Original Research

Exploring teachers' beliefs, inquiry pedagogy and pupil agency in practical inquiry-based science

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Abstract

This paper shares my recent PhD research on how teachers in England understood and taught practical inquiry-based science (IBS), using mixed and multiple methods, including anonymous questionnaire and case-based study. It highlights gaps between teachers' positive views of IBS and their teacher-led practices. Findings indicated that curriculum and testing demands limit pupil decision-making and open-inquiry opportunities, particularly in lower secondary lessons. My study suggests revising curriculum policies, providing targeted teacher professional development, and offering clearer guidance to support more effective IBS implementation through dialogic opportunities.

Introduction

After the Rocard Report (2007), European initiatives focused on promoting inquiry-based science education and 21st Century skills (Ananiadou & Claro, 2009). Furthermore, as global change accelerates, education systems must better equip pupils with relevant skills for the future (Abd-El-Khalick, 2012; Bocock, Sharp & Ritchie, 2025; Dawson, Venville & Donovan, 2024; OECD, 2022). These key skills include critical reasoning, problem-solving, collaboration and autonomous thinking.

Inquiry-based science (IBS) teaching includes developing these skills, which has long been promoted internationally, and also a means to enhancing pupils' engagement in school science, understanding the nature of science (NOS), fostering high degrees of scientific literacy, and nurturing essential capabilities for future citizenship and employment (e.g. Bächtold, Cross & Munier, 2024; Capps, Shemwell & Young, 2016; Furtak *et al,* 2012; NRC, 1996, 2000, 2013).

IBS has been and continues to be central to many educational reforms (Anderson, 2000; Tang *et al,* 2020). In England, inquiry (enquiry) has featured in England's National Curriculum since 1989 (DfEE, 1989) and remains integral through the current 'Working Scientifically' strand (DfE, 2015) of the national science curriculum.

Effective IBS is frequently misunderstood and not well integrated into classroom practice (Morris, 2025). IBS is complex and not just an investigation or a practical activity. For example, 'inquiry IN science' is considered an instructional approach to developing an understanding of specific science content by the end of the activity. 'Inquiry ABOUT science' relates to pupils undertaking the process of inquiry as a means to better understand the tentative nature of science (NOS) and to build knowledge while developing inquiry-based skills and competencies (Capps & Crawford, 2013). Therefore, IBS is both a process and a way to understand science.

Inquiry-based teaching can be categorised by levels based on where the locus of control lies. This ranges from teacher-centred, closed inquiry at one end of the spectrum to child-centred, open inquiry at the other (Minner, Levy & Century, 2010; Wenning, 2007; Tafoya, Sunal & Knecht, 1980), with many opportunities for pupils' decision-making.

Drawing on the Next Generation Science Standards (NGSS) (2013) documentation, Crawford (2014, p.515) proffers the following definition of inquiry teaching, upon which my research drew: *'Engaging students in critical thinking skills, which includes asking questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models, and communicating findings in the pursuit of deepening their understanding by using logic and evidence about the natural world'.*

My research examined the perspectives and practices of inquiry-based science education among upper primary (UP) (ages 10-11) and lower secondary (LS) (ages 11-12) teachers in England. The process and findings may also be relevant to early years and all primary and secondary age groups.

Research questions (RQ)

RQ1: What are the differences and similarities in the ways that upper primary and lower secondary teachers in England:
(i) understand practical inquiry-based science?
(ii) enact practice to support practical inquiry-based science in their classrooms?

RQ2: How do science teachers in upper primary and lower secondary classrooms in England describe, set up and support students' decision-making opportunities in practical inquiries?

RQ3: How do students' reported experiences of decision-making opportunities within practical inquiries compare with their teachers' stated intentions and reflections?

