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why & how?
PRIMARY SCIENCE TEACHING TRUST

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PRIMARY SCIENCE TEACHING TRUST

Editorial

● Suzanne Gatt

Driving my children to school was always an interesting time for conversations. It was the time when they tended to make unusual observations and ask me the strangest questions. I must confess that, probably like many parents, I sometimes tended to dread these conversations, as often I was unsure about how to best answer their queries. I remember vividly one instance when my daughter, barely seven years old, asked whether our brains move when we move our heads. As I tried, in panic, to go back to my biology studies to see how best I could respond in a simple way that she would understand, I inquired why she was asking about the brain. She explained how, the day before, she had wondered whether her brain inside her head moved when she lay down in bed and put her head on the pillow to sleep. I have to admit that at that moment I really had no idea how to respond to her observation. Should I mention the Cerebrospinal Fluid around the brain, or avoid providing a technical answer? In the end, I promised that I could help her look up some information about the brain, relieved that the episode was temporarily over.

I am sure that these instances are common and there are many parents who are often unsure how to react to the multitude of questions that their children pose. It is also why young children are considered as intuitive scientists (Gopnik, 2012).

Children are naturally curious and have an intrinsic motivation to learn, an aspect that has not changed from one generation of children to the next, despite all technological developments. They also start learning science from the home context (Sikder, 2015). Young children are always interested in natural phenomena around them, such as sunrise and sunset, thunder, animals and their babies and many other aspects that we adults take for granted. From a very young age of a few months, babies are often seen to repeatedly drop toys to test if they will always fall onto the floor. As babies grow older, they will extend their explorations, for example, by spending hours playing in sand, adding water to sand, and trying out different activities to see what happens. This leads them to ask incessant questions.

Teachers and parents can capitalise on children's innate curiosity by providing rich experiences that promote questioning and explorations. Intriguing direct experiences of scientific phenomena, whether involving playing with ice, making boats out of play dough, adding substances to water, etc., can easily serve to promote inquiry (Johnston & Tunnicliffe, 2014). Inquiry builds on children's natural disposition to explore. However, children need guidance if we want them to develop their natural curiosity into scientific investigation skills. To achieve this, they need to practice how to investigate their questions by engaging in rich scientific inquiry experiences (Ashbrook, 2016). Scientific inquiry enhances children's natural curiosity, helping them to develop a range of scientific skills: how to explore objects, materials and events; to ask questions that can be tested; how to make careful accurate systematic observations; to record their observations in different forms; compare, sort, classify, and order their own observations; identify patterns and relationships; and eventually develop tentative explanations and ideas. They do this as they work collaboratively in groups, sharing, discussing and confronting their ideas.
This issue of *JES* considers children's interests and curiosity about the world and implementing

inquiry. The paper by **Bartoszeck and Tunnicliffe** tackles children's natural curiosity about the crab in Brazil and their conceptions of what they think is inside their bodies. Natural inquiry leads children to formulate their own ideas and explanations. These ideas are relevant to the process of learning science and thus, children's ideas need to be the starting point for learning science.

My colleague **Amanda McCrory** presents inquiry within the national primary science curriculum and the challenges that it presents to teachers. It is the first part of our contribution as Editors to the journal. Inquiry has been promoted in many countries, in Europe as well as the US. Mainstreaming inquiry in the primary curriculum is thus a struggle for many countries.

Mujtaba, Tunnicliffe and Sheldrake's article focuses on teachers' perceptions of inquiry-based learning following a professional development course implemented as part of a European Funded project, Pri-Sci-Net. The article includes reflections particularly related to the impact on the teachers' practice and on the students. A gender perspective is provided.

The Primary Science Teaching Trust (PSTT) has contributed an interesting article. **Morgan, Franklin and Shallcross** talk about trails and describe how they use out-of-school activities to promote exploration and the understanding of physical concepts related to light, sound, electricity, etc. The article provides an example of the variety of different authentic inquiries that can be organised outside the classroom context. Taking children out to gardens, streets and parks builds on children's natural interest in the world and promotes exploration where children can engage directly with scientific phenomena within the science primary curriculum.

