



QuSmart - A scientific question-asking routine to improve the way primary children work scientifically

This document details the theoretical understandings and classroom strategies that relate to a 6-stage routine to improve the quality of children’s scientific question-asking. This supports primary teachers and children to working together to improve how scientific questions are stimulated, produced, handled, developed, decided upon and reviewed when working scientifically.

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1. Introduction

This report draws together the research and development study undertaken between 2019-2021 – a partnership between The University of Manchester and the Primary Science Teaching Trust.

QuSmart set out to identify how children and teachers could improve the thinking processes that initiated and developed scientific question asking. The study has been aligned to the Science National Curriculum for England, however the strategies described in this report are likely to be transferable to other settings across the world. Fundamentally, the vision has been to give children greater choice and agency when working scientifically, enhancing the opportunity to build on repeated and regular experiences and moving away from prescriptive practical work that lacks purpose (Bianchi et al, 2021).

The methodology for the study, which embraced teachers as collaborative researchers, is published (Bonsall & Bianchi, 2019; in review). It provides the outcomes of an initial scoping of literature associated with the ways in which children learn to ask and build scientific questions, and outlines the four principle papers that underpin the development of the QuSmart routine, described herein. Most importantly, it illustrates that there is a lack of contemporary academic research published in this field and that few routines for children to learn how to ask and build scientific questions which marks the relevance and timeliness of this study.

Inevitably the restrictions imposed on education over the period of the CV19 pandemic mean that the opportunity for further in-school trialling must be taken. This will provide the theoretical approaches with empirical evidence that will strengthen the narrative of the implementation of QuSmart with different age groups, in different contexts.

2. What's the purpose of QuSmart?

The work of Paulo Freire, a Brazilian educator and philosopher and a leading advocate of critical pedagogy, helps us to recognise why the QuSmart programme is so fundamental to enhancing children's question asking. In his conversation with fellow philosopher, Antonio Faundez, discuss that,

'... what teachers ought to teach... should be supremely how to ask questions. Because, I repeat, knowledge begins with asking questions. And only when we begin with questions, should we go out in search of answers, and not the other way round.' (Freire, 1989. p35)

Their thinking supports the experiences of QuSmart team, and we've been inspired, to make this practical and accessible to teachers in primary schools. Here we outline a pedagogical approach that focuses attention on the role of question-asking when working scientifically, which we continue to apply and review in primary classrooms in England.

We know that by **getting this right will mean added benefit and value to both teacher and child**, whose experience of science enquiry will be more thoughtful, considered and reflective. By considering a deliberate routine to ask and build scientific questions prior to the starting practical work, QuSmart seeks to provide a routine that can be regularly used and practiced that will result in improving the scientific evidence children gain when working scientifically such that they forge new knowledge and understandings in the science classroom.

The routine doesn't aim to be restrictive but liberating and supportive of teachers who may desire a child-centred approach to science enquiry but fear the range and scope of questions that children ask. This interest has resulted in a pedagogy to empower and support teachers to enable children to ask, handle and build scientific questions, embracing a child-focused model of teaching and learning.

It tackles an issue that Freire explains to be critical:

'... The problem which the teacher is really faced with is how in practice progressively to create with the students the habit, the virtue, of asking questions, of being surprised.

For an educator with this attitude there are no stupid questions or final answers. Educators who do not castrate the curiosity of their students, who themselves become part of the inner movement of the act of discover, never show disrespect for any question whatsoever. Because, even when the question may seem to them to be ingenuous or wrongly formulated, it is not always so for the person asking it. In such cases, the role of educators, far from ridiculing the student, is to help the student to rephrase the question so that he or she can thereby learn to ask better questions.' (Freire, 1989. p35-37)

This seemingly simple skill, often identified as the first step in the enquiry process, enables children to be **active learners** – to enjoy agency and power within the learning, as they are invited to reflect on what they don't already know, to ask questions about their lives and their learning that enable them to address areas of learning that they find tricky or puzzling. **To enquire is to offer pupils the opportunity to coconstruct the learning process**, with each other and with the teacher, something that the QuSmart team value and makes vivid a socially constructivist approach to teaching and learning.

As you go forward in this document to read and understand more about the QuSmart Routine and the associated range of strategies, you will be acknowledging how integral **collaborative and social** practices are in learning. These features are significant in constructivism as we understand it through the work of Lev Vygotsky, a post-revolutionary Soviet psychologist. Vygotsky's work explored how social interactions supported cognitive development. He explained that learning is not just the assimilation and accommodation of new knowledge but the process by which this happens, which he explains cannot be separated from a social context – talking and thinking together.

Every function in the child's cultural development appears twice: first, on the social level and, later on, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals. (Vygotsky, 1978, p57).

Furthermore, Correia and Harrison (2020, p371) help us to explain the way QuSmart influences teaching and learning of science enquiry. Their clarification of three categories of inquiry-based learning in science include:

- Directed - teacher leads inquiry and decision-making.
- Guided - pupil as apprentice, group or class decision-making.
- Independent - pupil leads inquiry and decision-making.

In this way QuSmart supports teachers and children to shift towards guided enquiry. By doing so we encourage teachers to further value and develop opportunity for children to have **autonomy and agency when working scientifically**, and acknowledge that how, *'teachers introduce and organise inquiry in their classrooms affects the degree of autonomy and choice that the learner is allowed to exhibit within the inquiry activity'* (p358).

A wide range of factors will influence the use of the QuSmart routine, including curriculum goals, school ethos, pupil age and ability. We seek to inspire and challenge teachers and senior leaders to review the current norms and ways of working in school and to reflect on **the purpose of working scientifically** in the primary classroom. Throughout this document we offer professional prompts and stimulus to question, develop and hone our awareness and knowledge of practice in

order to ensure we attend to developing the fundamental, yet falsely deceptive simple life skill – that of asking scientific questions.

3. Why bother with scientific question-asking?

Children's opportunities to ask and investigate their own questions in primary school is limited. The Wellcome Trust's Report on Primary Science Education (2017) noted that child-led and child-designed investigations were being undertaken 'occasionally' or 'never' in 47% of schools. It is through these rich opportunities that children can be taught to develop their skills in questioning so as to have an authentic engagement with enquiry and work scientifically.

The profile of primary school science in England isn't what it should be. The negative turn following the removal of the standard assessment tasks (OFSTED, 2013) is a reality that we must challenge so as to improve the chances of young people and their capacity to engage fully with a fast moving society. We know that the Science Capital of many children is low, especially those within areas of social disadvantage. It's our responsibility to do as much as we can to inspire them into science and to widen their future aspirations into STEM (Archer et al, 2013).

We know that children's science learning is over-reliant on teacher talk and direction and their own curiosity, scientific interest and questions aren't encouraged enough. This leads to lack of motivation towards working scientifically and an inconsistent understandings of how to model working and thinking scientifically across schools and the sector as a whole (Watson et al, 1998; Bianchi et al, 2021).

QuSmart embraces research and innovation past and present in turning the flow of talk in primary science classrooms away from being mainly teacher driven to being a shared and guided experience towards enquiry (OFSTED 2013).

We are excited by the prospect of QuSmart increasing the autonomy and control that children have when working scientifically. The benefits offer potential beyond just the science classroom but to the children's life outside it and well into the future. At a time where fast media means that information and news is a touchscreen away the QuSmart speaks to enabling young people to be:

- empowered to ask the 'right' kind of questions at the 'right' time
- judge and evaluate the questions and evidence presented to them
- make better choices about what information to trust and base their decisions on.