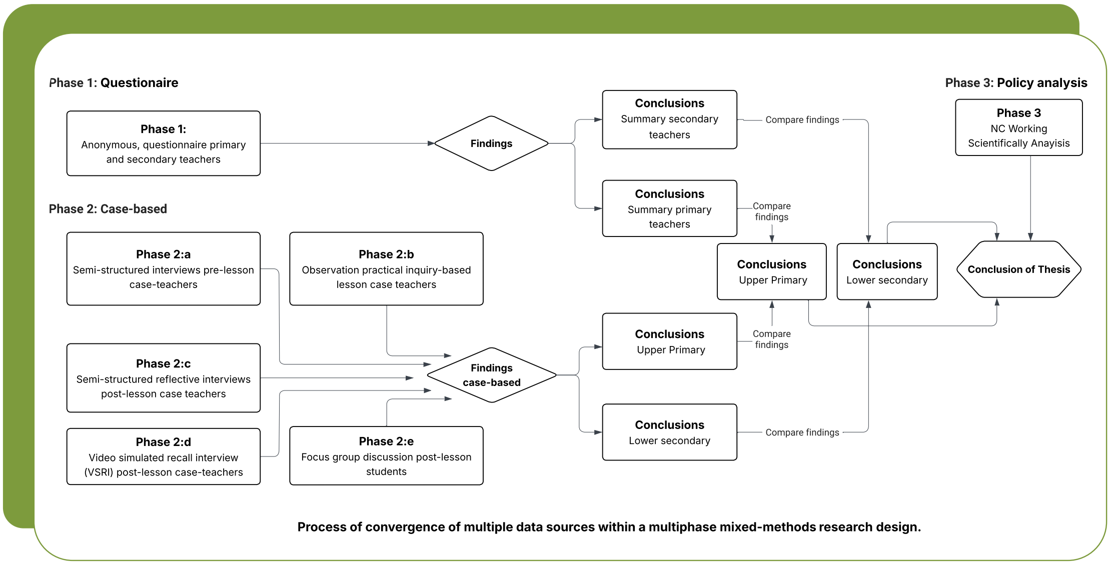
RQ4: How far can the National Curriculum policy documents for working scientifically help explain similarities or differences observed in upper primary and lower secondary classrooms?

Methodology

I adopted a complex mixed-methods study (Tashakkori & Creswell, 2007, p.4), which had multiple phases, multiple data sets and drew on multiple frameworks for analysis. This multi-phase research design enabled a degree of comparison between and across teachers in UP and LS.

My research was grounded in a constructivist interpretive stance, recognising the multiple realities of educational practice and drawing on both quantitative and qualitative tools to gather data and analyse. Verbatim transcripts from each interview and focus group discussions were analysed using multiple frameworks to indicate where pupil decision-making opportunities arose or where missed opportunities occurred.

Figure 1. Showing the convergence of each phase.



Phase 1 involved a questionnaire distributed to numerous UP and LS teachers through a range of gatekeepers, such as science subject associations, and initial teacher training establishments across England. Sixty-six teachers met the criteria for inclusion in the study. The questionnaire was anonymous and gathered data on the year group whom they taught most, these teachers' beliefs, perceived benefits, and challenges related to IBS, along with their understanding of curriculum expectations for 'Working Scientifically'.

Phase 2 involved four primary Year 5/6 (age 9-11) case teachers and three secondary Year 7 (age 11-12) case teachers, who had volunteered from across three counties in England. In addition, a small group of pupils from each observed lesson was involved in a focus group discussion. Each case teacher worked in different geographical and socio-economic areas, serving pupils with varying needs. This provided a wide lens through which to consider patterns and themes within this group of teachers, rather than seeking generalisability (Tight, 2017, pp.31-33).

Each volunteer teacher needed to meet the following criteria:
(a) Currently teaching science to upper primary, i.e. Years 5-6, or lower secondary, i.e. Year 7, in England;
(b) Using the statutory National Curriculum Working Scientifically objectives (DfE, 2015) within their school's schemes of work; and
(c) Be willing to be observed teaching a practical inquiry-based science lesson of their choice within their normal school programme of science.

The teachers in my study illustrated the transition year groups from upper primary to lower secondary schooling.

Besides interviewing teachers, focus group discussions with pupils, and observing classroom practices, the English science National Curriculum documents for Working Scientifically were also scrutinised to assess how policy advice might orient practice guidance. This is relevant when considering the need to foster a coherent programme of science education across compulsory ages of upper primary to lower secondary (Ofsted, 2015, 2023), along with the importance of teachers designing positive and relevant experiences of practical science for the children (Abrahams & Sharp, 2010; Murray & Reiss, 2012).

Phase 3 involved a document analysis of 'Working Scientifically' in the primary and secondary policy documents. I drew on both inductive and deductive approaches to compare and contrast the two policy documents.

The term 'inquiry' (enquiry) is used in the research questions instead of 'investigation' to reflect the complexity of practical inquiry-based science and the varying levels of teacher and pupil control involved. While the UK spelling 'enquiry' was used in teacher questionnaires and participant documents, to align with the National Curriculum, the internationally-recognised spelling 'inquiry' is adopted throughout this paper, as it is increasingly being recognised even in the UK.

