investigation, indicating the **adaptive** nature of scaffolding, to guide without it becoming recipe-driven.

Drawing on the literature, survey and interview findings, we propose that this new model for practical work pedagogy (Figure 2), can be used to support teacher decision-making before and within the lesson. To exemplify the model further, we present examples where practical work has been used purposefully, mapped onto the model elements in the following case study boxes.

Examples mapped onto the practical work pedagogy model

Case study 4
Magnet strength tests
(Interview participant 3 from England, children aged 7-8)

Embodied science learning		Practical work pedagogy	
'Hands-on' sensory engagement	Explored a range of magnets. Tested strength using number or distance to attract paper clips etc.	**Purposeful setting up**	To collect results and apply their knowledge of magnets, I gave them a whole array of magnets and asked: which is the strongest magnet? How can you find out?
Minds-on' cognitive engagement	They all thought the huge horseshoe was the strongest magnet initially. Interpreted their results to order by strength.	**Explicit connecting**	We discussed previous learning (scientific vocabulary like attract, repel and magnetic materials).
Multimodal communication	Discussed how to test magnet strength. Recorded and discussed their results.	**Adaptive scaffolding**	One little boy, who really struggled with maths and English, had the idea of using a ruler to see which attracts the paper clip at 5 cm etc. To access the activity, he drew each magnet next to the ruler.

Case study 5
Blubber hands
(Interview participant 1 from Northern Ireland, children aged 9-10)

Embodied science learning		Practical work pedagogy	
‘Hands-on’ sensory engagement	The children put their hand in a bowl of ice cold water and timed how long they could stand it. Then they tried with a rubber glove full of lard.	**Purposeful setting up**	We did ‘blubber gloves’ from the Polar Explorer STEM pack, to show animal adaptations.
Minds-on’ cognitive engagement	We measured the temperature of the water with thermometers. The water hadn't changed, but they were able to hold their hands a lot longer. We linked it to blubber and animals.	**Explicit connecting**	We were doing a cold lands topic, including adaptations of animals that live around the poles. We also linked it to the Polar Explorer ship and to the Titanic, because it’s a very local topic for us.
Multimodal communication	They discussed why they thought that the blubber hands helped.	**Adaptive scaffolding**	Most loved getting messy, but for those with sensory issues, they could put their hand in a double glove or place their hand on top of the glove with this ice underneath.

Case study 6

Testing materials to block a hole in bucket (Survey participant 70 from England, children aged 4-5)

Embodied science learning		Practical work pedagogy	
'Hands-on' sensory engagement	They tested their initial choices for materials to stop the bucket leaking and were then encouraged to test others to see if they could find a better one.	**Purposeful setting up**	A problem to solve: there's a hole in my bucket so I can't fill up the water tray. They were provided with a range of resources including paper, fabric and carrier bags, a shiny party hat, sieves, boxes and bowls.
Minds-on' cognitive engagement	Asked to say what they thought would happen if they tried the materials. The children learned about testing their prediction, talking about what they observed, how water behaves and names and properties of materials with a focus on waterproof and strong.	**Explicit connecting**	Teacher modelling of vocabulary such as waterproof, strong, shallow, soak, drip, paper, card, plastic. Discussion prompts throughout to talk about what they were doing.
Multimodal communication	There was lots of discussion of what they observed and why it was happening: it's got holes in it, it falls apart when it gets wet, it's holding the water, it spills when I carry it, it works at first but then the water comes through.	**Adaptive scaffolding**	Small group, adult directed task. To start, I asked them to choose something they thought would be good for transporting the water and something that would not work. Further learning was stimulated by including this as a free-flow activity (outside!) once it had been introduced to all groups, with different objects and materials provided and children encouraged to suggest alternatives.

Case study 7

Investigating bubbles
(Interview participant 5 from Scotland, children aged 7-8)

Embodied science learning		Practical work pedagogy	
'Hands-on' sensory engagement	We took bubble wands outside to wave and watch the flight time: how long does it take for the bubbles to either hit the ground and pop or disappear out of view? What direction did it go?	**Purposeful setting up**	I used 'windy ways' from CREST to develop observational skills. I gave them stopwatches to help them compare.
Minds-on' cognitive engagement	Above that excitement there was a genuine interest, running back over to say, our bubbles have just done this and we saw this and oh, look, that one's still carrying on over there	**Explicit connecting**	We started inside the classroom talking about creating bubbles and whether they fall straight down. We linked to other concepts that we had done earlier in the year: about liquids, gases and gravity.
Multimodal communication	It sparked so much discussion both outside and back in the classroom about things that they had observed, not just the timing of how long the bubbles. We drew diagrams and made notes on whiteboards too.	**Adaptive scaffolding**	They worked together in small groups. There was a lot of discussion around their own observations and demonstrating the importance of repeating the process several times: why not everybody got the same result.

Purposeful set up includes deciding on the focus for the lesson. The core purpose of the lesson is not decided by the activity, but tailored to the needs of the children, as the following example demonstrates.

Both lessons take place in the context of moth adaptation, but the experience of the class is the deciding factor in whether to make this an enquiry or a simulation.

