Children's scientific question-asking – an initial scoping of academic literature

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Abstract

The Primary Science National Curriculum for England requires children to be able to ask and investigate scientific questions. As questioning is a foundational habit of mind of scientists, we set out to scope the academic literature that addresses the nature of children's scientific question-asking and to identify routines for teaching and learning exemplified within them, as the basis for a 2-year research and development project (QuSmart). A six-stage method was developed to involve researchers, professional development leaders and teachers in order to select four principle papers for the project. This paper describes this method and presents a review of these principle papers, drawing out key points that relate to the study aims. This initial scoping of academic literature 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 are identified.

Keywords: Scientific questions, children's scientific questioning

Introduction

Questions and questioning underpin the foundational habits of mind of scientists (Çalik *et al*, 2012). Questions are embedded in the problem-finding and problem-solving processes that underpin scientific endeavour and innovation, and natural reactions to the world around us, from the earliest years of development. Questions become the way in which we encourage children to look, wonder and talk about their observations, thinking, theories and findings when exploring the world around them.

In this paper we begin to document the initial scoping of literature associated with the ways in which children learn to ask and build scientific questions. We seek to find relevant academic guidance to form a set of principle papers, which guide the formation of the 2-year research and innovation study, supported by the Primary Science Teaching Trust (PSTT). The project furthers Bianchi's earlier work on wonder-filled science education and child-focused approaches to science learning and thinking skills (Bianchi, 2014; Murphy *et al*, 2006; Bianchi, 2016).

Programmes of Study for Key Stages 1 and 2 (ages 5-11) of the National Curriculum in England expect children to be able to ask simple and relevant questions using different types of enquiry to answer them. The requirement by the end of the primary years for children to reach the national standard is that they can also recognise and control variables (National Curriculum in England, n.d., p.6). The term 'scientific question' in fact is, as such, assumed given the subject context, which also offers challenge in its deceptively simple label for a complex designation.

Bianchi's work to inspire children to engage in scientific question-asking and investigation is demonstrated through the national campaign, Great Science Share for Schools (GSSfS). Launched in 2016, GSSfS (www.greatscienceshare.org) supports and facilitates an increased opportunity for children to ask and communicate their scientific questions and investigations with new audiences. It also offers insight into the nature of support required for senior leaders, teachers and pupils to best meet this essential need. It has provided insight into the nature of support required for senior leaders, teachers and pupils who are committed to offering increased opportunity for children to ask and communicate their scientific questions and investigations with new audiences.

The annual campaign responds to the evidence from the *State of the Nation Report of UK Primary Science Education* (Leonardi *et al*, 2017), which identified that, in 47% of schools, child-led and child-designed investigations are undertaken only 'occasionally' or 'never' (Leonardi *et al*, 2017). The long-term implication of this is better understood through the concept of 'science capital', which Archer *et al* recognise results in limited STEM career aspirations of children (Archer *et al*, 2015; Godec *et al*, 2017).

A two-year study (named QuSmart) seeks to establish classroom practices and routines that better enable children to learn to ask and develop scientific questions. The research question asks whether routines in children's scientific question-asking can improve attainment and attitudes in working scientifically in the primary phase and, in doing so, we seek to identify concepts and possibilities of the phrase 'children's scientific questions' that exist within the current literature, from which to:

- develop understanding about the nature of children's scientific questions;
- identify routines for children to learn how to ask and build scientific questions; and
- improve teacher confidence to create learning opportunities and an environment where children ask and build their own scientific questions.

This paper explains the means by which four principle papers were arrived at, through a collaborative process of academic paper identification and sifting. It offers the reader insight into the landscape of practice in this field and, in doing so, guides the development of the innovation and intervention phase of the QuSmart project.

Methodology

The methodology followed a 6-stage process, as defined in Figure 1. The search aimed to provide an initial scoping of the field, purposeful to highlight the range of existing research for the QuSmart project. Stage 1 included an initial search of academic paper abstracts. It was undertaken utilising Google Scholar, using key search phrases over a 10-year timeframe (2009-2019).

Table 1. Key search phrases.

Key search phrases
What is a scientific question?
Children's questions
Children's questions in science
Teacher training in primary science (UK)
How do teachers use questions?
Questions + 'Reggio Emilia approach to learning'

In Stage 2, abstracts were sifted for relevance to the research question, with specific focus on questions in relation to the science curriculum in contemporary British schools. Stages 3-6 were created by the researchers to support the engagement of project designers and teachers in the literature scoping with a view to agreeing principle papers.

Stage 3: the papers were ranked using a Red, Amber, Green (RAG) system and coloured on an EXCEL spreadsheet accordingly. The ranking was conducted according to the aims of the project at the time and a star was allocated to a paper if it aligned with at least one of the QuSmart aims.