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Frameworks for analysis

The various frameworks used for analysing the multiple data sets included Robin Alexander's (2006) teacher talk types, Suarez *et al's* (2018) framework to determine where student agency might arise, and Tafoya, Sunal and Knecht's (1980) typology to help determine the level of inquiry being described by the questionnaire teachers and observed in the case-based teachers' lessons (see Table 1). This typology can be easily utilised across all stages of school education.

▼ **Table 1.** Levels of inquiry (adapted from Tafoya, Sunal & Knecht, 1980).

	Type of inquiry	Question/problem provided by	Procedure designed by	Solutions determined by
1	Confirmation	Teacher	Teacher	Teacher
2	Structured	Teacher	Teacher	Student
3	Guided	Teacher	Student	Student
4	Open	Student	Student	Student

Drawing on multiple datasets strengthened my findings and provided an opportunity for a degree of triangulation.

However, limitations are recognised through the self-selection bias among questionnaire respondents and volunteer teachers in the case-based phase, along with time constraints on classroom access, and the challenge of capturing real-time pupil collaboration and argumentation during practical lessons is acknowledged.

A further limitation could be argued as researcher bias in the approaches undertaken to analyse, or the choices made when reporting findings. However, the high level of description gathered through the verbatim transcripts of interviews and the audio from the observed lessons provides a reasonable degree of transparency and trustworthiness in the findings and conclusions that I have drawn. I do not argue that findings are generalisable to the broader population of teachers, although this does not mean they are not. Generalisability was not the focus of my study.

Results and analysis

Teacher beliefs vs. classroom reality

While both UP and LS teachers expressed support for IBS and described it as enjoyable and beneficial for pupils, observed lessons revealed a significant gap between teacher intention and practice in terms of pupils' decision-making experiences and their learning of science.

In practice, most lessons were teacher-directed, with limited pupil agency or opportunities for critical reasoning and reflection. Teachers retained control over key decisions, particularly during the conclusion and evaluation phases of inquiry, a pattern consistent with previous research (Abrahams & Millar, 2008).

A lack of conceptual clarity was identified, such as the teachers commonly using terms such as 'experiments', 'investigations' and 'inquiry' – all being used interchangeably as if they were synonyms.

More child-centred approaches were indicated by the UP teachers in both Phase 1 and Phase 2, such as involving pupils in raising their researchable questions, and showing greater willingness to allow pupils to explore open-ended questions. UP teachers planned their IBS over a series of lessons compared to LS, where the focus was on developing science knowledge within a single 'stand-alone' lesson. Most LS practicals were structured or guided inquiry, with fixed outcomes and limited pupil choices. However, even in these UP settings, opportunities for pupils to engage in dialogic exchanges, critically interpret data, or collaborate meaningfully were limited.

Lesson observations in UP and LS showed limited teacher scaffolding to develop pupils' skills in evaluating evidence or engaging in scientific reasoning. The emphasis, especially in LS lessons, was on task completion, rather than reflection or justification of findings. Opportunities for dialogic talk, cognitive challenge and cognitive engagement were minimal, particularly during the plenary aspect of the observed lessons. This suggests that, despite positive beliefs about the learning potential for pupils, IBS pedagogical enactment often draws on traditional teacher-directed instruction.

Pupils' perspectives on inquiry and decision-making

Pupils in both UP and LS settings reported enjoying practical science lessons more than their other science lessons and indicated that their teachers made most decisions. LS pupils particularly viewed teachers as the experts responsible for safety and accuracy, reinforcing a perception of science as a dangerous, risky experience. These findings highlight a disconnect between pupils' roles in IBS and the aims of inquiry pedagogy, which promotes greater learner autonomy and ownership of the investigative process, including data analysis.

The limited dialogic talk and argumentation in observed lessons suggest that opportunities for collaborative sense-making (which is crucial to developing scientific reasoning in IBS) were curtailed. Pupils often worked in groups for logistical reasons rather than to engage in structured collaborative thinking.

Focus group interviews revealed that pupils were not taught how to discuss, question, or critique evidence effectively. This suggests a need for the explicit teaching of discussion and argumentation skills, which concurs with recent findings that many pupils struggle with effective communication in group settings (Mercer, Hennessy & Warwick, 2025).

Interestingly, Year 7 pupils often reported that they had done little science in Year 6 due to a lack of 'labs' and 'bunsen burners' and a high focus on SATs preparation and statutory testing.

