Reflections on guidance to orientate untrained practitioners towards authentic science for children in the early years

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Abstract

There are currently a number of concerns facing early years education in England. A diverse range of pre-school settings for 0-5 year-olds exists. Those settings in the government-maintained sector are required to have at least one qualified teacher, whilst settings in the Private, Voluntary and Independent (PVI) sector are not required to employ a qualified teacher. Moreover, there is no requirement for a qualification to work in early childhood education and care settings.

While the proportion of unqualified practitioners varies according to setting, about a tenth of adults working in early years in England are unqualified. Moreover, although the majority of settings are graded 'good' or 'outstanding', there are doubts about the quality of provision, particularly in relation to science. Criticisms tend to centre on practitioners' knowledge and confidence in relation to science and the quality of science experiences on offer. We argue that views of what constitutes science education and approaches to young children's learning have developed and changed, with contemporary science adding epistemic and communicative dimensions to longstanding concerns with process and content.

Current social constructivist views of learning, together with neuroscientific evidence, point to the brain being primed for social interaction (Hinton & Fischer, 2010). These considerations offer grounds for optimism that changes in emphasis within science education bring the subject closer to developmental perspectives on the education of the whole child. We suggest that the epistemic and communicative elements that are increasingly recognised as authentic and essential to science education can be enhanced by early years practitioners drawing on their existing holistic cross-curricular skills. While acknowledging the benefits of specialist early years training, there are messages to be drawn for all practitioners, including, and perhaps especially, those whose access to training is limited or less than optimal. The fresh perspective that we suggest is to bring early years science into closer alignment with wider holistic practices. From this standpoint, we draw on some insights from our research to suggest strategies that combine theory with practical and applied approaches to early years science education. It is striking that the foundations for an epistemic approach can be identified in existing early years curricula and practice and are ripe for more focused attention. Specifically, we refer to the encouragement of multimodal expressive skills, critical listening, and expecting reasons for ideas (or 'claims') in dialogic exchanges that increasingly expect evidence in support of beliefs.

Keywords: Early years, epistemic, discourse

Introduction

A recent report by the Department for Education (2017b) claims that 94% of three year-olds and 99% of four year-olds in England access some government-funded early years education and care (Department for Education (DfE), 2017b). Early years provision is available through a variety of settings, including maintained settings (usually nursery school attached to a school or local authority nursery), or through the Private, Voluntary and Independent sector (PVI), which tends to include private and voluntary day nurseries, playgroups, pre-schools and childminders.

In England, a qualification to work with children in the early years phase is not required. Nutbrown (2012) recommended that, by 2022, all staff should be qualified. The data relating to the proportion of qualified staff in settings suggest continuing concerns about the proportion of early years staff having no qualifications. For example, according to Simon, Owen and Hollingworth (2016), a quarter of childcare workers held no suitable qualifications. A report in the same year by the National Day Nurseries Association (NDNA) (2016) claimed that the proportion of unqualified early years staff in nursery settings in the UK was more than one in ten. Our aim in this article is to consider the support needs of the entire spectrum of early years staff, including unqualified personnel, as well as those holding early years and teaching qualifications of some kind.

Notwithstanding the lack of formal qualifications amongst some staff, reports suggest that almost all (85%) eligible children receive their early childcare in settings graded as 'good' or 'outstanding' (DfE, 2017a). In contrast, a recent study of the impact of nursery attendance on children's learning (Blandon, Hansen & McNally, 2018) demanded greater attention to the quality of teaching and learning. Accumulated international research signals that deficits in the science achievements of young children that persist throughout schooling, across race, ethnicity, gender and socio-economic levels, may influence career choices (Trundle, 2015; Morgan, Farkas, Hillemeier & Maczuga, 2016; Sackes, Trundle, Bell & O'Connell, 2011). Criticisms of the nature of early years science education point increasingly to the lack of focus on children's learning (Sylva, Melhuish, Sammons, Siraj-Blatchford & Taggart, 2010). This lack is often attributed to low levels of confidence and science content knowledge amongst early years practitioners (Kallery & Psillos, 2001; Garbett, 2003), as well as to an inadequate understanding of the nature of science (NOS) (Bell & St Clair, 2015). Critics of early years science practices point to the absence of effective science instructional techniques (Tu, 2006) and the fewer opportunities available for children to engage with science activities compared with literacy and mathematics (Sackes *et al*, 2011). Early years activities are widely understood to offer an almost exclusive focus on children 'doing' through hands-on activities (Inan & Inan, 2015) and rarely explore NOS issues (Akerson, Buck, Donnelly, Nargund-Joshi & Weiland, 2011).