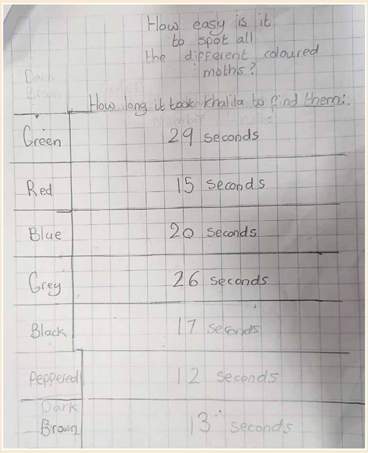
Case study 8
Choosing an appropriate core purpose

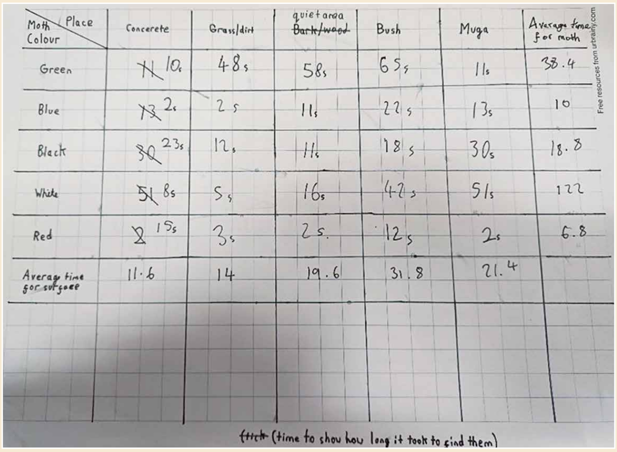
Moths example 1: concepts core purpose

Linked to evolution, we coloured big and small moth templates. We went outside and one group hid moths of the same colour, then the other group had to look for them. We talked about why we found most of the big moths, but struggled to find the small moths. Because it's easier to see and catch the bigger moths. It was really easy to find the red and yellow ones, but harder to find green and blue ones because they're dark colours. We linked it to the evolution of the peppered moth. The small and dark moths were harder to find so they survived, and if they survived more of them reproduced.

(Interview participant 10, from England, children aged 10-11)

Moths example 2: concepts and practices core purposes





About halfway through the evolution topic, so they've got some prior knowledge about how animals are adapted to suit their environments, we did the peppered moth simulation activity. Our enquiry question was which moths would survive the longest in the playground and we were working like scientists by recording observations and results in a table. I created some templates of little moths and we planned as a class. Each group set up an investigation to either count how many moths were 'eaten' (found) on different surfaces by their peers, or time how long it took them to find different coloured moths on one wall. My knowledge aim was about animal adaptation and being suited to the place where they live. My main focus was to find out whether they could make their own table and record in it, because we had used scaffolded tables the week before. The tables they produced are clear, I can see what they investigated and some children are starting to take repeat readings.

(Interview participant 12, from England, children aged 10-11)

Commentary

In moths example 1, the core purpose was conceptual, to practically simulate the importance of camouflage for survival. In example 2, because the children had recently worked on collecting results in tables, the teacher turned the lesson into an enquiry, with both core purposes of recording results and applying their knowledge of adaptation.

5b. Prompts for stakeholders

The aim of this document was to go beyond a report of research findings and create actionable guidance for practitioners. Throughout the report we have included models and examples for discussion.

Readers are encouraged to share and discuss these with colleagues, to support the development of practical work in their setting. Table 4 contains further prompts to support reflection on the use of practical work.

Table 4: Prompts for stakeholder discussions

Stakeholders	Example prompts for discussion
Teachers	**Thinking about recent science practical work in your class:** • What were the core purpose(s)? • What science learning were you connecting to? • What were the opportunities for discussion/communication? • How did you adapt your instructions during the activity? • How effective was the practical activity for children to meet the core purposes of the lesson?
Science leads and school leaders	**Thinking about science practical work in your school:** • Which practical work purposes are well embedded, which are not? • How confident are colleagues with using practical work to teach science practices and/or science concepts? • What support do colleagues need to be able to use formative assessment to adapt their scaffolding in practical lessons? • How can colleagues be supported to share examples of effective use of practical work?
Professional development leads and initial teacher educators	**Thinking about practical work in your programme:** • Are the intended purposes of practical activities made explicit and feasible? • Do examples of practical work included in your programme support hands-on, minds-on communication? • How do you support the planning of purposeful practical work, adapted for learners?
Policy-makers and resource developers	**Thinking about practical work in your policy/resources:** • Is the definition of 'hands-on', 'minds-on' learning experiences and communication? clear? • Are the purposes of practical work in science explicit? • Are the examples focused and manageable, ie. core purposes selected and adaptation exemplified?

6. Closing remarks, authors and advisory group

Our thanks go to all of the stakeholders who have participated in the study via the survey and the interviews, or to those who have provided feedback on draft guidance at events such as the STEM Learning primary science conference, the SEERIH conference, Focus4TAPS Facilitator meetings and the Association for Science Education annual conference.

In addition, we have benefitted from the expert input of the advisory group throughout the study, who are listed below, with our thanks.

For anyone seeking to continue the discussion, please email **primary.science@bathspa.ac.uk** with your comments. We expect that out of this study, further thinking will arise and lead to future projects in our ongoing support for primary science.

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> *...igniting their natural curiosity and sense of wonder, driving them to give possible explanations for what they have seen.*
>
> **Hanley et al., 2020, p.2559**

7. Appendices

Appendix 1. Recommended sources of support and curriculum links

The following organisations were mentioned by participants in the research:

- Association for Science Education (ASE)
  www.ase.org.uk
- BBC bitesize
  www.bbc.co.uk/bitesize
- British Science Week
  www.britishscienceweek.org
- Centre for Industry Education Collaboration (CIEC)
  www.york.ac.uk/ciec
- CLEAPSS (inc. health & safety)
  primary.cleapss.org.uk
- CREST awards
  www.crestawards.org
- Edina Trust
  www.edinatrust.org.uk/science-grant-scheme
- Explorify
  explorify.uk
- Institute of Physics
  www.iop.org
- Great Science Share for Schools
  www.greatscienceshare.org
- Ogden Trust
  www.ogdentrust.com
- Pan London Assessment Network (PLAN)
  www.planassessment.com
- Primary Science Teaching Trust (PSTT)
  pstt.org.uk
- Primary Science Quality Mark (PSQM)
  www.psqm.org.uk
- Royal Institute
  www.rigb.org/learning/grants-schools
- Royal Society
  royalsociety.org/news-resources/resources-for-schools
- Royal Society of Chemistry
  edu.rsc.org/primary-science
- Science & Engineering Education Research and Innovation Hub (SEERIH)
  www.seerih.manchester.ac.uk
- SSERC
  www.sserc.org.uk
- STEM Learning
  www.stem.org.uk
- Teacher Assessment in Primary Science (TAPS)
  pstt.org.uk/unique-resources/taps
- Young STEM Leaders
  www.youngstemleader.scot

Table 5: Curriculum links

Curriculum	Example linked to **practices** core purpose	Example linked to **concepts** core purpose	Example linked to both core purposes of **practices and concepts**
National Curriculum for England, DfE 2013	NC aim: 'develop understanding of the nature, processes and methods of science through different types of science enquiries that help them to answer scientific questions about the world around them.'*	'The principal focus of science teaching in key stage 1 is to enable pupils to experience and observe phenomena, looking more closely at the natural and humanly constructed world around them.'	'Working scientifically' is described separately in the programme of study, but must always be taught through and clearly related to the teaching of substantive science content in the programme of study.'*
Curriculum for Wales, 2019	Progression step 2: 'I can ask questions and use my experience to suggest simple methods of inquiry.'	'Being curious and searching for answers is essential to understanding and predicting phenomena.'	Progression step 1: 'I can explore the environment, make observations and communicate my ideas.'
Northern Ireland National Curriculum, CCEA 2007; Progression, CCEA 2019	'Children should have opportunities to use their senses in order to develop their powers of observation, their ability to sort and classify, explore, predict, experiment, compare, plan, carry out and review their work.' (NC p.37)	'Children are naturally curious and often ask profound questions about themselves and the nature of the world around them. The purpose of this Area of Learning is to help children explore and find age appropriate answers to some of these big questions.' (NC p.37).	'By doing science in schools, pupils will be able to develop behaviour and skills that reflect those of real scientists. The emphasis will be on knowledge acquisition as a result of the process of questioning, observing, investigating, identifying patterns, explaining and initiating enquiry.' (2019, p.4)
Education Scotland Experiences and outcomes, 2009; Benchmarks, 2017	'Develop the skills of scientific inquiry and investigation using practical techniques.' (Es&Os p.1)	'Develop curiosity and understanding of the environment and my place in the living, material and physical world.' (Es&Os p.1)	'Practical activities contribute in an important way to learning within the sciences and allow learners to further develop their skills and understanding of scientific concepts.' (Benchmarks p.2)

* Where Working scientifically practices are the core purpose, these are still taught within the context of the substantive content, it is just that we are not trying to teach new substantive content at that point too.

Appendix 2.
Scoping literature review: summary of methods and findings

Method

The initial literature review search was carried out in May 2023 using the Bath Spa University library databases of ERIC, Education Research Complete and Academic Search Premier, ordering by date (2013 -24), checking the title and abstract for all 1379 entries. The search string, inclusion/exclusion criteria and number of entries can be seen below. We repeated the search in Google Scholar to capture articles that may not feature in the academic databases, ordering by 'most relevant' and checking titles/abstracts for the first 200 entries. A check was also made in individual key journals in the field, together with the addition of 'follow on' articles that were mentioned in included entries. For example, many included articles referred to definitions of practical work from seminal work by Abraham and Millar (2008, 2009), so whilst pre-2013, these were included to see the origin of more recent work.

Search string: (primary OR elementary) AND ("science education" OR "science teaching" OR "science learning" OR "science instruction") AND ("practical work" OR "working scientifically") -"preservice teachers" -"teacher candidates"

Inclusion criteria: 2013 onwards, in English, full text available, relevant to practical work in primary science (focused on classroom practice, may include empirical work with children or discussion of science teaching, research with secondary students to be included if implications for practical work in primary).

Exclusion criteria: contexts outside of school (e.g. informal learning, museums), study of pre-service teachers, study talks only in general terms about science teaching (e.g. project-based or inquiry-based or problem-solving teaching approaches discussed without any explicit mention of practical work/'hands-on', so could be non-practical inquiry).

Grey literature was collated from:

- the latest statutory guidance for each nation England's Department for Education (DfE), Education Scotland, Curriculum for Wales, Council for the Curriculum, Examinations & Assessment (CCEA) in Northern Ireland).
- policy statements and relevant guidance from key UK organisations from 2013 onwards, for example, Wellcome, Education Endowment Foundation, Association for Science Education, The Royal Society, Royal Society of Biology, Royal Society of Chemistry, Institute of Physics.
- examples of recent and ongoing projects and resources for teachers from 2013 onwards, drawing on the organisations listed above, together with charities who produce primary focused materials such as the Primary Science Teaching Trust.
- recommendations from the Advisory Group, which contained representatives from each of the four nations.