At the time, these were to:

- improve understanding about the nature of scientific questions;
- identify routines to engage children in asking scientific questions; and
- build teacher agency to create more opportunities for children to ask their own scientific questions.

As such, papers that had conducted research in a primary education setting, and in a science classroom setting, and papers that had either a taxonomy or classification of questions or questioning routines, were ranked more highly than papers without most of or any of these elements.

A range of people were involved in the literature scoping and review. Table 2 provides detail of the roles involved in the project and associated groupings.

Table 2. Roles involved in the project and associated groupings.

Role	Description
Research Director	Establishment and oversight of research process.
Research Associate	Research practitioner collaborating with the Director. Undertaking literature searches and leading the research process.
Professional Development Leaders	Experienced Professional Development Leaders involved in the project design and professional learning experiences.
Lead Teachers	Practicing Science Subject School Leaders recruited to the project due to their experience and interest in curriculum development and the project focus.
Core Research Team	Research Director and Research Associate.
Wider Research Team	Research Associate, Research Director and 2 Professional Development Leaders.
Extended Research Team	3 Lead Teachers and the Wider Research Team. Each teacher paired or 'buddied' with a member of Wider Research Team.

Figure 1. Process of principle paper identification.

Stage 1. Initial broad literature search

- Key search terms entered into GoogleScholar
- Undertaken by Research Associate

Stage 2. Joint abstract sifting

- 92 abstracts resulted from the initial search
- 43 selected as 'highly relevant' by Research Associate
- Selected abstracts shared with Research Director (Core Research Team), in order to individually identify 20 key papers considered most relevant to the research question and aims. In the event 32 papers were deemed to be relevant

3. Individual read and rate

- The Research Associate, Research Director involved two Professional Development Leaders (Wider Research Team)
- Focus was to read all relevant papers and rank them in relevance to the project and aims

4. Priorisation and theming

Wider Research Team discussed and agreed the features of the paper that linked to the aims of the project. The Wider Research Team brought to the discussion any 'other' documentation, e.g. chapters, resources, that they saw to be critical to the project
4 papers/documents debated and identified as 'Principle Papers', all others named as 'Core Papers'

5. Co-review with Lead Teachers

The Extended Project Team, involving teachers and the Wider Research team, formed pairs. Each pair read a principle paper, reviewed their thinking together and shared their opinions/findings with the Extended Research Team in a half-day research discussion meeting. The focus was to identify key messages/ learning and approaches to be taken forward into the innovation phase of the project

6. Innovation phase - co-development in practice in primary school classroom settings

Findings & discussion

In this section, each principle paper is summarised and key points drawn out in response to the research aims of the study.

❒ Overview of principle paper 1: *A Critical Examination of PISA'S Assessment on Scientific Literacy* (Kwok-Chi Lau, 2009)

This paper was concerned with examining the following:

'Despite Hong Kong's top rankings in PISA's assessment of scientific literacy, science teaching and learning in Hong Kong was found not to be conducive to the development of scientific inquiry abilities and underscoring the nature of science (NOS), two essential components of scientific literacy' (Lau, 2009, p.1062).

The study usefully investigates the notions of *knowledge of science* and *scientific enquiry* and the importance that questions hold within that discourse (*ibid*, p.1073). In particular, there is a focus upon *identifying scientifically investigable questions*, which is a 'competency' assessed by PISA (*ibid*, p.1083). Here, the PISA explanation is as follows: *'scientific issues must lend themselves to answers based on scientific evidence'* (*ibid*, p.1083).

Key point(s):

The paper explores why this is problematic, but the discussion is useful here because it shows us the types of issues that are exposed when trying to pin down the notion of scientific questions. Indeed it states '*...instead of telling students that some questions, by nature, cannot be investigated by science, we should make them more aware of the inherent limitations of science in dealing with those questions'* (*ibid*, p.1084).

The paper concluded that there were considerable issues around *Knowledge about science* and *Knowledge of science*, and of relevance to our research were *'problems with the concept of "scientifically investigable questions" and "identifying research question of an investigation", raise questions about what the PISA's measure of scientific literacy actually means'* (*ibid*, p.1086).

❒ Overview of principle paper 2: *Acquiring Scientific Skills* (Goldsworthy, 2000)

The research is concerned with investigating what skills children require to 'deal with scientific evidence' and how teachers can help them to acquire those skills. The chapter defines 'scientific enquiry' as *'pattern-seeking, exploring, classifying and identifying, making things, fair testing and using and applying models'* (Goldsworthy, 2004, pps. 33-35), a definition that was arrived at following wide surveying of science teachers.