The tendency to prioritise low level hands-on activities contrasts sharply with growing evidence that early years children show remarkable capabilities to express and reason about their own ideas and those of others (Piekney & Maehler, 2013; Mercier, 2011; Kuhn, Amsel & O'Loughlin, 1988; Carey, 2004). Gopnik (2014) acknowledges young children's capabilities in distinguishing fact from fiction – an important precursor to weighing evidence. Increasing evidence of children's early capabilities led the US NRC (2007) report to the Committee on Science Learning K-8 to recommend an increase in the quality and challenge of science experiences offered to young children. They concluded that: *'All young children have the intellectual capability to learn science. Even when they enter school, young children have rich knowledge of the natural world, demonstrate causal reasoning, and are able to discriminate between reliable and unreliable sources of knowledge. In other words, children come to school with the cognitive capacity to engage in serious ways with the enterprise of science'* (National Research Council, 2007, p.vii) Despite this wider recognition of children's early capabilities, there is continued evidence of a mismatch between capabilities and the learning environment. In 2015, drawing on evidence of their review of practice and of some of the evidence of children's emerging scientific reasoning skills, Trundle and Sackes (2015) claimed that: *'Despite these capabilities, children's emerging skills usually are not the target of instructional practices in typical early childhood classrooms'* (Trundle & Sackes, *op. cit.*, p.242). In 2015, the OECD set out the alignment of early years curricula with the goals of primary education (OECD, 2015) in an initiative designed to help children realise their potential.

Historically, in England there has been a widespread acceptance of the notion of science for all and a recognition of the value of science learning for children's wider development. Science was introduced as part of the core curriculum for the primary years (5-11 years) in 1989 (HMSO, 1989) and forms part of the early years foundation stage (EYFS) (3-5 years) curriculum within an area of learning entitled 'Understanding of the world' (EYFS, 2012). The curriculum makes explicit that it is through this area that children's communication and language should be strengthened and applied, so wider curricular links are explicitly acknowledged.

Over the years, there has been debate about what constitutes science education, and the early debate centred on a tension between the teaching of science processes or content. In more recent years, educators' views of science have been extended to include an emphasis on social, communicative and epistemic processes as realised in science discourse practices (Duschl & Jimenez-Aleixandre, 2012; Duschl & Grandy, 2013). By making explicit the relationship between communication, language and emergent science, the early years curriculum provides key opportunities for the introduction of early discourse practices and ways of thinking scientifically within high quality social interactions between children, and between children and supporting adults. Developments in understanding learning more generally have shifted from behaviourist and information processing perspectives towards dominant views from cognitive psychology about the social construction of learning (De Corte, 2010). The focus on the social nature of learning is further supported by contemporary evidence from neuroscience, which describes the brain as being primed for social interaction (Hinton & Fisher, 2010).