Table 6: Scoping literature review summary

Search	Records screened by title/abstract from keyword searches	Eligibility check of full article	Included articles relevant to study	Studies with empirical data from primary phase
BSU library databases*	1379	25	14	6
Google Scholar	200	52	17	7
Additional journal finds**	198	56	42	29
Grey literature	62	62	47	12
Total	**1839**	**195**	**120**	**54**

* Includes: ERIC, Education Research Complete, Academic Search Premier
** Follow on references (e.g. from EEF systematic review, Bennett et al. 2023) and hand search of key science ed/primary journals at later date: IJSE, RSTE, J of Sci Ed&Tech, Edn 3-13, JES

The initial screening in May 2023 involved applying the inclusion criteria to the title and abstract of each entry. Large numbers of the entries were unrelated to the research, for example, in the field of primary health care, so were excluded. All entries were then logged and checked by two of the team for their relevance to the research. Articles were excluded where, for example, they focused on informal contexts (outside of primary school), remote learning or generic project work, without explicit reference to practical activities. The literature was revisited at regular intervals until September 2024 to include new publications.

Included documents were coded in relation to the research focus, identifying practical work definitions, purposes and empirical outcomes. These findings were collated to provide examples to explore with stakeholders in the next phases of the research.

Summary of findings

We found that many articles were not explicit about their definition or enactment of practical work in primary science, leading to the decision to create a new definition as discussed above. We were surprised at the relatively small number of articles utilising empirical data from the primary phase; the rest being theoretical pieces or secondary phase studies. The dominance of the secondary perspective is perhaps to be expected, with the importance of science and the ongoing debate around the use of practical work in that phase, but it also points to the need for exploration from the primary perspective, as this study seeks to do.

The wide range of purposes listed by different authors and the lack of consensus across different age phases and contexts, was a key outcome for this part of the research. The range of purposes from the literature were collated into the list in Table 7, in preparation for the survey.

Table 7: **Literature-base for range of purposes of practical work**

Purposes listed in the survey	Example sources of literature
Experience scientific phenomena	Northern Ireland Curriculum (2007), DfE (2013), Stylianidou (2014), Osborne (2015), Walan & McEwen (2017), Curriculum for Wales (2019), Hanley et al. (2020), Ofsted (2021), Earle (2022), Tang et al. (2022), Manches & Mitchell (2023), PCAG (2023), Pun & Cheung (2023)
Engage and motivate	NGSS (2013), Langley (2014), Royal Society (2014), Smrečnik et al. (2014), Todas & Skoumios (2014), Dunlop et al. (2015), Gatsby (2017), Ruiz-Gallardo & Paños (2017), CCEA (2019), Pereira et al. (2020), Vinko et al. (2020), Bangoy (2022)
Agency, child led learning	Harlen (2014), Hall (2015), Stylianidou et al. (2018), Curriculum for Wales (2019), Bianchi et al. (2021), Lucas & Hanson (2021), Pun & Cheung (2023)
Developing understanding of the scientific method	Millar & Abrahams (2009), Smrečnik et al. (2014), Gatsby (2017), Akuma & Callaghan (2019), Vinko et al. (2020), Oliveira & Bonito (2023), Ofsted (2023)
Scientific skills, observe, gather and measure data scientifically	Millar & Abrahams (2009), Johnston (2013), SCORE (2013), Park & Abrahams (2016), Gatsby (2017), Akuma & Callaghan (2019), Pereira et al. (2020), Luxton & Pritchard (2023), Ofsted (2023)
Developing understanding of what it means to do science and be a scientist	Education Scotland (2009), DfE (2013), Abrahams et al. (2014), Needham (2014), Royal Society (2014), Hall (2015), CCEA (2019), Curriculum for Wales (2019),
Learn and use scientific vocabulary, communication	Northern Ireland Curriculum (2007), DfE (2013), NGSS (2013), Smrečnik et al. (2014), Fotou & Abrahams (2015), Stylianidou et al. (2018), Tang et al. (2022), Manches & Mitchell (2023)
Developing conceptual understanding	Millar & Abrahams (2009), DfE (2013), Löfgren et al. (2013), NGSS (2013), Abrahams et al. (2014), Hodson (2014), Needham (2014), Royal Society (2014), Roberts & Reading (2015), Education Scotland (2017), Gatsby (2017), McCrory (2018), Omilani et al. (2019), Pereira et al. (2020), Ofsted (2021), PCAG (2023)
Develop personal and social skills e.g. oracy, collaboration, perseverance	Hodson (2014), Todas & Skoumios (2014), Hall (2015), Holman (2016), Gatsby (2017), Lucas & Hanson (2021), CCEA (2022)
Relate science learning to the children's own world and cultural context	Education Scotland (2017), Walan (2017), Curriculum for Wales (2019), Golubović-Ilić & Ćirković-Miladinović (2020), Tytler et al. (2021), CCEA (2022), Luxton & Pritchard (2023), Pun & Cheung (2023)

Studies of young children's experiences in the classroom tend to be small scale, due to the time and costs involved in classroom observations. Larger scale studies often consider the effectiveness of practical work as part of a larger teaching programme, so it can be difficult to isolate the impact of practical work within classroom practice. Recent empirical studies with a specific focus on children's experiences of practical work in primary science are listed in Table 8.

Table 8: Empirical studies focusing on children's experiences of practical work in primary science

Study	Sample	Area of research	Relevant key findings
Todas & Skoumios (2014)	12 children aged 11 in Greece	Observation of independent practical work in groups of 4	Most time was taken with manipulating materials rather than linking practice with theory.
Leuchter et al. (2014)	244 children aged 4-9 from 15 schools in Switzerland	Structured learning for floating and sinking	Children's misconceptions decreased (pre/post test, intervention group), more correct predictions and more elaborated explanations
Park et al. (2016)	22 lessons from 5 teachers of 10-12 year olds in South Korea	Unintended knowledge learnt in practical work lessons	Factual knowledge gained by phenomenon-based reasoning was most commonly found, additional to the teacher's planned learning objectives.
Polikoff et al. (2018)	1615 children aged 9-10 in 17 schools in US	STEM unit using toy cars ('speedometry')	STEM unit using familiar toy cars led to significant increases in student knowledge and positive emotions.
Zhang (2018)	205 children aged 9-11 in 2 schools in US	Role of 'giving answers' in hands-on investigations	Withholding answers did not support learning of science concepts or reasoning skills.
Tang et al. (2022)	25 children aged 11 in Sweden (study also included secondary aged)	Observation of classroom practice with physical objects and gestures	Physical objects uniquely support meaning-making, for example by providing material interaction, sensations and providing evidence.
Thomas Jha & Price (2022)	26 children aged 5-6 in UK	The role of hands-on interactions in meaning making	Sensorimotor experience alongside discourse can help to make concrete connections to support the development of science ideas.