White & Gunstone (1992) describe how important questions are to reveal student's understandings however they stress that they occur too rarely and are often unpredictable. 'This unpredictability means that students' questions rarely play any planned part in teaching and assessment', going on to encourage that questions become common and that teachers plan to build on them to promote and monitor learning (p158).

This report provides an evidence-based approach that offers theoretical and practical routines to use in primary science settings.

Scientific Question-asking within the Primary Science National Curriculum (NC) for England

The QuSmart research and development was focused on trialing approaches with mainstream teaching and learning of science in primary school settings in England, with a target age group of 7-11 year olds (Key Stage 2). It was quickly evidence that the work was relevant to younger age phases, and would have applicability to other nations. For the purposes of this report, the authors have referenced the English NC for exemplification.

Examination of the Science National Curriculum (DFE, 2014) shows how from Key Stage (KS) 1, 5-7 year olds are taught to ask **simple** questions. They are developed to ask **relevant** questions at KS2 (7-11 years) in which they should experience different types of scientific enquiries to answer questions which include recognising and controlling variables. The terms 'simple' and 'relevant' have not been defined by the DFE, although published resources have offered interpretation of this for teachers (Turner et al, 2011).

Key Stage 1 (5-7 years):

They should be encouraged to be curious and **ask questions** about what they notice. They should be helped to develop their understanding of scientific ideas by **using different types of scientific enquiry to answer their own questions, including observing changes over a period of time, noticing patterns, grouping and classifying things, carrying out simple comparative tests, and finding things out using secondary sources of information**. They should begin to use simple scientific language to talk about what they have found out and communicate their ideas to a range of audiences in a variety of ways. (highlight and underline added, P4)

Lower Key Stage 2 (7-9 years):

Pupils should be taught to use the following practical scientific methods, processes and skills through the teaching of the programme of study content:

- **asking relevant questions and using different types of scientific enquiries to answer them**
- setting up simple practical enquiries, comparative and fair tests
- making systematic and careful observations and, where appropriate, taking accurate measurements using standard units, using a range of equipment, including thermometers and data loggers
- **gathering, recording, classifying and presenting data in a variety of ways to help in answering questions**
- recording findings using simple scientific language, drawings, labelled diagrams, keys, bar charts, and tables
- reporting on findings from enquiries, including oral and written explanations, displays or presentations of results and conclusions

- **using results to draw simple conclusions**, make predictions for new values, suggest improvements and raise further questions
- identifying differences, similarities or changes related to simple scientific ideas and processes
- **using straightforward scientific evidence to answer questions or to support their findings.** (P14)

During Years 5 and 6, pupils should be taught to use the following practical scientific methods, processes and skills through the teaching of the programme of study content:

- **planning different types of scientific enquiries to answer questions**, including recognising and controlling variables where necessary
- taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate
- recording data and results of increasing complexity using scientific diagrams and labels, classification keys, tables, scatter graphs, bar and line graphs
- using test results to make predictions to set up further comparative and fair tests
- reporting and presenting findings from enquiries, including conclusions, causal relationships and explanations of and degree of trust in results, in oral and written forms such as displays and other presentations
- **identifying scientific evidence** that has been used to support or refute ideas or arguments. (P25)

Figure 1: Curriculum reference to questions within the Science National Curriculum for England (DFE 2014)

4. What is question-asking for?

The design of the QuSmart programme has been underpinned by research literature and key texts by authors who promote question-asking within the classroom. In particular four academic papers were identified for this purpose (Bianchi & Bonsall, 2019). These enable us to understand further why children's development of scientific question-asking, handling and building is more than 'just a good thing to do'. PISA (2015) recognises the importance of evidence in decision making.

Scientific literacy is defined as the ability to understand the characteristics of science and the significance of science in our modern world, to apply scientific knowledge, identify issues, describe scientific phenomena, draw conclusions based on evidence, and the willingness to reflect on and engage with scientific ideas and subjects. One aspect is that students understand the significance of science and technology in their daily lives. **They should be able to apply a scientific approach to assessing scientific data and information in order to make evidence-based decisions.** (Kwok-Chi Lau, 2009, *highlighting added*)

Pivotal to the creation of QuSmart were the readings of Rothstein & Santana (2015) and Berger (2014) in their creation and review of the **Question Formulation Technique** (QFT). This approach, created by the Right Question Institute, suggests a method to support all people to create, work with, and use their own questions. It is a generic approach designed to stimulate three types of thinking: divergent thinking, convergent thinking, and metacognitive thinking in order to build skills for lifelong learning, self-advocacy, and democratic action.

This work aligns with QuSmart's aims to, 'encourage or even allow questioning is to cede power - not something that is done lightly in hierarchical companies or in government organisations, or even in classrooms, where a teacher must be willing to give up control to allow for more questioning' (Berger 2014, p 6). The key areas of difference and specialisation that QuSmart contributes to this discourse results from the embedded way that this approach works in primary science classrooms. So far, set within an English educational context, we know that there will be synergy and applicability further afield, as fundamentally QuSmart is embedded in the process of science enquiry itself (Figure 2).



Figure 2: The science inquiry process in a 'Working Scientifically Wheel' (TAPS, 2020)

As QuSmart encourages teachers to involve children in a process of scientific question asking, there is a required pedagogical strengthening of child-focused or child-led approaches. It is important to clarify that in 'ceding power' in this way in the primary science classroom we are seeking to encourage children to develop agency and autonomy in asking and developing their own scientific curiosity and questions, which will inevitably influence the teacher-learner relationship between teacher and children.

- QuSmart is not a process that relinquishes the teacher's role in the classroom – in fact they're required more to guide and facilitate learning.
- QuSmart is not negating the requirement for subject knowledge development and embraces us to think with rigour about the misconceptions and tricky bits, and to focus on new knowledge and understandings.
- QuSmart is not about the promotion of discovery learning yet does encourage teachers to listen and value children's questions and interests, actively using these as they guide and curate the science learning process.

There are a number of assumptions that we are also making in terms teacher engagement with the QuSmart. In applying the routine, there is an expectation that teachers have:

- understanding of the enquiry cycle (plan-do-review)
- introduced and explored the key scientific vocabulary related to enquiry, such as 'independent' and 'dependent' variables, range, sample size, cause and effect to their pupils.
- use of assessment-for-learning practices in science, such that they elicit children's starting points are responsive to these in their teaching and provide feedback on progress

5. What is the QuSmart routine about?

Ultimately, QuSmart seeks to improve the way children work scientifically, by placing keen focus on asking and refining their scientific questions prior to investigating, and with hindsight from evidence. In order to do this we offer further understanding into what a scientific question is both in terms of definition and example.

Defining a scientific question

The definition of a 'question' and what its purpose can seem simple or obvious, however a standard definition is not shared by the teaching profession. Many variations provide food for thought, including some of those gathered during this study, e.g.

- Something you can investigate.
- Questions that help us understand the world that we live in.
- A question that will lead to figuring out why something happens.
- A key to a reality: we might be able to unlock a certain knowledge about the world with it.
- Something that allows me to discover something new based on a method that make the answer measurable.
- Something with a specific outcome.
- A question based in the area of discovery, to either prove a theory or to test a hypothesis.
- A question that attempts understand a theory / concept.

Such a difference in perspective can lead to worthwhile professional dialogue, yet can also result in misunderstandings. Because of this we provide a QuSmart definition of what a **scientific question** is.