In this article, we consider how the development of scientific literacy can be encouraged 'bottom-up', using approaches consistent with contemporary developments in science education research and a 'whole child' perspective on young children's learning. This perspective acknowledges the training needs of early years practitioners, but suggests building on, rather than the wholesale replacement of, existing skills. We argue that the contemporary understanding of what constitutes science education offers new possibilities for early years practitioners to make significant contributions to an authentic science experience for young children. Our long-standing interest in developmental progression underpins our view that science capabilities can be understood as gradually emerging from more basic, foundational or general skills. Just as children are building up domain-specific ideas about science phenomena, they are also building up ways of communicating, sharing and reviewing those ideas in their early interactions. Learning environments sensitive to these emerging capabilities can promote a culture in which the exchange of ideas is valued and understood as central to learning. We suggest how the encouragement of gradually increasing interactive, reasoning and communicative skills can be nurtured in ways consistent with more current ways of characterising science proficiencies. This strategy requires specification of developmentally appropriate activities that can become central to early years practitioners' interactions with young children. In turn, this stance implies the need for a practical agenda that builds on current best practices, and meets the requirements of an updated view of science education. To describe real possibilities of operationalising this viewpoint, we draw on quantitative and qualitative evidence derived from three relevant projects (children 3-7 years).

Review of authors' relevant project activity

Young children's developmental capabilities relevant to emergent science within early years holistic curricula and practices were explored in a recent assessment project. Construction of the Child Development Assessment Profile (CDAP, Welsh Assembly, 2011) necessitated defining and measuring psychometrically aspects of 'whole child development'. The developmental assessment criteria that were validated in the first study with a large-scale sample were illuminated by two further pieces of research to which we refer.

A second study looked at the qualitative interactions between children and practitioners in settings, drawing on qualitative data from a collaborative exploration of emergent science within the holistic early years practices of twelve settings. Teachers of children aged 3-7 years worked within their usual holistic approaches with their classes of children, with the authors operating as participant observers. Exchanges between teachers and researchers resulted in the gradual shaping of existing practices towards a focus on the collection of children's ideas using a variety of modes, including action, speech, drawing and 3D modelling. Once ideas were collected, children were encouraged to listen to each other's ideas and to explain their own reasoning. Data collected included examples of children's work, teachers' journal notes, teachers' writing and researchers' classroom visit notes. The study helped to trace, in the course of all-inclusive activities, developmental learning progressions between general and emergent science skill proficiencies.

Further evidence of synergy between early years practices and epistemic views of science was found in a third study, which explored the ways in which children expressed and exchanged ideas and the way they used mathematical tools to collect evidence to inform their thinking. This research-based design project involved ten schools, each focusing on teaching and learning within evolution and inheritance (4-11 years). Here, we draw on some of the qualitative evidence from four of these teachers having responsibility for children 4-7 years. Data collected included examples of children's work, teachers' journal notes, teachers' writing and researchers' classroom visit notes.

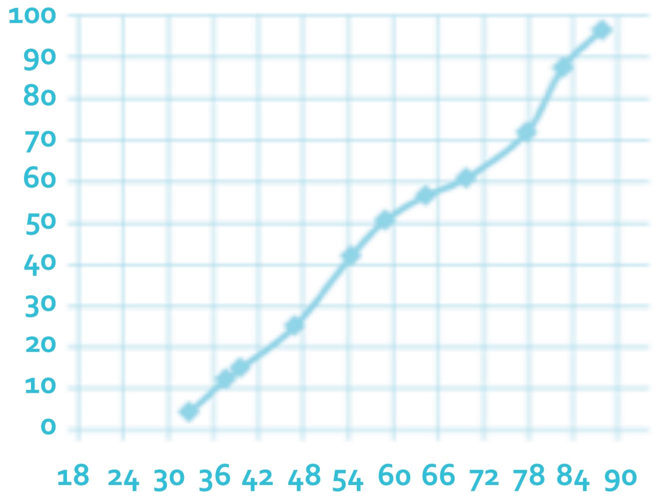
Evidence from outcomes of each of these projects helped the identification of approaches within existing early years curricula and practices that have the potential to offer a more authentic science experience to young children.