The UP teachers also stated that there was a reduction in time for practical science teaching in Year 6. This might adversely impact science learning and inadvertently reinforce a view that science is factual and test-driven. It also indicates a missed opportunity for using IBS to maintain curiosity and build foundational skills necessary for effective transitioning to a secondary science curriculum.

Curriculum policy and transition challenges

Analysis of the two 'Working Scientifically' (WS) curriculum policies shows inconsistencies in vocabulary and terminology, and a lack of clear progression guidance, which likely disrupts continuity between primary and secondary education.

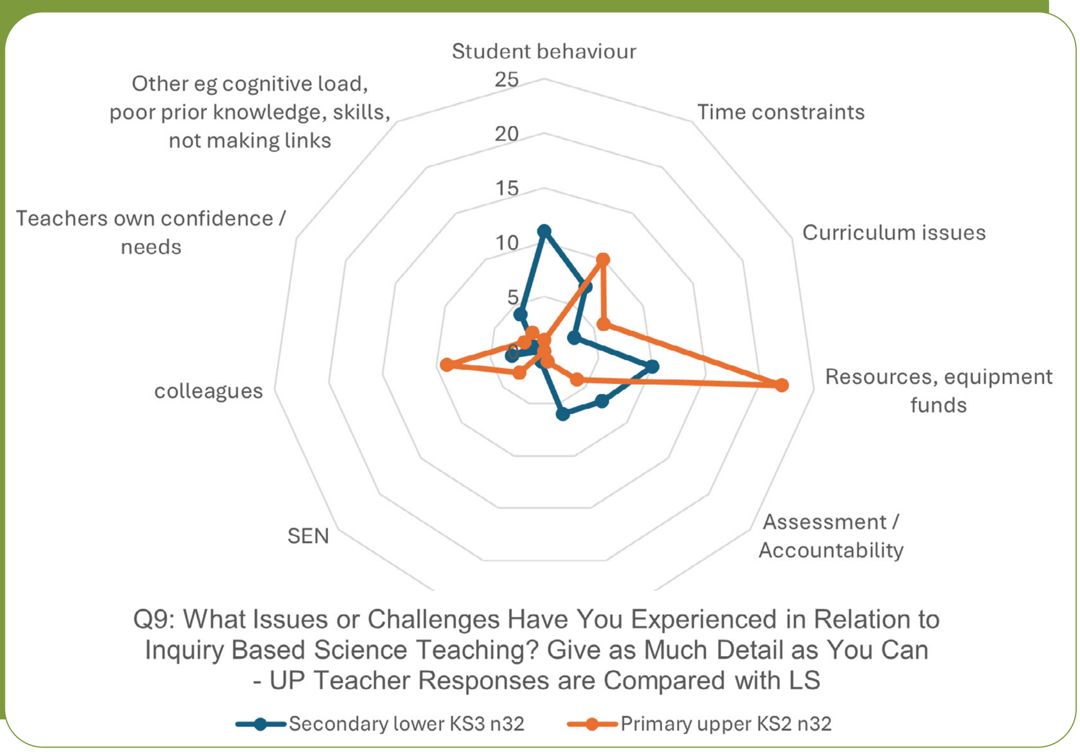
While teachers in primary phases are trained as generalists, they do have science training and have supplementary guidance in the Key Stage 2 (ages 7-11) WS documents. However, LS teachers, although subject specialists, often need to teach outside their degree expertise, yet their policy document has no equivalent non-statutory guidance to support their enactment of WS. Teachers involved in both phases of the research indicated awareness of WS expectations for their respective year groups, but had limited understanding of adjacent key stages. This limited familiarity may result in challenges with curriculum alignment during classroom instruction, particularly for LS teachers who are expected to build on content taught in UP.

All teachers reported pressure to cover the science curriculum, and heavy assessment requirements hinder practical science and IBS practice. LS teachers especially identified high-stakes testing and curriculum demands as ongoing barriers to open inquiry (Quick, 2024).

Issues and challenges in relation to IBS

In Phase 1, UP teachers cited their biggest challenge with IBS as a lack of resources. In contrast, LS teachers cited poor student behaviour (see Figure 2).

▼ **Figure 2.** The issues and challenges of IBS: UP and LS teachers' views compared.