A scientific question that leads to evidence being gathered, conclusions drawn and new knowledge learnt

Let us consider the features of this definition:

A scientific question 'that leads to evidence being gathered'

Watson, Goldsworthy & Wood Robinson's early work in the AKSIS project (1998, 2000) reinforces that questioning is a scientific skill and 'what children do to collect and make sense of evidence'. She goes on to explain that scientific enquiry relates to understanding the nature of evidence and the use and application of scientific skills. We embrace this clear purpose for scientific questioning in the QuSmart definition, as it enables teachers and pupils to clearly recognise the outputs from scientific questions within an enquiry.

White & Gunstone (1992) also support this perspective with their use of 'thinking questions' to explain those that demand and probe understanding and that encourage evidence gathering.

A scientific question leads to 'conclusions drawn'

Lau Kwokchi (2009, P1067) clarify what PISA's criteria for Scientific Literacy is - describing one aspect of this to be 'the capacity to use scientific knowledge, to identify questions and to draw evidence based conclusions'. Here the focus on evidence is reinforced again with the added element of conclusions being highlighted.

A scientific question leads to 'new knowledge learnt'

Chouinard, Harris and Maratos (2007) suggest that a question provides 'targeted information 'exactly when they [the learners] need it' when they encounter a problem with their current knowledge state... a gap in their knowledge, some ambiguity they can't resolve, some inconsistency they've detected.' In this way 'purposeful question using/posing' is when the person asking successfully achieves a change of knowledge stage.'

The identification of a 'gap' in knowledge supports us in acknowledging the need for children to be working on questions that enable them to address or tackle knowledge or an area of learning that is tricky, uncertain or new to them. It supports us to make vivid the need for children not to be undertaking science enquiries which don't challenge them to extend or progress their scientific skills or understandings.

In defining the QuSmart definition for scientific questions we embrace children as 'natural researchers', a way of learning promoted within the Reggio Emilia traditions - a philosophy for education that encourages teachers to design learning experiences that encourage curiosity, the ability to ask questions, willingness to experiment and desire to take time to discover on their own' (Steglein p164). In this approach both Steglein and QuSmart recognise the importance of the teacher-child relationship which is focused on co-operative and nurturing pedagogies.

Taxonomy of scientific questions

Questions are as varied as our imagination. This means that the prospect of encouraging children to ask simple or relevant scientific questions can result in us feeling unsure of how to best work with them. This genuine fear is inevitable and can lead to 'safer' routes of practice where a pre-formulated enquiry question is offered to the children from the outset, or subliminally steered towards through clever teacher-led discussion. We can't underappreciate that classrooms are very busy places and the pressure of the curriculum and to 'get work in books' continues to bear down heavy on us all.

QuSmart doesn't avoid or dismiss this reality, yet needs to work within it to continue to seek to improve the experience and outcomes of working scientifically if we are to do justice to our children and the curriculum.

What we have come to understand within this study is that when asking scientific questions a one-size-fits all approach doesn't work. The variety of children's questions will mean that there are many relevant ones asked, although not always at

the time you wish them to be asked! Questions are different and have different purposes. We should embrace and value their variety and learn how best to handle and develop them. This is the heart of the QuSmart process.

The **QuSmart Taxonomy** provides us with an overview of 5 different types of scientific question. This is not considered exhaustive and further research will continue to inform this area.

Scientific questions that lead to evidence being gathered, conclusions drawn and new knowledge found and can be in the form of:

Quick-fire, fact-finding questions	Undisputable. Closed. Yes-No answer. Prompts a reaction or response.	What is a magnet? How do Volcanos work? How is bread made? Who discovered gravity? What are the names of the planets? How are fossils made?
A question leading to an exploratory or making activity	A playful activity with a scientific focus to find out more, see what something does.	What colour hair do people in our class have? Do raisins dance in lemonade? Can oil and water mix?
A scientific question leading to simple enquiry	to observe a change or affect.	How far will my O-glider travel? What melts ice? How fast would the ice in the freezer melt? Which paper towel soaks up the most water? When I change the size of the spinner's wings, what happens to the time it takes to fall? How does the mould grow on this orange if we leave it for 3 weeks?
A scientific question leading to a relevant enquiry	to evaluate the effect of one thing on another (cause-effect)	What will happen to the temperature of the hot water if we let it cool down and take its temperature every 5 minutes?, If we make the elastic band different lengths, what will happen to the pitch of the note when we pluck it?, How does the shape of the glider's tail affect the distance that the glider will travel?, How much does your heart rate change when you do different exercises?

<p>A scientific question to evaluate certainty of information</p>	<p>to evaluate the trustworthiness to acquire better/deeper understandings about the world around us</p>	<p>How certain are we that plastics are harming the planet? Can we be sure that medicines work? What proof is there that exercise improves our mood? Can we trust adverts that say that a particular product works? How certain are we that eating 5 fruits and vegetables each day helps make us healthier?</p>
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Terminology associated with scientific questioning

Another area of potential difficulty in this area of work is with the range of scientific vocabulary that relates to enquiries. For most success, teachers and children benefit from shared, common understandings being used across age phases. Support will need to be given for consistency in pupil understanding, for instance through a glossary of terms – see Appendix 1.

6. How can the science subject leader support QuSmart?

QuSmart is a way of working with children that requires teachers to adopt a particular way of teaching. It could be described as a ‘Signature Pedagogy because when we work in this way, and adopt the routine in our classroom, we are developing a culture of practice that will shape how we behave as teachers.

“Signature pedagogies make a difference. They form habits of the mind, habits of the hand and habits of the heart...” (Shulman, 2005)

As a subject leader for science, it is important that the school culture values and supports the practice that is being encouraged. Without this, there is a risk that children will see a disconnect between what one teacher values and another. By taking the lead in understanding and monitoring how children’s scientific question-asking is being taught, listening to teacher’s experiences and valuing children’s responses to it, you can be a champion for best practice.

Refining practice will take time. All change needs embedding and that needs to be appreciated from the outset. QuSmart is not about one-off quick fixes, but a change in the way we think about the purpose and nature of children’s voices and the influence they have to our planning.

As a subject leader it will be important to gauge the readiness of colleagues to adopt a QuSmart approach. A staged approach to development has been found to be useful when managing change, and understanding the position and aspirations of colleagues is valuable within this process. Figure 3 shows the Trajectory of Professional Development (ToPD, Bianchi, 2018), a framework to support teacher reflection (Earle & Bianchi, 2021)

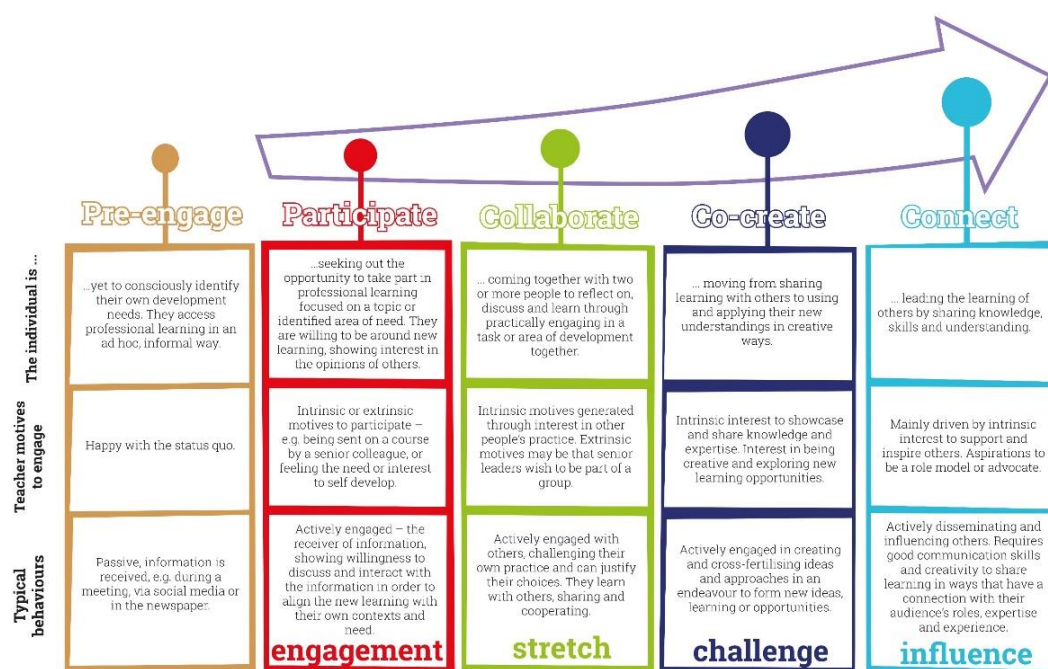


Figure 3: Trajectory of Professional Development

Question prompts to review individual and school readiness for QuSmart are provided in Table 1.