Appendix 3.
Survey: summary of methods and findings

Method

The rationale for the survey was to explore professionals' understanding regarding the purpose of practical work in primary science. The survey first asked questions relating to participants' work context:

- Which region of the UK they worked
- What their role or roles were within supporting primary science practical work
- How long they had been a teacher (if applicable)
- The recency of their teaching experience (e.g., whether they were currently teaching, or the length of time they have been out of the teaching profession
- Their highest level of science education

Participants were then asked to describe, in their own words, what they thought the purpose of practical work is within primary science. This question was shown before the 10 statements in order to ensure that participants reported their true thoughts, rather than being shaped by the statements we provided.

On continuing with the survey, participants were shown the list of 10 reasons that professionals may have for conducting primary science practical work with children. Participants were first asked to read each of the 10 statements and rate to what extent they felt each was important for children's learning of primary science: 'not very important', 'somewhat important', or 'most important'. Participants were then asked to read the same ten statements again and instead rate their likelihood for being reasons why teachers use practical work in a primary classroom: 'not likely', 'somewhat likely', or 'very likely'.

Participants were then asked to describe an anonymous example of practical work in primary science that they felt was effective.

Summary of findings

In total, 231 professionals completed the survey. The majority of participants (77%) were from England, with the remainder from Wales (11%), Scotland (8%), and Northern Ireland (4%) respectively. In terms of the job roles of the participants, a majority were primary teachers with and without responsibility for leading science practical work (54% and 11% respectively). The remaining participants reported being in other senior or professional roles, such as educational consultants (11%). Concerning the experience of participants within primary science, a majority of respondents were currently teaching primary science (72%), and had been in the teaching profession for over ten years (62%). The majority of the total participants reported being educated to GCSE level or equivalent (42%), though a considerable minority of respondents were educated to graduate level or higher (undergraduate degree: 26%; postgraduate degree: 12% doctoral: 5%).

We found that the definitions that participants provided regarding what they thought was the purpose of practical work commonly described one or more of the 10 statements that we shared in the survey. As this question was asked before participants were shown the ten purposes, we were reassured that professionals' understanding reflected the themes raised from our literature review.

Regarding the perceived importance of the 10 purposes, as we have shared above, each statement was rated highly on perceived importance, with 'being engaged and motivated', 'develop scientific skills', and 'experience scientific phenomena' being rated most highly. Despite the perceived importance of these purposes, when participants reported their perceived likelihood, we found considerable variation. A majority of participants reported that many of these purposes were 'not likely' or 'somewhat likely' reasons to be enacted in the classroom. However, despite the apparent differences between perceived importance and likelihood of these specific purposes, several participants shared interesting examples of practical work that they deemed to be effective. Some of these examples are shared above.

There were two key limitations with the survey. First, we were unable to establish why these purposes were more or less likely to be reasons for practical work in primary science. Second, our ability to decipher and make sense of the practical examples given by participants in terms of their perceived effectiveness was dependent on the level of detail they provided in their written answer. We sought to address both of these limitations through a deeper exploration within the interviews.

Appendix 4. Interviews: summary of methods and findings

Method

Qualitative research was undertaken with primary teachers who had completed the survey to further explore the purposes of practical work, identify enablers and barriers and capture ways in which practical work is enacted in classrooms and observed as being effective. Design of a semi-structured interview was informed by the literature review, survey findings and initial descriptors of the purposes of practical work. Participants were asked about their role, specifically in terms of teaching and/or supporting practical work in primary school science and to talk about:

- a specific example of primary science practical work that was valued
- the ways in which practical work was considered effective or had met its purpose
- factors and contexts which were seen as making practical work more or less likely to happen in their individual classrooms and schools
- local contextual factors in relation to practical work.

The interview protocol was piloted with one teacher from each country. A total of 34 interviews took place during the summer term of 2023.

Table 9: Participant representation across the four UK nations

Country	Number of teacher interviews
England	20
Wales	4
Northern Ireland	3
Scotland	5

Interviews were conducted online with permission to record and auto-transcribe. Transcriptions were checked and improved for accuracy, anonymised and uploaded to a digital, shared folder and stored password protected. Interview transcripts were read and systematically coded and analysed. This led to the generation of a series of themes and sub-themes on which to build an understanding of the overarching and interlocking issues.

Summary of Findings

Practical work was seen as an essential component of primary science teaching and learning. Primary teachers were enthusiastic about using hands-on, practical activities and reported that positive outcomes could be achieved. A wide range of purposes were described, with the predominant aim of developing students' scientific knowledge and skills and, providing direct and hands-on experiences with an intention to engage and motivate young children and to stimulate their curiosity (Table 10).