Quantitative evidence of early years practices relevant to authentic science

The 'Child Development Assessment Profile' (CDAP, Welsh Assembly, 2011) was a holistic baseline assessment profile to assess all children (3-5 years) on entry to foundation phase in Wales. A national pilot undertaken as part of the development involved 1195 children in 269 settings. Practitioners trained in the use of the CDAP assessed the children in their care in the course of their usual day-to-day interactions, referring to six Developmental Areas and a total of 114 items, each addressing an observable behavioural criterion. The retrospective review of the criteria identified behaviours of interest to science educators at three levels:

- 'General developmental' criteria accounted for about two-thirds of assessed behaviours. They were defined as those likely to be prerequisites to all learning.
- 'Science enabling' criteria, representing about one quarter of assessed behaviours, were defined as those that would support science-related activities without having been nurtured in a context readily identified as scientific.
- 'Science-specific' criteria (9 of the 114, or 8%) included showing curiosity, giving reasons, explaining how things happen, holding a point of view, describing logical sequences, planning inquiries and empathising with the listener (Russell & McGuigan, 2016a). These latter capabilities are essentially about thinking, reasoning and sharing understanding with others and are congruent with an epistemic view of science. Figure 1 exemplifies the form of item analysis undertaken on all 114 criteria.

Figure 1: Science-specific item: 'Gives reasons for why things have happened or are happening' (age norm 48-60 months).



Children's capability to offer explanations for changes that they see happening was assessed through this criterion. Located within the 'Thinking and reasoning' domain of the CDAP, causal reasoning is of foundational importance to the development of science understanding. (Percentage success on y axis, age in months on x axis.)

It is worth emphasising that these nine 'science-specific criteria', identified as relatively discrete and measurable entities, were revealed within a 'whole child' curriculum in which science did not feature as a separate subject. The developmental data confirm that the foundations of an epistemic approach can be found within a broad and balanced early years curriculum in which the focus was child-centred, experiential and play-orientated.

Qualitative evidence: expressing ideas; listening; and reasoning with evidence

The data drawn from the two qualitative early years research projects suggest some key instructional practices, which resonate with a simplified approach to argumentation that is both developmentally appropriate and consistent with the epistemic aspect of the NOS (Russell & McGuigan, 2016b). Together, the qualitative studies provide evidence of three developmental learning progressions that help trace the managed emergence of authentic and foundational science experiences for young children. Using illustrative evidence from these studies, three skill areas: 'expressing ideas', 'listening' and 'reasoning with evidence' highlight how all early years practitioners might support children as they make progress towards some of the social and communication skills valued in epistemic views of science.

Expressing ideas

On initial entry to settings, some children may be hesitant to express their ideas. As with spoken language, the conventions governing communication using different formats such as gesture, drawing and modelling have to be learned and their introduction managed by the supporting adult. Gradually children will gain the capability to exploit a range of representational formats and make choices about which best suits their intentions. Barely-formed ideas will be developed even as children represent and discuss their ideas. The ability to draw on a range of modes allows the same idea to be represented in different ways; the redundancy reveals nuances that may not be possible in any single mode. The triangulation of different modes is intended to generate richer understandings, not to avoid the oral mode.

The value of verbal expression is unquestionable, but can be extended and enriched by multimodal forms of communicative expression. Amongst the many examples gathered, in one class of 6 and 7 year-olds, a teacher invited children to make model pets to show their ideas of pet families ('babies' and their 'parents'). Children used feathers, art straws, paper and sponge balls to make their imaginary pets. They tended to make the offspring smaller than the parents, but with the same characteristic eyes, feathers, etc. Their 3D models provided an engaging focus for interactions designed to encourage the expression and sharing of meanings. With the help of a supporting adult, one child mentioned that the young pet would look exactly like its mother, only smaller. Others shared this view or thought that a boy pet would look exactly like its father. The concrete form of the 3D modelling helped children keep track of the focus of the discussion. In terms of science discourse, the ideas that children expressed, whether verbally or in drawings and models, could be understood as claims.

Increasingly, children become aware of their own beliefs as ideas to be expressed and shared with others. Children's tendency to offer the same idea as their peers will be likely to diminish with experience and encouragement. Creating a positive environment in settings, with the expression of ideas being explicitly valued by receiving praise and attention, will encourage their further expression.