Being clear on why you are doing this	Being clear on the starting points	Planning and inspiring change	Knowing how you'll know a difference has been made
What is your rationale for starting to use a QuSmart approach?	Are teachers aware of the NC requirements for working scientifically?	Have all teachers received enough information and support to try the QuSmart routine?	How will teachers share their planning with you/each other?
What is the purpose of doing this – what do you want to change?	Is there a common definition of a scientific question in your school?	Which topic will teachers start to use the QuSmart routine?	What would be useful information to gather to understand if QuSmart has influenced the way children ask questions?
What is the current approach to working scientifically in your classroom and across school?	What types of scientific questions are currently asked that lead to an enquiry?	When in the learning sequence will the QuSmart routine be tried?	When would be useful to review impact on the teacher – on their pedagogy?
Are senior school staff supportive of this development?	Is there a common understanding of enquiry vocabulary across school?	Which year group will teachers start to use the QuSmart routine?	When would be useful to review impact on the children and how will this be done?

Table 1: QuSmart Readiness Check

Getting started - QuSmart Question Detector

One of the critical aspects when implementing change is to know your starting points. Initially it is important to find out what types of questions in science are being asked in your classroom, how often and for what purpose. This enables teachers to review whether any fit the scientific question definition. To do this activities such as question-detecting in books has been designed to support teachers to elicit the breadth and depth of the questions being asked and investigated in classrooms. Further study in its use will be required to gain a full insight to its relevance and impact.

4. The QuSmart Routine

The QuSmart Routine stimulates teachers and children to work with questions in transformative ways to progress from *interesting* questions to *scientific* questions. In this section we present the 6 stages which are sequential and cyclical (Figure 4). For each there are a range of strategies to implement the routine in practice, with signposts to resources and activities that can support children's skills and knowledge development at each stage.

Important messages about the QuSmart Routine:

1. It has been designed to give opportunity and structure for *all* children to work **collaboratively** in groups of 3 or 4.
2. It promotes children's curiosity and inquisitiveness so that children ask scientific questions that lead to them having a **deeper understanding** about the world that they live in.
3. Each stage develops from the last. All the steps are important and are **sequential**.
4. Teacher-child and child-child **talk is essential**, making for a noisy yet productive classroom!
5. Is not dependent on a child's ability, and should be used inclusively.

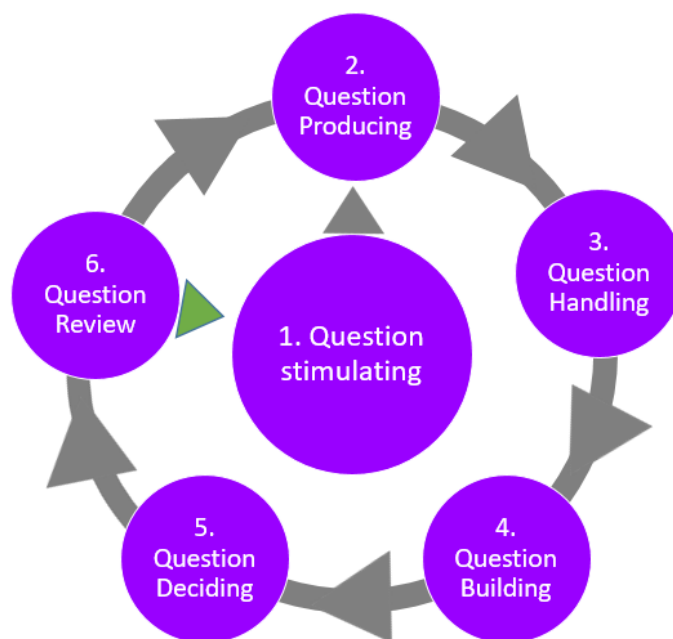


Figure 4: The QuSmart Routine

Stage 1: Question Stimulating

Why do we need this stage?

To inspire children's curiosity in areas that they are uncertain about

What is Question Stimulating about?

Knowing what your children don't know is essential to this step. When choosing a stimulus it is helpful to think about the aspects of a topic that cause children uncertainty or where misconceptions often arise. By focusing in on these aspects you are more likely to promote new learning for children that broadens and deepens their current understanding.

The scientific questions that children ask in lessons should align with the teaching and learning objectives that you have planned for as part of a learning sequence. To achieve this teachers use stimuli, sometimes called 'lesson hooks', which can include using artefact, image, demonstration, video etc. to create interest and curiosity a topic. Green (2020, P125) suggests that a lesson hook must include a clear goal, be directly challenging a common misconception and draw on children's prior knowledge. The choice of a stimulus will be dependent on your curriculum map and different for each class and therefore requires the professional insight of the class teacher. Identifying common misconceptions or areas of uncertainty that children find tricky can be found through resources such as the Pan-London Assessment Network (PLAN).

As a result of this step you aim to trigger the children’s interest so that they are stimulated to invest effort as they have become explicitly aware of the gaps in their understanding. If the stimulus is successful they will be motivated to want to know and want to find out more *for themselves* – using and extending their initial ideas and knowledge.

How do I purposefully select a QuSmart Stimulus?

Table 2 provides structure to stimulus selection. It is designed to support you in considering the purpose of a stimulus – which may vary dependent on topic or class. The table is aimed to provide teachers with some guidance, however it is not seen to be an exhaustive list of possibilities. QuSmart builds on this to support teachers to consider what they want the stimulus to **do**. Here we recognise that a stimulus has to be fit for purpose and that they vary. We may wish children to experience a sense of novelty, want them to compare and contrast, explore certainty, visualise their thinking, have their assumptions challenged through contradiction, make or see connections between ideas and explore the relevance of a new idea to what they already know.

Many tools (activities or approaches) we can use to do this are already in existence and you may already use them. In Table 2, we link the approaches outlined in Active Assessment (Naylor et al, 2004) to guide purposeful stimulus selection.

<i>What do you want the stimulus to do?</i>	<i>Why do we do it?</i>	<i>What do I use?</i>
Engage children in something new or unknown to them	Novelty	Objects, photos, videos, Making a list
Promote the comparing and contrasting of 2 or more objects	Comparison	Objects, Odd One Out, Analysing data, Making a list
Elicit children’s existing conceptual understanding	Certainty	True/false quiz, Card sort, Diamond Nine, Analysing data, Concept Map
Expose how children think things work	Visualising	Drawings, Annotated diagrams and drawings
Prompt dialogue and argumentation	Contradiction (cognitive conflict)	Statements, Deliberate mistakes, consumer reports, Concept Cartoons, Diary entries
Make connections between ideas and concepts	Connectivity	Concept map, Graphic organisers, Fishbone, Bug

Exploring meaning making and how children link and understand things	Relevance	Analysing data, Concept Map
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Table 2: Deciding on the purpose of question stimuli

What difference will it make?