Table 10: The purposes of practical work in primary science

Most common	• Develop an understanding of the scientific enquiry method and scientific skills • Conceptual understanding • Experience scientific phenomena • Engagement, interest and motivate
Less common	• Development and use of scientific vocabulary • Lead own learning • Relate science to own world • Foster cross curricular learning • Development of wider/social skills
Least likely	• Understand the nature of science, what it means to be a scientist

Practical work was being used to develop an understanding of the scientific enquiry method and scientific skills, often situated within a full investigation. Hands-on and direct experience of scientific phenomena was seen as an important part of primary science learning and highly valued by teachers. Practical work experiences were designed to engage, interest and motivation but this was more challenging in some science topics than others. Teachers wanted young children to have the freedom and opportunity to explore and to discover things for themselves. Planning and designing practical activities in order for children to develop and use scientific vocabulary is rare, however, this was regarded as a positive and observable outcome. Teachers talked about hearing their children discussing what they had been taught previously, applying and connecting their learning and using appropriate terminology. Practical work is less frequently used to provide opportunities for children to work independently and to make decisions for themselves and therefore to lead their own learning. Teachers from England rarely talked about the potential that practical work afforded for children to make connections between different subjects, foster cross curriculum learning, develop wider social skills and relate science to the real world. This was seen more as a broader purpose of the primary science curriculum as a whole.

Resources to enable children's full participation were limited, as were the resources for teacher professional development. There is a desire for all primary teachers to have some science focused professional development, other than for those in a science subject leader role. Protected planning time and after school meetings are used for formal and informal professional development. Teacher knowledge, skills and confidence to deliver practical work can be developed if there is the time for primary teachers to rehearse practical activities. Primary schools are operating on small budgets, consequently, children often work in large groups. The lower status of science, compared to mathematics and English within national and school curricula is seen as a concern and mitigating factor.

Using outside spaces and taking advantage of enrichment opportunities is beneficial for practical work. External funding is useful and helps to build both capacity and capability to innovate and to sustain practical work. Primary science subject lead teachers are aware of a wide range of CPD, online resources and often take advantage of these.

Teachers rely on their own personal reflections and observations of children's learning during lessons to assess the effectiveness of practical work. Children's learning through practical work was observed through their engagement in scientific talk, questioning, answering, and discussions and whether children could recall their prior science learning or if they could connect and apply their learning from a previous lesson.

There are two limitations of the interviews. First the method of recruitment (invitation through the research team's primary school database and networks), those who took part in the in-depth interviews may not reflect the teacher population as a whole. Second, the semi-structured nature of the interviews means that no inferences can be drawn about the scale or frequency of attitudes or opinions and statements. Within the report we have not quantified the number of responses to a particular theme, but provided an indication e.g. most likely, least likely as to the proportion of interviewees who have commented under a given theme.

Appendix 5.
References

Abrahams, I., & Millar, R. (2008). Does Practical Work Really Work? A Study of the Effectiveness of Practical Work as a Teaching and Learning Method in School Science. *International Journal of Science Education*, 30 (14): 1945–69. https://doi.org/10.1080/09500690701749305

Abrahams, I., Reiss, M. J., & Sharpe, R. (2014). The impact of the 'Getting Practical: Improving Practical Work in Science' continuing professional development programme on teachers' ideas and practice in science practical work. *Research in Science & Technological Education*, 32(3), 263–280. https://doi.org/10.1080/02635143.2014.931841

Akuma, F. V., & Callaghan, R. (2019). A systematic review characterizing and clarifying intrinsic teaching challenges linked to inquiry-based practical work. *Journal of Research in Science Teaching*, 56 (5): 619-648.

Bangoy, R. M., (2022). Practical work approach: a tool to improve the creativity skills of the students in recycling. *Globus: Journal of Progressive Education*, 12, 1: 100-103.

Bennett, J., Dunlop, L., Atkinson, L., Compton, S., Glasspoole-Bird, H., Lubben, F., Reiss, M., & Turkenburg-van Diepen, M. (2023) *A systematic review of approaches to primary science education*. Education Endowment Foundation.

Bianchi, L., Whittaker, C., & Poole, A. (2021). *The 10 Key Issues with Children's Learning in Primary Science in England.* The University of Manchester & The Ogden Trust.

CCEA (Council for the Curriculum Examinations and Assessment). (2019). *Science and Technology within the World Around Us: Progression Guidance.* CCEA.

CCEA (Council for the Curriculum Examinations and Assessment). (2022). *Science and Technology Progression Pathway.* CCEA.

Convertini, J., Arcidiacono, F., & Miserez-Caperos, C. (2023). Teachers' interventions in science education at primary school. The role of semiotic resources during argumentative interactions in classroom. *Research in Science & Technological Education*, 42(1), 94–113. https://doi.org/10.1080/02635143.2023.2243835

Curriculum for Wales. (2019). *Curriculum for Wales: Science and Technology.* https://hwb.gov.wales/curriculum-for-wales/science-and-technology/

DfE (Department for Education). (2013). *National curriculum in England: science programmes of study.* https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study

Dunlop, L., Compton, K., Clarke, L., & McKelvey-Martin, V. (2013). Child-Led Enquiry in Primary Science. *Education*, 3-13 43 (5): 462–81. https://doi.org/10.1080/03004279.2013.822013

Earle, S. (2022). Research review: Early Science research summary - use of play and role of the adult. *Journal of Emergent Science*, 22: 5-12 https://www.ase.org.uk/resources/journal-of-emergent-science/issue-22/research-review-early-science-research-summary-use-of

Education Scotland. (2009). *Curriculum for excellence: sciences@ experiences and outcomes.* Education Scotland. https://education.gov.scot/media/jcxpmwd5/sciences-eo.pdf

Education Scotland. (2017). *Benchmarks: Sciences.* Education Scotland.