We hope that you enjoy this edition and that it inspires you to organise inquiry activities where children nurture their curiosity about the world and explore their ideas as a process of learning science.

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Scientific enquiry and engaging primary-aged children in science lessons:...

● Amanda McCrory

...reflections on provision for scientific enquiry in primary schools in England and Wales (Part 1)

Abstract
The first part of this paper reflects on and discusses the concept of scientific enquiry in primary schools in England and Wales, including possible barriers to the provision of the primary science curriculum via enquiry. The second part of this paper, which will be published in Issue 14 of JES, will report and critically reflect upon how schools can deliver a high quality primary science curriculum via enquiry to engage children in science education and promote a lifelong passion for learning science.

Keywords: Barriers, curriculum, engagement, enquiry, perceptions, provision

Children's perceptions of science
How do primary-aged (EYFS, Key Stages 1 and 2, ages 0-11) children view science? On the whole, is their attitude to learning about science and the world around them positive or negative? The Wellcome Trust (2014) notes that children start to *'develop perceptions about whether science is for them towards the end of primary school,'* (2014: 4) and it is therefore imperative that *all*, not some, primary school children experience exciting and inspiring science that reinforces their understanding of the *nature of science.*

Although I now work in Initial Teacher Education (ITE), at heart I am a primary science teacher – and, as a science educator, nothing gives me more pleasure than engaging with children when they are learning science and with my student teachers when they are learning to be effective facilitators of the science curriculum. I have never met a child who is not curious and does not want to explore and investigate in science, unless they have experienced the *boredom of not being taught science effectively* or indeed *learn to believe* that science is not for them.

We know from limited research into investigating primary-aged (0-11 years) children's attitudes to science that, in general, these pupils have positive attitudes to practical science and that this tends to emerge from a young age (Murphy *et al*, 2005; Silver & Rushton, 2008; Berland & Reiser, 2011; Tunnicliffe, 2015); thus they are likely, on the whole, to leave primary school – if they receive good provision in science education – thinking positively about science, even though primary-aged children can find some concepts in science difficult to understand (Loxley *et al*, 2014).

Teachers can find the more abstract concepts of science challenging to teach (Harlen & Qualter, 2014) and it is therefore recognised that more needs to be done to improve teacher effectiveness in developing children's conceptual understanding of science via enquiry, not only in primary but also secondary schools (Abrahams & Reiss, 2012; 2014). It is hoped that the changes to the Primary Science Curriculum in England and Wales (2013) will be a step towards enabling primary science classroom teachers to achieve this.

The primary science curriculum and enquiry
As readers are no doubt aware, science in state maintained primary schools in England and Wales focuses on biology, chemistry and physics – via these disciplines, scientific knowledge and conceptual understanding are taught and developed. Scientific enquiry – referred to in the National Curriculum for Science as *'working*

scientifically' – is an essential tool for children to ask and answer scientific questions about the world around them. Understanding the nature, processes and methods of science is an important aim of science education in the primary school:

- *'While it is important that pupils make progress, it is also vitally important that they develop secure understanding of each key block of knowledge and concepts in order to progress to the next stage. Insecure, superficial understanding will not allow genuine progression: pupils may struggle at key points of transition (such as between primary and secondary school), build up serious misconceptions, and/or have significant difficulties in understanding higher-order content.*

- *'Pupils should be able to describe associated processes and key characteristics in common language, but they should also be familiar with, and use, technical terminology accurately and precisely. They should build up an extended specialist vocabulary. They should also apply their mathematical knowledge to their understanding of science, including collecting, presenting and analysing data.*

- *'The social and economic implications of science are important but, generally, they are taught most appropriately within the wider school curriculum: teachers will wish to use different contexts to maximise their pupils' engagement with and motivation to study science*' (DfE, 2013:3).

In addition, *working scientifically* specifies the understanding of the nature, processes and methods of science for each year group and should be embedded within the content of biology, chemistry and physics, focusing on the key features of scientific enquiry, so that pupils learn to use a variety of approaches to answer relevant scientific questions.

These types of scientific enquiry should include:
- observing over time;
- pattern seeking;
- identifying,
- classifying and grouping;
- comparative and fair testing (controlled investigations); and
- researching using secondary sources.