By using stage 1 in the QuSmart routine, it is anticipated that there will be a shift in practice as shown in the table below. Only further research and trialling will enable the team to understand this in reality.

<i>From</i>		<i>To</i>
Children thinking, 'I learn what the teacher says I have to learn.'		Children thinking, 'I learn because I'm not sure about something and I'm interested to find out more!'
Teachers stating the title of the lesson e.g. 'The Heart'		Teachers purposefully selecting a stimulus that varies dependent on topic and learning objective. Where this is an object/artefact, there should be enough available for all children to access the stimulus in groups.
Questions being numerous or very limited which lack relevance to the learning objective of the lesson.		A range of focused questions being asked which are aligned to the learning objective of the lesson, and giving opportunity for further development/ exploration.

Stage 2: Question Producing

Why do we need this stage?

To generate & harvest children's questions. For *all* children to be included and feel their questions are valued.

What is Question Producing about?

From the question stimulus children quickly and naturally move into producing questions. The rules of engagement in this stage should be made clear to the children so that they feel empowered to pool their questions together. Teachers should resist correction or refinement at this stage. We adopt many of the principles that are used in the Question Formulation Technique (Rothstein & Santana, 2015), including:

- all questions matter,
- ask as many questions as you can,
- do not stop to discuss questions,
- capture questions without changing or refining them,
- all questions must be phrased as a question, not a statement.

As a result of question producing and capturing all questions, children have had a chance to think freely without having to worry about the quality of the questions they ask, there has been a chance to listen and be listened to. This step is usually fast paced with the only sound in the room is that of children asking questions. By pooling lots of questions children are less inclined to think their first question is the 'best' question.

How do I encourage children to Question Produce?

This stage in the QuSmart routine seeks to harvest numerous questions at a fast pace (5-10 minutes), so that children are less emotionally connected to specific questions. The aim is to try and avoid children thinking that, 'My question is the most important question because I asked it'. The teacher explains to the children that the pool of questions will be worked with and changed so encourages inclusion and values questions that might otherwise get left behind.

Some examples of strategies used within the Great Science Share for Schools, that can be used for pupils to produce questions include:

Question Spinner

What you need?

A pair of scissors, pencil and a paperclip.

How does it work?

- 1 Print and cut out of the spinner.
- 2 Place the paperclip over the centre of the circle.
- 3 Place the tip of the pencil through the paperclip onto the centre of the circle.
- 4 Flick the paperclip to let it spin.
- 5 Ask a question using the question word that the paperclip lands on.



Print off the wheel on the next page for cutting out!

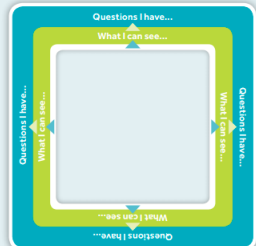
Question Frame

What you need?

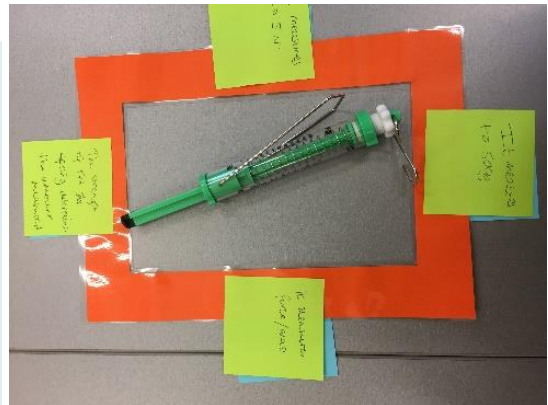
A pair of scissors, a pencil, an object that you're curious about, sticky labels (optional).

How does it work?

- 1 Make a frame out of an old cardboard box or use the printable. Be careful when cutting out the window in the centre.
- 2 Place the frame over an object or image, so that it appears in the window.
- 3 Observe what it looks like and describe what you can see.
- 4 Now, think about questions you have and jot them on a sticky note around the side of the frames.
- 5 Select the question(s) you wish to share.



Print off the frame on the next page for cutting out!



Question Hand

What you need?

A piece of paper, pen/pencil.

How does it work?

- 1 Draw around both your hands on a piece of paper and cut them out.
- 2 Write one of these phrases on each finger of one hand:
 What if...
 Where does...
 Who can...
 How does...
 Is there...
- 3 On each finger of the other hand write a word that is linked to the science theme. Think about what you're curious to find out about.
- 4 Bring your hands together and create 2 new questions that you want to ask by linking the words on two fingers!
- 5 Write your questions in the palm of each hand and share with someone else.



Print off the hand on the next page for cutting out!



Question Teller

What you need?

Scissors.

How does it work?

- 1 Print and cut out around the outside of the question teller.
- 2 Fold the paper to create the teller. You could follow the directions at: www.wikihow.com/Fold-a-Fortune-Teller
- 3 Think about the science you're interested in and use the teller to create questions.
- 4 Use the teller with someone else to find out what questions they have to!



Print off the Question Teller on the next page for cutting out!

What difference will it make?

By using stage 2 in the QuSmart routine, it is anticipated that there will be a shift in practice as shown in the table below. Only further research and trialling will enable the team to understand this in reality.

From		To
Children asking a few questions		Children asking as many questions as possible in a set amount of time
Teachers intervening too soon to amend or improve questions <i>for</i> the children		Teachers assisting children to gather as many questions as possible, reserving judgement and not intervening to improve questions in the first instance
A few questions being valued		All questions being valued
Children feeling that they have to get the question 'right' and 'as good as it can be' the first time round		Children knowing that questions will be changed and improved at a later stage
Children feeling the question is the best because it's theirs		Children feeling a sense of team-ness or group ownership of questions through the pooling of their questions with others

Stage 3: Question Handling

Why do we need this stage?

We need this step for children to sort, classify and understand the different types of question they have produced.

Having generated a 'pool' of questions the team of children now start to sort them into different groups and to analyse them in terms of how they are written and what type of question it is, they may group according to the number of variables, the type of evidence being collected etc.. No questions should be eliminated at this stage, just ordered into groups. This stage in the QuSmart routine seeks to extend children's understanding *about* questions, which includes them starting to understand of what it means to ask a 'scientific' question.

What is Question Handling about?

The QuSmart approach encourages to value all questions, whether they are open and closed, scientific and non-scientific questions, as all are useful for different purposes. By encouraging children to work with their questions, by handling them, sorting them, talking about them together, we encourage them to increasingly take ownership over the question development. By defining groups of questions from the large 'pool' there are now smaller groups and subsets of questions. No questions have been removed at this stage. This stage should also be completed at pace, not dwelling or ruminating too long about the categorisation, but enjoying the reading, moving and sorting and debating about the question.

As a result of question handling children will have a shared language to describe and analyse questions. There is increasing de-personalisation of 'my question' as questions taken forward can be justified in relation to the features of the question type and not the individual that articulated the question.

How do I encourage children to Question Handle?

A strategy offered for this stage which had some basic trialling undertaken was **Shuffle & Sort**. An activity used to develop the skill of question handling.

This task should be done in between two children. Using the children's questions on small cards/slips of paper or sticky notes, ask the children to agree on how to sort the cards into 2 groups. This stage should also be completed at pace, not dwelling or ruminating too long about the categorisation, but enjoying the reading, moving and sorting and debating about the question (10 minutes is appropriate).