Listening to others' ideas

Children are normally required to attend to adults when spoken to. Some settings might have a routine to focus children's responsiveness, for example, children wiggling their fingers in the air and turning to face the adult to signal attention. Similarly, the importance of listening to children and the modes of behaviour required in a discussion must be explicitly introduced to children by the managing adult as an integral part of most activities.

Initially, children tend to think that everyone shares the same idea. Adults can facilitate children's growing awareness of alternative viewpoints, by deliberately drawing attention to the diversity of ideas expressed, modelling reactions of interest and surprise and valuing any alternative viewpoints. For example, a class of 4 and 5 year-olds preparing for a farm visit shared ideas about some of the different animals that they expected to see. The practitioner made a class list of children's drawings and spoken ideas, which helped to bring the different ideas to children's awareness.

A step on from children accepting the diversity of ideas is active listening and responding in ways that demonstrate detailed and thoughtful engagement with the discussion. Active listening within these early exchanges might be revealed as children introduce relevant, albeit different – perhaps opposing – viewpoints, as well as additive, supportive expressions of ideas. The supporting adult must make the rules of these exchanges explicit, so that children learn to respond respectfully to the ideas of others in what might be described as an early form of peer review.

For example, a group of nursery children planting bulbs and deciding what bulbs need to grow (4 year-olds) were encouraged to respond to others' ideas by first saying, *'I like [Ruby]'s idea but I think…'.* All the children adopted this technique of explicitly referring to the name of the owner of the idea and first expressing a liking for the expressed idea, before introducing a gentle challenge to each idea or claim. The strategy helped to ensure that children experienced the sharing of ideas as a positive, enjoyable process. Once acknowledged by the teacher to be a regular and required feature of children's interactions, the tactic helped to ensure that children developed the ability to compare ideas and express counterclaims in ways that respected each other's right of expression.

Approaches that include the encouragement of listening actively to others and an increased awareness of the diversity of others' ideas constitute an authentic and valid approach to science. In their early interactions with children, supporting adults help children towards productive exchanges in which children become confident enough to express ideas, empathic and respectful in the giving of feedback and resilient in handling others' feedback. It is these early exchanges that resonate with epistemic science practices. We were reminded of the value of the early and gradual introduction of 'argumentation' skills by two Year 5 girls (aged 10), who had just experienced a lesson in which they had reviewed and critiqued each other's ideas for the first time. They had found the requirements to critique and perhaps disagree with others' ideas unfamiliar and disconcerting:

'I think it was quite weird arguing with my friends because, ermmm, we all like, agree with them most of the time, so it was a bit weird arguing with them.'

'I think it was a bit weird as well, because I normally agree with them and then I'm not agreeing with them today.'

Reasoning with evidence

Encouraging the giving of reasons marks a shift in science thinking towards self-awareness as to what and why a belief is held, rather than an alternative idea. This shift requires children to develop metacognitive skills through which they can reflect upon and manipulate ideas. The shift also requires children to develop the capability to use evidence to support their ideas. Initially, children's reasoning may take the form of assertions or assumptions of delegated authority, with statements such as *'I just know'*, or *'Everyone knows that!'*. In these instances, children may think that there is general agreement in relation to a particular idea, so there is little motivation to seek justifications to support thinking. Yet reasoning is important, because children can be helped to choose between ideas on the basis of the reasons given to back them up. Encouraging children's regular use of 'because' immediately following an idea helps to invite the giving of reasons. The reasons that children offer may draw on their own conceptual understanding, first-hand experiences or their imagination.

Our evidence suggests that, with practice, children show impressive competency to express ideas, to justify their ideas with reasons and to critique thoughtfully those of others. In this manner, they progress to comparing and modifying their own ideas through consideration of the reasoning and evidence they have heard.