Harlen (2013) and Furtak *et al* (2012) argue that inquiry practices improve science learning outcomes, but that implementation is frequently undermined by curricular rigidity and assessment pressures (OECD, 2018). Abd-El-Khalick and Lederman (2000) emphasise that understanding the NOS is essential for scientific literacy, yet this is often neglected in inquiry-based lessons, which focus too much on data collection and results tables without the critical reflection needed from raising a question to reviewing evidence. Furthermore, Anderson (2002) and Crawford (2007) highlight the importance of teacher knowledge about different inquiry levels and the importance of learner agency. My findings align with the extensive international literature highlighting the affordances and constraints of IBS pedagogy (e.g. Strat *et al*, 2023; Tao & Chen, 2024). In addition, without explicit policy guidance and training support for teachers, the crucial elements of pupil agency and cognitive challenge, essential in effective IBS, will remain under-exploited in classroom practice.

Professional development needs

My research findings suggest that effective implementation of IBS requires professional development for teachers that extends beyond technical knowledge or single workshops. Effective IBS is complex, and professional learning is more likely to be successful when incorporated into initial teacher training and maintained (Crawford, 2000, 2007) as a component of continuous professional development (CPD).

Effective CPD should include:

- Opportunities to experience inquiry-based science pedagogy as learners themselves;
- Structured reflection time on practice, including video-stimulated dialogue; and
- Peer collaboration and mentoring within communities of teacher practice.

Teachers also deserve support to develop the dialogic competencies necessary for facilitating greater frequency of open-ended inquiries. This involves training in questioning strategies, feedback techniques, and managing cognitive conflict. Without this, even well-intentioned IBS lessons can revert to procedural activity.

My study supports a model of CPD that is locally led but nationally supported, enabling teachers to integrate inquiry skills progressively and align them with curriculum goals. A national strategy should consider developing communities of practice of teachers across schools who can model, mentor and help embed inquiry-based pedagogies across departments and phases.

Policy recommendations

To better support inquiry-based pedagogy, national curriculum policy should:

1. Clarify terminology related to practical science, distinguishing between types of inquiry, experiments and demonstrations.
2. Provide explicit progression pathways for inquiry skills and IBS principles from Key Stage 1 (ages 5-7), Key Stage 2 (ages 7-11), to Key Stage 3 (ages 11-14).
3. Include glossaries and exemplars to support teachers' understanding.
4. Reduce the over-emphasis on content coverage, linked to high-stakes testing.
5. Introduce expectations for dialogic practice and argumentation as part of scientific inquiry and understanding the NOS.

Enhancing curriculum policy with constructivist approaches and emphasising process skills and pupil agency should help to bridge the gap between policy directive and classroom practice. Additionally, inspectorate frameworks should recognise and support inquiry-led teaching that promotes skills development and depth of understanding over curriculum coverage.

Reflections

Effective IBS is recognised as complex, requiring adaptable pedagogies, coherent policy support and sustained professional development. The teacher's role is not as a passive observer but an active partner with a shift from that of a 'knowledge giver' to a facilitator (Crawford, 2000) who promotes active engagement at a cognitive level and pupil decision-making. A greater degree of dialogic interactions would mirror the practices of professional scientists. In doing so, pupils become more agentive and work collaboratively, leading to deeper learning and greater engagement with school science (Tao & Chen, 2024; Tang *et al*, 2020).

The findings from my study resonate with current calls for educational reform, including the current curriculum review in England, to reduce the amount of content. There is an opportunity to highlight the relevance of inquiry-based principles and pedagogy in preparing pupils for the challenges of the 21st Century. This is not suggesting that there is no place for direct instruction. It is suggesting a better balance, where the focus is on pupil understanding of science knowledge and process skills, with high degrees of pupil engagement.

Although the study teachers were enthusiastic about practical IBS, they often lacked a full understanding of IBS pedagogy and aims, which likely contributed to missed opportunities for pupils' decision-making and critical reasoning. Pupils greatly enjoyed inquiry-based science, but were unclear about their roles and how these might differ in other science lessons that they might undertake.

My findings suggest that a shared understanding of the core principles of IBS, and explicitly indicating how it differs from other practical science activities, is needed, rather than a unified single definition.

Future research directions

Further research is needed in the UK and could explore:

- A longitudinal study of IBS implementation across the transition phases of UP and LS;
- Pupils' experiences of IBS and their perspectives on their role, including making decisions, leading their inquiries and reflections on their learning;
- Effective models of inquiry-based CPD across different school contexts and pupil ages; and
- The impact of school leadership and culture on supporting teachers and sustaining inquiry practices.

There is scope for comparative international research examining how different systems support or constrain inquiry-based teaching and how continuity is supported across different key stages.

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