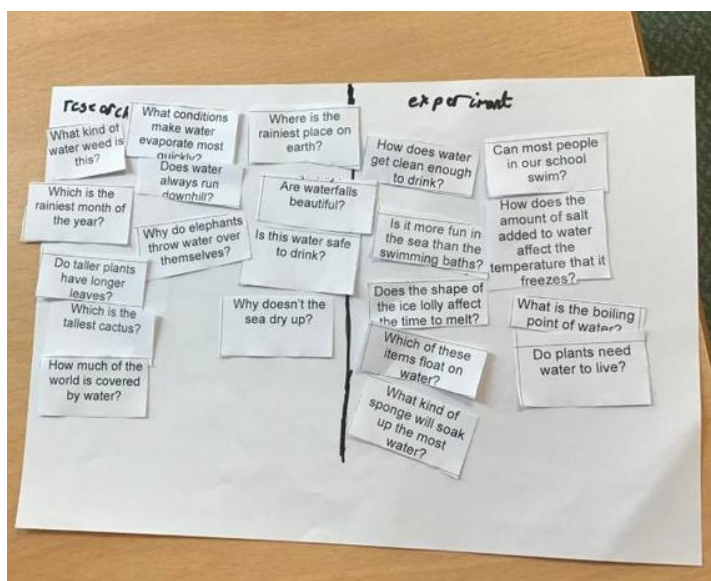


Figure 5: Question handling using Shuffle & Sort

Encourage them to group multiple times, asking them to find how many different types of groups they can find. Welcome conversations about the different questions and allow the children to decide on the group names, continuing to build ownership of the question development. Keep records of the different groups using a photograph should that be helpful to reflect on the learning process.

What difference will it make?

By using stage 3 in the QuSmart routine, it is anticipated that there will be a shift in practice as shown in the table below. Only further research and trialing will enable the team to understand this in reality.

From	To
Children being told which question they will investigate	Children working with their own questions to self-organise those questions that are best to take forward and develop
Children feeling that the question doesn't belong to them	Children having a strong sense of understanding and ownership of their own questions
Children having little autonomy in which questions they investigate	Children self-auditing their own questions, beginning to discriminate for themselves those worthy of taking forward towards investigation

Stage 4: Question Building

Why do we need this stage?

We need this stage for children to develop or transform questions into ‘scientific’ questions.

What is Question Building about?

In this stage children develop questions from early ideas to ‘scientific’ questions that are fit for purpose (refer to the Taxonomy of scientific questions, see Section 4). This stage involves guiding children to improve their questions by rewording or adapting questions, resulting in fewer and better scientific questions. Children will continue to work collaboratively to use the questions they have handled and that they have identified have potential to be developed as a scientific question.

All questions should benefit at this stage from the ‘build’ process. Several questions of similar focus may be merged together and reframed in order to build the best question to address this area of interest. As a collaborative process, the ownership of the questions is with groups of children rather than any one child.

Using the QuSmart definition supports children and teachers to refine their questions – that of:

A scientific question stimulates enquiry so that evidence is gathered, conclusions drawn and new knowledge learnt

As a result of question building each group of children will have a number of questions that are capable of generating evidence within an investigation.

How do I encourage children to Question Build?

At this stage the QuSmart team have developed the Question Builder – a tool to support children to consider the concepts that improve scientific questions. We focus teacher’s attention to guide pupils to think about issues of testability, accuracy, reliability and validity.

The builder prompts children to challenge each other about whether the question they’re working on has real purpose because they don’t know the answer already; whether it has variables identified; whether they are clear on the equipment and using it correctly; that the range and readings taken are broad and appropriate and that sample size is considered and variables well thought about.

Figures 5 – 9 provide an overview of a question building process that requires further trialing before widescale dissemination into the sector. It is based around four key elements of the question: testability, accuracy, reliability and validity. Across the four

elements the children's question develops towards a well-honed scientific question from which the children have the autonomy to go forward to collect evidence.

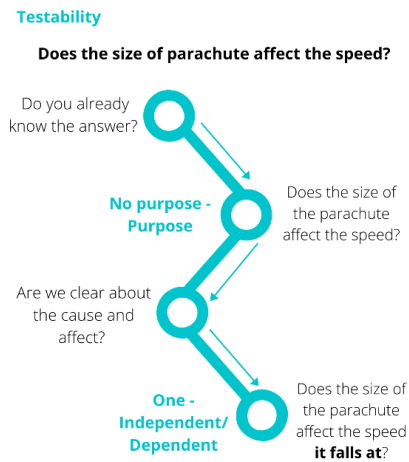


Figure 5: Considering the testability of the question

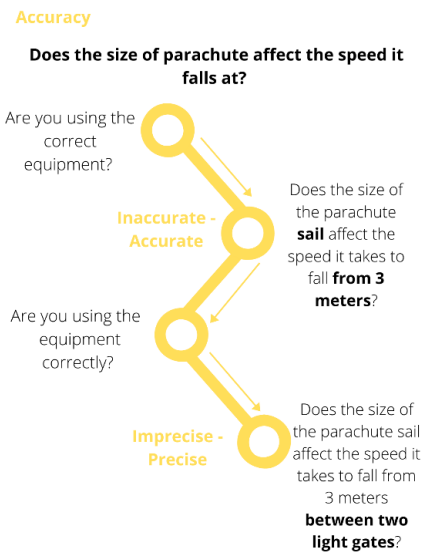


Figure 6: Considering the accuracy of the question

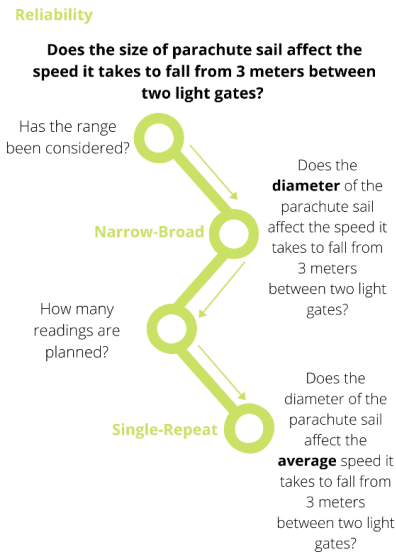


Figure 7: Considering the reliability of the question

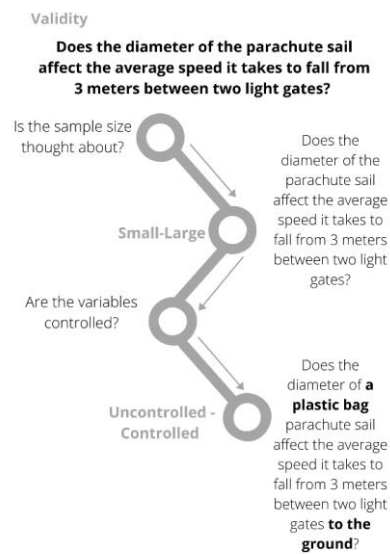


Figure 8: Considering the validity of the question

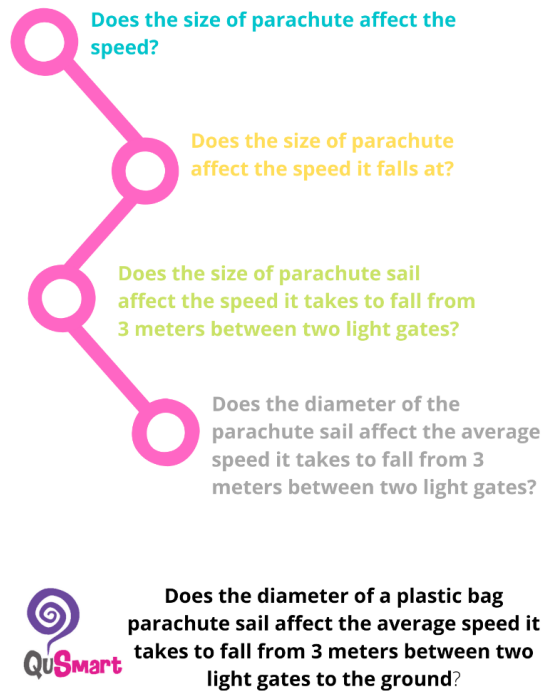


Figure 9: Review of the question building process

What difference will it make?