In a class of 5 and 6 year-olds, children exploring materials outdoors climbed into an old boat in the school grounds to discuss their ideas about the materials that had been used to make it. The teacher made clear her requirements that children should listen carefully and decide whether they agreed or disagreed with each other's ideas, and why:

Teacher (T): *'We are going to listen very, very carefully now and think about whether we agree or disagree with each other's ideas about the materials used to make the boat, and why.'*
Jo: *'Screws are made out of metal and the green bit isn't.'*
T: *'Ok. What is the green bit made out of, Jo?'*
Jo: *'Wood, and screws are not.'*
Eleanor: *'I think Jo's idea is true but when you paint the metal it looks like it is made out of wood.'*
T: *'Ah! The metal looks like the wood because it is a painted the same colour as the wood.'*
Nerys: *'I know why they decided to build it from wood… because, to keep it waterproof.'*
T: *'Ah! So they decided to build the boat from wood to keep it waterproof. So, is wood a waterproof material then?'*
[The group responded in unison with either 'No!' or 'Yes!', suggesting that they were divided in their understanding as to whether or not wood is waterproof.]

Erin: *'No, because it's not a soft material.'*
T: *'Because it is not a soft material. So are waterproof materials soft?'* [Note the reflecting back of the expressed idea and its reformulation as a question.]
Erin: *'Yes'.*
T: *'Has anyone else got anything to say about Erin's idea?'*
Anna: *'I don't think that that's true because I only think waterproof materials are made out of plastic.'*
T: *'Anyone got anything else to say about those ideas?'*
Nerys: *'I am beginning to change my mind because actually I think plastic is waterproof.'*
T: *'But what about wood?'*
Nerys: *'Wood can rot in the rain so I don't think it is waterproof.'*
Anna: *'Plastic doesn't rot down so I think Nerys's idea is true.'*
T: *'What do you think about wood, then? Do you think wood is a waterproof material?'*
Anna: *'Wood is not, because if you leave it outside for a long time, it will rot down.'*
T: *'Has anyone got anything else that they could say linked to that?'*
Harry: *'If you jump on the boat it will just break because it is plastic.'*
T: *'What do you think the boat is made of?'* [Teacher seems to be checking out the child's understanding.]
[Harry knocks the boat to check or test his ideas: *'Out of wood'*. [Tapping the boat shows the child is looking for evidence through testing as part of the conversation.] (Russell & McGuigan, 2016b)

In such exchanges, children are being inducted into a process whereby they can explain why they believe one idea in preference to others and, importantly, use evidence to support their own view. The supporting adults must be active in probing responses and encouraging children to think about others' ideas along with their own, and to require them to explain their reasons.

This process helps to bring about changes in understanding as weaknesses and strengths in ideas are recognised. In the example, we see children exchanging and building on each other's ideas thoughtfully and showing remarkable capabilities to acknowledge the influence of each other's ideas on their own reasoning.

Conclusions

On first stepping out of the home into their early years settings, many children may be reticent in expressing themselves and interacting with others' ideas. With adult support, they display a developing capability to express their ideas confidently, to listen actively and to critique positively the ideas of others. Through practice routines, they gradually learn to adopt strategies that help them to challenge the ideas of others, sensitively and with respect. As they progress, they demonstrate an awareness of how they know and why their ideas have changed, cognitive growth aligned with an epistemic aspect of the nature of science. Our analysis seeks to link general early years practices to these authentic science approaches, by tracing developmental learning progressions between general behaviours and the emergence of more science-specific behaviours.

Our collaborative research with practitioners has revealed some of the ways in which these approaches can be supported seamlessly in early years practice. The aim is not to promote heuristics that will encourage disparate, discrete science skills, but rather to show how the interactions arising in some of the experiences provided in early years settings might be thought of as enabling of the broader epistemic and communicative view of contemporary science.

Focusing on science education within the whole child framework of early childhood practitioners reveals the potential alignment between early years curricula and practices and current views of contemporary science. While acknowledging the advantages that a specialist training in science confers on practitioners, there are messages to be drawn for all, including those with more limited access to professional development and training. Our research signals some tentative practical guidance for all early years practitioners, embedded in their whole child approaches to early years education. The task ahead is to disseminate these possibilities.

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