Fotou, N., & Abrahams, I. (2015). Doing with ideas: the role of talk in effective practical work in science. *School Science Review*, 359: 25-30.

Gatsby. (2017). *Good Practical Science.* The Gatsby Charitable Foundation: London. https://www.gatsby.org.uk/uploads/education/reports/pdf/good-practical-science-report.pdf

Golubović-Ilić, I., & Ćirković-Miladinović, I. (2020). Learning science in preschool by using a research approach. *Acta Didactica Napocensia,* 13 (1): 77-86.

Hanley, P., Wilson, H., Holligan, B., & Elliott, L. (2020). Thinking, Doing, Talking Science: The Effect on Attainment and Attitudes of a Professional Development Programme to Provide Cognitively Challenging Primary Science Lessons. *International Journal of Science Education*, 42 (15): 2554–73. https://doi.org/10.1080/09500693.2020.1821931

Harlen, W. (2014). Helping children's development of inquiry skills. *Inquiry in Primary Science*, 1: 5-19 https://www.platformsamenonderzoeken.nl/wetenwatwerkt/wp-content/uploads/sites/3/2021/06/Helping-childrens-development-of-inquiry-skills-2014.pdf

Hodson, D. (2014). Learning Science, Learning about Science, Doing Science: Different Goals Demand Different Learning Methods. I*nternational Journal of Science Education*, 36 (15): 2534–53. https://doi.org/10.1080/09500693.2014.899722

Johnston, J. (2013). The effect of two pedagogical approaches on the scientific development of predictions and hypothesis in the early years. *Journal of Emergent Science*, 6: 6-11. https://www.ase.org.uk/resources/journal-of-emergent-science/issue-6

Kang, S., Lu, M., Black, J. B., & Kim, S. (2022). Mindful movements matter: differentiating active body movements in underprivileged students' learning of physics concepts. *Research in Science & Technological Education*, 42(2), 412–430. https://doi.org/10.1080/02635143.2022.2093344

Kennedy, D. (2014). The Role of Investigations in Promoting Inquiry-Based Science Education in Ireland. *Science Education International*, 24 (3): 282-305. https://eric.ed.gov/?id=EJ1022335

Kersting, M., Karlsen, S., Ødegaard, M., Olufsen, M., Kjærnsli, M., & Suhr Lunde, M. L. (2023). Studying the quality of inquiry-based teaching in science classrooms. A systematic video study of inquiry-based science teaching in primary and lower-secondary schools. *International Journal of Science Education*, 45(17), 1463–1484. https://doi.org/10.1080/09500693.2023.2213386

Langley, M. (2014). Supporting Teachers and Technicians in the Delivery of High-Quality, Effective Practical Science. *School Science Review*, 96 (355): 63-69.

Leuchter, M., Saalbach, H., & Hardy, I. (2014). Designing Science Learning in the First Years of Schooling. An intervention study with sequenced learning material on the topic of 'floating and sinking'. *International Journal of Science Education*, 36(10), 1751–1771. https://doi.org/10.1080/09500693.2013.878482

Löfgren, R., Schoultz, J., Hultman, G., & Björklund, L. (2013). Exploratory Talk In Science Education: Inquiry-Based Learning And Communicative Approach In Primary School. *Journal of Baltic Science Education*, 12 (4): 482-496.

Lucas, B., & Hanson, J. (2021). Reimaging Practical Learning in secondary schools: a review of the evidence. *Royal Academy of Engineering*. https://raeng.org.uk/practical-learning

Luxton, K., & Pritchard, B. (2023). *Improving Primary Science: Guidance report.* London: Education Endowment Foundation.

Manches, A., & Mitchell, E. (2023). Embodied Learning for early and primary science: Key implications from the Move2Learn project. *Journal of Emergent Science*, 24: 23-32. https://www.ase.org.uk/resources/journal-of-emergent-science/issue-24/embodied-learning-early-and-primary-science-key

Millar, R., & Abrahams, I. (2009). Practical work: making it more effective. School science review, 91 (334): 59-64. http://www.gettingpractical.org.uk/documents/RobinSSR.pdf

Mujtaba, T., Sheldrake, R., Hodgen, J., & M. Reiss. (2022). *Focus for Teacher Assessment of Primary Science (Focus4TAPS): Evaluation Report.* London: Education Endowment Foundation. https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/focus4taps

Nag Chowdhuri, M., King, H. & Archer, L. (2021). *The Primary Science Capital Teaching Approach: teacher handbook.* UCL Institute of Education: London, UK.

Needham, R. (2014). The Contribution of Practical Work to the Science Curriculum. *School Science Review*, 95 (352): 63-69.

NGSS (Next Generation Science Standards). (2013). *Science and Engineering Practices in the NGSS – Appendix F.* https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

Northern Ireland Curriculum. (2007). *The Northern Ireland Curriculum: Primary.* Belfast: Council for the Curriculum Examinations and Assessment (CCEA).

Ofsted. (2021). *Research review series: science.* Ofsted. https://www.gov.uk/government/publications/research-review-series-science/research-review-series-science

Ofsted. (2023). *Finding the optimum: the science subject report.* Ofsted. https://www.gov.uk/government/publications/subject-report-series-science/finding-the-optimum-the-science-subject-report--2

Oliveira, H., & Bonito, J. (2023). Practical work in science education: A systematic literature review. *Frontiers in Education*, 8, 1151641. https://doi.org/10.3389/feduc.2023.1151641

Omilani, N. A., Akinyele, S. A., Durowoju, T. S., & Obideyi, E. I. (2018). The effect of the assessment of practical-based work on pupils' problem solving and achievement in Basic Science and Technology in Odeda local government of Ogun State, Nigeria. *Education* 3-13, 47(6), 760–772. https://doi.org/10.1080/03004279.2018.1534874

Osborne, J. (2015). Practical work in science: misunderstood and badly used? *School Science Review*, 96 (357):16-24.