By using stage 4 in the QuSmart routine, it is anticipated that there will be a shift in practice as shown in the table below. Only further research and trialling will enable the team to understand this in reality.

From		To
Children investigating questions they already know the answer to		Children finding out new knowledge and developing new understandings
Questions being unfocused and broad		Questions being focused and rigorous
Children having superficial engagement when investigating scientific questions		Children having deep and meaningful engagement with questions that matter to them
Children doing science investigations for the sake of them		Children doing science investigations that develop a genuine sense of scientific literacy and citizenship

Stage 5: Question Deciding

Why do we need this stage?

We need this step to support teacher and children in deciding on the science question to take forward and the appropriate science enquiry approach most suited to investigate their scientific question.

The class is guided by the teacher to take on the role of a judging panel to make a justified decision. The QuSmart approach anticipates that the teacher will clarify the criteria for selection, e.g. 'We are seeking three questions that: Will help us most with our understanding of...; that we can generate evidence from in our class today; that we might want to ask an expert; or we might find out about over the next week?'

What is Question Deciding about?

This stage is teacher-led and supports the class to prioritise the questions that will lead towards a science enquiry that progresses their development of skills or knowledge. The important feature in this stage is that the children can articulate a rationale for the questions chosen to take forward into the investigation.

As a result of question deciding children make use of the agreed question to work scientifically, collecting data, observations or information. The scientific method and enquiry skills enable children to systematically gather and interpret data towards a conclusion.

How do I encourage children to Question Decide?

Question deciding can be supported using classification keys. A useful question key is provided in the BBC Terrific Scientific Teacher Resource Pack (Figure 10), enabling children to identify which enquiry type their question relates to.

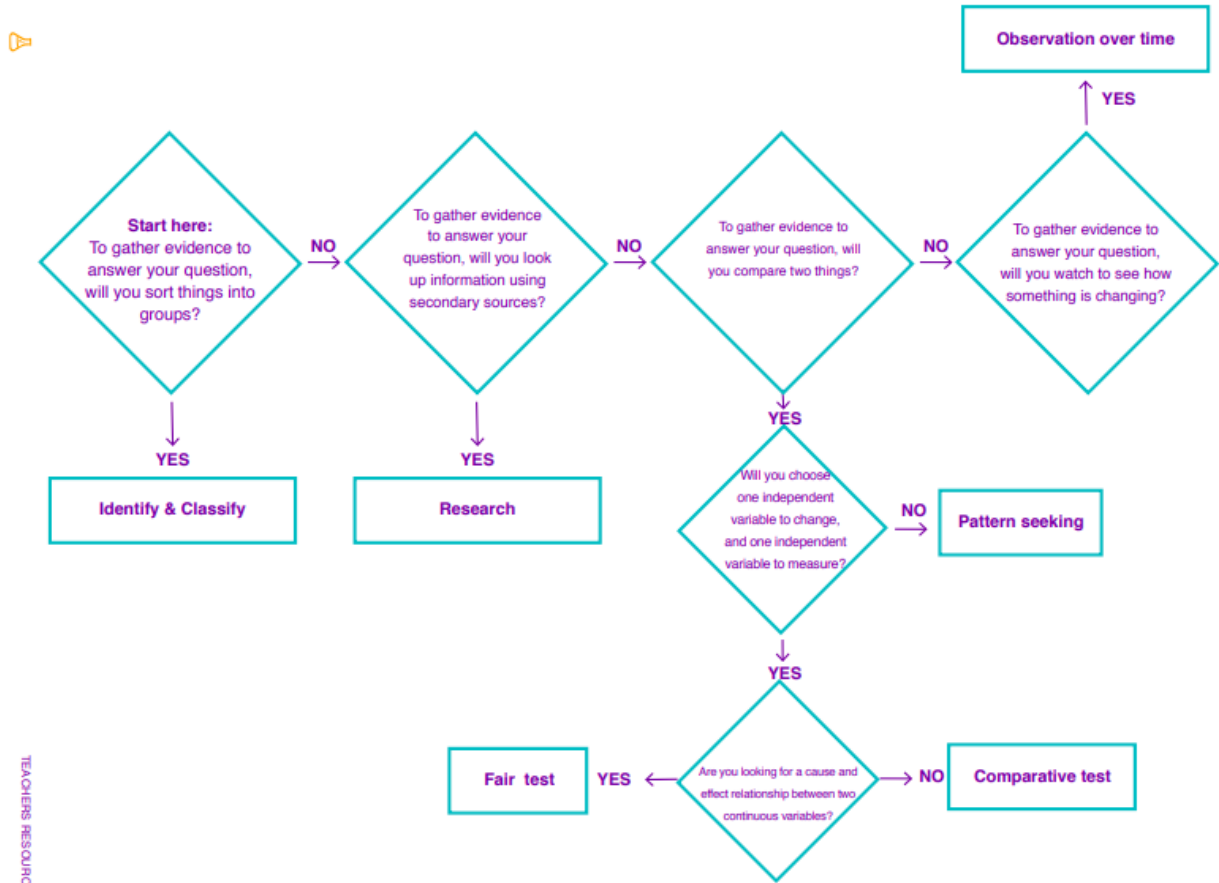


Figure 10: BBC Terrific Scientific Question Classification Key

What difference will it make?

By using stage 5 in the QuSmart routine, it is anticipated that there will be a shift in practice as shown in the table below. Only further research and trialling will enable the team to understand this in reality.

From		To
Children relying on an adult to decide which question to investigate practically		Children having agency to identify the 'best' question to investigate is the one that allows them to achieve success based on criteria.
Children not having up-front awareness of the type of enquiry the question leads to		Children having clarity on the type of enquiry, and therefore the type of evidence they expect to gather
Children losing control of their question as an adult steps in to direct activity		Children retaining control and working with the teacher to co-decide the way forward with their enquiry.

Stage 6: Question Reviewing

Why do we need this stage?

We need this step to make the skills developed transferrable to other learning contexts, including other enquiries. Encouraging children to recognise what they have learnt through reflection is a form of metacognitive development – that of self-awareness. It is important to note that we are not evaluating the quality of the question but the quality of the process undertaken.

What is Question Reviewing about?

This step challenges children and teachers to review the thinking they have done, what they have learned from it and how they can use the learning again to improve working scientifically in the future. As a result of evaluating the children develop as critical thinkers and learn important skills for life.

How do I encourage children to Question Review?

Collaborative discussion should continue at this stage of review. Structuring children's talk using a Think-Pair-Share is a means by which this can happen, encouraging individual and group thinking.

	Question Produced	Question Handled	Question Built
Think – what would I say about the way I have...			
Pair - what would we say about the way we have...			
Share - what would we all say about the way we have...			