Goldsworthy suggests the use of floor books, the 'if...then...' game and starter sentences as a way of encouraging children's use of scientific vocabulary, all of which lend themselves to adaptation into a routine of some kind (*ibid*, pps. 43-44).

Key point:

In her conclusion, Goldsworthy reframes a question posed by a child, which makes the question a more useful scientific question.

❒ Overview of principle paper 3: *An Analysis of Question Asking on Scientific Texts Explaining Natural Phenomena* (Jorge Costa, Helena Caldeira, Juan R. Gallastegui & Jose Otero, 2000)

This paper was investigating the following two key questions:

1. What kind of questions are asked by students of different grade levels who read science paragraphs dealing with natural phenomena?
2. How do type of task and grade level influence the number and quality of questions? (Costa *et al*, 2000, p.605).

'Question-asking is known to have positive effects on comprehension' (*ibid*, p.603). The focus of the research was 'finding out what kind of questions are asked by students who read these texts and, secondly, how task demand influences quantity and quality of formulated questions'. The ages of the 289 children involved were similar to the UK upper Key Stage 1 and lower Key Stage 2 (ages 7-9).

The authors state that:

'Asking questions may not be an easy task for all students. Generating a knowledge deficit question is a process comprising three distinct stages: anomaly detection, question articulation, and social editing (Graesser, Person & Huber, 1992). There are influential variables that operate on any of these three stages, which may prevent the generation of knowledge deficit questions. First, there are influences arising from cognitive and metacognitive variables. Shallow information processing…may limit anomaly detection – the first stage in the generation of knowledge deficit questions…' (Costa *et al*, 2000, p.603).

They also stress that *'students ask fewer questions in the classroom environment and, in addition, the frequently-asked questions have low cognitive level (Dilon, 1988; Pedrosa de Jesus & Maskill, 1990)'* (Costa *et al*, 2000, p.604).

Key point(s):
There were both positive and negative results, but the data gathered show that overall the *'students are capable of asking many questions when given the opportunity to do so'* (*ibid*, p.610) and, also, that students in the class condition of the research were able to ask more than three questions on average, but the questions were of varying quality. A useful finding was that *'limited questioning in regular science classes may not be caused by incapability to detect anomalies, but probably because of an environment hardly suitable for questioning as a mechanism for comprehension regulation'* (*ibid*, p.610).

❒ Overview of principle paper 4: *The Place of Children's Questions in Primary Science Education (*Fred Biddulph, David Symmington & Rodger Osborne, 1986)

This paper provides a rich context to the scholarship available, at the time, which was concerned with children asking questions in the classroom and how those questions related to primary science, specifically the ability of children to ask good questions (Biddulph *et al,* 1986, p.78).

The paper then discusses some of the reactions of teachers: for example, reservations towards their ability to effectively run the model because of their own lack of expertise in science, or a lack of available equipment. The authors attempted to address some of the issues faced by teachers by creating a set of guide booklets, one of them a Handbook, which is *'an introduction to the use of children's questions as a basis for investigations into primary science'* (*ibid*, p.84).

Key point:
In the conclusion, they state that *'In our view there is considerable value, to both children and teachers, in encouraging children to ask genuine questions during studies in science, and to have them find answers to these questions'* (*ibid*, p.86).

From this initial scoping, we adopt the PISA (2015) definition of the term 'scientific literacy', to reflect the ultimate reason for why children should develop the skills of scientific question-asking and building. PISA stated that:

'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' (PISA: Scientific Literacy, n.d.).

Of the four papers, only two are concerned specifically with primary science – Goldsworthy (2000) and Biddulph, Symmington & Osborne (1986). We recognise that, although these papers offer specific value to the area of study, neither talk explicitly about how teachers can teach children to build *their own* scientific questions. The other two papers – Kwok-Chi Lau (2009) and Caldeira, Gallastegui & Otero (2000) – are valuable in the way in which they offer understanding of the international landscape of how science education manifests and is analysed, and the positioning of children's scientific questioning within it.

We acknowledge, and embrace, the fact that the papers may not be viewed as contemporary, as would be otherwise expected in a scoping of this kind. This reflects the lack of published academic research in this specific field, providing inspiration to support the relevance of the study as a whole.

Conclusion

In this paper, we have demonstrated the outcomes of an initial scoping of literature associated with the ways in which children learn to ask and build scientific questions. We have named and outlined four principle papers that were arrived at through a collaborative identification and sifting process. These form academic guidance towards the 2-year research and innovation study, and provide early insight into the understanding of the nature of children's scientific questions. 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 are identified.

We will draw on this evidence and the principle papers in designing an innovation phase of the study, which will involve primary science teachers in the design and development of classroom routines for children's scientific questioning. The study will report on findings in subsequent academic publications.

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