Park, J., Abrahams, I., & Song, J. (2016). Unintended Knowledge Learnt in Primary Science Practical Lessons. *International Journal of Science Education*, 38 (16): 2528–49. https://doi.org/10.1080/09500693.2016.1250968

PCAG (Primary Curriculum Advisory Group). (2023). *Framework for a Future Primary Science Curriculum: Recommendations from the Primary Curriculum Advisory Group to the Royal Society of Biology, the Royal Society of Chemistry, the Institute of Physics, and the Association for Science Education.* PCAG.

Pereira, S., Rodrigues, M. J., & Vieira, R. M. (2019). Scientific literacy in the early years – practical work as a teaching and learning strategy. *Early Child Development and Care*, 190(1), 64–78. https://doi.org/10.1080/03004430.2019.1653553

Polikoff, M., Le, Q. T., W. Danielson, R., M. Sinatra, G., & A. Marsh, J. (2017). The Impact of Speedometry on Student Knowledge, Interest, and Emotions. *Journal of Research on Educational Effectiveness*, 11(2), 217–239. https://doi.org/10.1080/19345747.2017.1390025

Pun, J. K. H., & Cheung, K. K. C. (2021). Meaning making in collaborative practical work: a case study of multimodal challenges in a Year 10 chemistry classroom. *Research in Science & Technological Education*, 41(1), 271–288. https://doi.org/10.1080/02635143.2021.1895101

Roberts, R., & Reading, C. (2015). The practical work challenge: incorporating the explicit teaching of evidence in subject content. *School science review*, 96 (357): 31-39. https://durham-repository.worktribe.com/output/1436127/

Royal Society. (2014). *Vision for science and mathematics education.* The Royal Society.

Ruiz-Gallardo, J. R., & Paños, E. (2017). Primary school students' conceptions about microorganisms. Influence of theoretical and practical methodologies on learning. *Research in Science & Technological Education*, 36(2), 165–184. https://doi.org/10.1080/02635143.2017.1386646

SCORE (Science Community Representing Education). (2013). *Resourcing practical science in primary schools.* SCORE.

Smrečnik, I. D., Fošnarič, S., & Čagran, B. (2014). Analysis of the Implementation of Practical Work in the Area of Early Science Education of Primary School Pupils in the Republic of Slovenia. *New Educational Review*, 36: 235-265. https://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.ojs-doi-10_15804_tner_14_36_2_20

Spaan, W., Oostdam, R., Schuitema, J., & Pijls, M. (2022). Analysing teacher behaviour in synthesizing hands-on and minds-on during practical work. *Research in Science & Technological Education*, 42(2), 219–236. https://doi.org/10.1080/02635143.2022.2098265

Stylianidou, F. (2014). *Creativity in Science and Mathematics Education for Young Children: Executive Summary.* http://www.creative-little-scientists.eu/sites/default/files/Creativity_in_Science_and_Mathematics_Education.pdf

Stylianidou, F., Glauert, E., Rossis, D., Compton, A., Cremin, T., Craft, A., & Havu-Nuutinen, S. (2018). Fostering Inquiry and Creativity in Early Years STEM Education: Policy Recommendations from the Creative Little Scientists Project. *European Journal of STEM Education*, 3 (3), 15: 1-13.

Tang, K. S., Jeppsson, F., Danielsson, K., & Bergh Nestlog, E. (2022). Affordances of physical objects as a material mode of representation: A social semiotics perspective of hands-on meaning-making. *International Journal of Science Education*, 44(2), 179–200. https://doi.org/10.1080/09500693.2021.2021313

Todas, A., & Skoumios, M. (2014). Practical Work in Primary Science: Actions and Verbalized Knowledge. *The International Journal of Early Childhood Learning*, 20 (2): 37-50. https://doi.org/10.18848/2327-7939/CGP/v20i02/58951

Thomas Jha, R., & Price, S. (2022). Embodying science: the role of the body in supporting young children's meaning making. *International Journal of Science Education*, 44(10), 1659–1679. https://doi.org/10.1080/09500693.2022.2089366

Tytler, R., Mulligan, J., Prain, V., White, P., Xu, L., Kirk, M., Nielsen, C., & Speldewinde, C. (2021). An interdisciplinary approach to primary school mathematics and science learning. *International Journal of Science Education*, 43(12), 1926–1949. https://doi.org/10.1080/09500693.2021.1946727

van Uum, M. S. J., Verhoeff, R. P., & Peeters, M. (2016). Inquiry-based science education: towards a pedagogical framework for primary school teachers. *International Journal of Science Education*, 38(3), 450–469. https://doi.org/10.1080/09500693.2016.1147660

Vinko, L., Delaney, S., & Devetak, I.. (2020). Teachers' Opinions about the Effect of Chemistry Demonstrations on Students' Interest and Chemistry Knowledge. *Center for Educational Policy Studies Journal*, 10 (2): 9-25.

Walan, S., & McEwen, B. (2017). Primary Teachers' Reflections on Inquiry- and Context-Based Science Education. *Research in Science Education*, 47: 407–426. https://doi.org/10.1007/s11165-015-9507-5

Zhang, L., (2018). Withholding answers during hands-on scientific investigations? Comparing effects on developing students' scientific knowledge, reasoning, and application. *International Journal of Science Education*, 40(4), 459–469. https://doi.org/10.1080/09500693.2018.1429692

8. Further information

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