This simple scaffold structures children's thinking against the three core parts of the routine. Children could choose a variety of ways to note their review, e.g. colouring different boxes – RAG rate (red-amber-green); allotting marks out of 10; stars or happy faces. Most importantly they should justify their choice using the word 'because' in their response. This enables deeper reflection and the identification of particular behaviours or actions that can be transferred, or not, to future scenarios.

What difference will it make?

By using stage 6 in the QuSmart routine, it is anticipated that there will be a shift in practice as shown in the table below. Only further research and trialling will enable the team to understand this in reality.

From		To
Children not realising their areas of strength and development in working scientifically		Children gaining a stronger sense of what they do well, and where they can develop in working scientifically
Children rushing on to their next task and not receiving peer feedback about their work together		Children having a sense of completeness and forward learning, taking on board feedback from others

The end of the review stage can lead to two actions – ongoing iterations of questions resulting from the same topic, or engaging with new stimulus to invigorate new lines of questions related to a different topic or context.

5. What can QuSmart achieve for children?

The following table (Table 2) provides an overview of aspects of the enquiry cycle that the QuSmart routine can influence. It provides two scenarios – one of children’s science learning experiences without QuSmart, and the other when the QuSmart routine becomes a regular and integrated part of the learning process. Further study will be required to demonstrate this shift in practice.

Enquiry skills	Without QuSmart	→ With QuSmart
scientific questioning	Children who take the question from the teacher, or stick with the first question that seems sensible-enough	Children who know that the first question isn’t always the best question, and that they need to consider how it could be developed/improved for themselves
scientific questioning	Children who haven’t really ever thought about question types, as it’s been the number of questions that have been seen to be of more value	Children who realise they have a range of question types they can use to find out information and develop knowledge in science
scientific questioning	Children having a limited understanding for what scientific questions are, often seeing this as cause-effect. And in fact teachers who share this understanding	Children having a deeper understanding and recognition for what scientific questions are and knowing that there are different types
scientific questioning	Children are able to react to a <i>scientific</i> question they’ve been given by suggesting answers or ways to answer it (related to a context)	Children proactively ask questions in response to a context they’ve been inspired by
scientific questioning	Children are able to react to a <i>scientific</i> question they’ve been given by suggesting answers or ways to answer it (related to a context)	Children proactively ask questions in response to a context they’ve been inspired by
gathering evidence	Children who see themselves as reliant (and obedient) on the teacher to decide on the focus of an investigation, without knowing why that particular one was chosen	Children who see themselves as being reliant on each other to collaboratively/collectively make decisions about what to investigate, what not to investigate and why, and then to bring the teacher into that process

gathering evidence	Children work in pairs or small groups to plan and do an investigation – logistical/mechanistic		Children work in pairs or small groups to discuss and debate – cognitive/creative
gathering evidence	Children lack perseverance – it's something they're doing for the teacher instead of for themselves		Children are inspired and engaged in the enquiry process, showing resilience because they genuinely want to find out.
drawing conclusions	Children aren't always sure how what they've found out helps them, often because an investigation hasn't been initiated by a scientific question.		Children identify and articulate how their results (their evidence) supports them in answering their scientific question
drawing conclusions	Children find it difficult to draw a conclusion or that the conclusion is broad and lacks clarity		Children are able to reflect on evidence and drawing conclusions because they're clearer about the question is.
knowledge progressing	Children science learning is disconnected or sporadic, not linked to prior knowledge or understanding		Children science learning is more meaningful because it links to knowledge and understandings they already have
knowledge progressing	Children worry about getting it 'right', getting the 'right' results And in fact teachers who share this worry		Children are interested, willing and comfortable to work on a question they're not familiar with, that they genuinely don't know the answer to
knowledge progressing	Children go through the motions of enquiry because they're directed to do so. They are interested in what they're doing but it isn't progressing their knowledge on.		Children use questions as a means to investigate an area of knowledge that they're unsure or uncertain of. They use investigations to gather evidence to address the gap in their knowledge.

Table 2: A tale of two classrooms – with and without QuSmart

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About the team

Dr Lynne Bianchi is the Principal Investigator for this study, and the Director of the Science & Engineering Education Research and Innovation Hub (SEERIH) at The University of Manchester. She has over 20 years' experience in Primary Science Education and leads on the theory and practice of children's scientific questioning, through her research and campaigns such as the Great Science Share for Schools.

Dr Amy Bonsall is the SEERIH Research Associate of and co-Principal Investigator on this study. She was a Head of Drama at a number of state and private secondary schools in London before completing her MA and PhD. Amy is experienced in designing and implementing innovative research and analytical methods, including literature reviews, and she is well published. She is especially interested in creative teaching methods in science education and inclusive pedagogies.

Bryony Turford is an experienced primary teacher who now acts as a coach and consultant to support in-service primary science teachers across Great Manchester, Yorkshire and the Humber. She is a successful author with a specialism in publications related to enquiry-based learning, teacher professional learning and leadership. She engages with national groups including the Primary Science Teaching Trust, the Primary Science Quality Mark and the Association for Science Education at both membership and senior level. She is a regular speaker at national and international conferences and is an active champion for primary science in all aspects of her working life. She joined SEERIH in September 2016 as a Professional Development Champion.

Christina Whittaker is an experienced primary science consultant, with almost twenty years of working in roles that have school improvement as their core purpose. Committed to every child matters and as such the importance of professional reflection to consider need and to inform improvement. Tina currently holds several key roles within the primary science sector, these include: SEERIH Professional Development Champion, Science Across The City co-lead strategy and vision, and Primary Science Quality Mark senior hub-leader.

Steph Hepworth is the SEERIH Business Coordinator. She has sustained experience in the management of large-scale funding bids, finance and communications related to educational projects. She is a qualified teacher and the National Campaign Coordinator for the Great Science Share for Schools.

Katherine Goodier is the SEERIH Administration Assistant. She has administration experience in both school and Higher Education settings and supports SEERIH's delivery of educational programmes and projects. She is the Regional Campaign Administrator for the Great Science Share for Schools.

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Appendix

Accurate	when something correct in all details; exact
Biased	unfair or prejudiced in some way
Conclusion*	when you say what you found out in an investigation
Credible	able to be believed; convincing
Critical	analysing the merits or faults of an approach, process or piece of evidence
Explanation*	saying why you think something happened
Evidence	anything that can be used to prove something. It can relate to the available facts or information that allow us to determine whether a belief or proposition is true or valid. *you get this when you get results from an investigation
Data	facts or numerical information collected for information or analysis
Dependent variable	the variable being measured or observed in a scientific experiment
Independent variable	the variable that is changed in a scientific investigation to measure the effects on the dependent variable
Investigation*	what you are doing when you collect information or evidence to help you answer a scientific question
Measurements*	you use equipment to get these. They are written in numbers and units.
Observations	looking carefully to gain information and notice details
Question	a request for information, a problem for discussion, a matter of some uncertainty or difficulty
Range	the variety of things, usually of the same type, often thought about as having an upper and lower limit
Reliability - Reliable	the consistency of a measure, as demonstrated through the range of measures taken and how many times they were taken
Repeated results	you use these to get as much agreement in the data you collect, to find the average or most likely outcome
Reproducible	the extent to which an approach or process can be copied or repeated

Results	an outcome or effect
Scientific question	a question that stimulates enquiry so that evidence is gathered, conclusions drawn and new knowledge found
Sample Size	the number of things from which you gather data
Validity	is about the accuracy of something that's measured, as appropriate and fit for purpose
Variables*	things that you change, measure or keep the same when you are doing an investigation

*Referenced from Goldsworthy & Ponchaud (2007)