'Pupils should seek answers to questions through collecting, analysing and presenting data' (DfE, 2013: 3).

Working scientifically will be developed further at Key Stages 3 and 4 (age 11-16), once pupils have built up sufficient understanding of science to engage meaningfully in more sophisticated discussion of experimental design and control (DfE, 2013: 4). Scientific process skills need to be developed, as they are the bedrock for children to be able to understand conceptual science, as well as engage in and enjoy science.

Engaging children in science education via enquiry – considerations…

The collaborative, social constructivist approach to teaching and learning science does much to motivate and engage students in learning science, and teachers who focus on teaching science via enquiry, including curiosity and creativity to promote scientific thinking and reasoning skills, are in fact *'equipping learners with lifelong skills'* (Ofsted, 2013). The social constructivist learning perspective is ideal to facilitate an environment of working scientifically (Skamp & Preston, 2015), this being:
- the active process where children make sense of the world around them by linking new conceptual knowledge to their existing frameworks (the act of constructing knowledge on the basis of taking into account what is already known), ensuring that ideas and concepts in science make sense to them; and
- a way to develop understanding via the notion of learning from the more knowledgeable other; where pupils work together to search for meaning, understanding and/or solutions (Vygotsky, 1978), which provide just the right amount of challenge for those taking part – thus learning through communication and interaction with others.

The changes made to the Primary Science National Curriculum (2013) in England and Wales now emphasise the *whole scientific process*, this being a shift from the sporadic, occasional use of enquiry – often epitomised by teacher-led instruction or indeed class work restricted to a series of formulaic instructions, which inhibit independence (Ofsted, 2013) – to *working scientifically* being the way in which primary-aged children learn scientific concepts (Smith, 2015).

In addition to this, the curriculum recognises that children need to understand science as an 'ongoing' process, where primary-aged children are encouraged to understand that scientific ideas change and develop over time and see themselves as scientists in the classroom: '*the best teachers of science look for ways to enable their learners as scientists!*' (Cross & Board, 2014:17), rather than disconnected from '*real life*' science.

Therefore, primary science needs to be embedded in issues that are meaningful to children and taught using pedagogies that engage children, as clearly highlighted by Bilton, Bento and Dias (2017) in their engaging book, '*Taking the First Steps Outside – Under Threes Learning and Developing in the Natural Environment*'. Primary science needs to be valued and taught regularly – the last point is particularly important; children cannot be expected to develop their process skills or conceptual understanding if science is not embedded in the curriculum and visited regularly.

Ofsted (2013) recognises that the most effective science teachers make it a priority to '*first maintain curiosity*' (Ofsted, 2013:4) in their pupils and, if this is adopted as a key principle in the teaching of science *via working scientifically* (via enquiry), then this will be fruitful in a number of ways:

- it will foster an enthusiasm and love for science whilst also promote the notion of scholarship in the National Curriculum – this is the idea that teachers should be fostering a love of lifelong learning;

- it will combat the stereotypical image of a scientist, which more often than not still, even today, predominantly involves a white man, in a lab coat, working alone in a laboratory strictly following the rules of an inflexible scientific method until he makes a discovery – no collaboration, no communication and no diversity. At some point in history, science has largely been the domain of white males, but this is no longer the case and children need to understand that diversity is not only now the norm, but also facilitates specialisation – the notion that different scientists who specialise in different areas within a field can indeed tackle the same topic from different angles, resulting in a deeper understanding of the topic. This is important for children in the primary school to understand if we want them *to see themselves as future innovators and scientists* and if we want them to make links between science and other areas of the curriculum, e.g. maths or music; taking an in-depth, relational view of science, rather than understanding scientific concepts in an isolated or procedural way; and

- it will challenge '*the entrenched viewpoints which depict science as boring or just too difficult*' (CBI, 2015:3), so that some primary-aged children are not switched off from science by the age of 11, thereby enabling pupils to fulfill their potential.

Possible barriers to engagement in enquiry in primary science

For some primary-aged children, barriers to learning and enjoying science can sometimes lie with the classroom teacher and his/her [lack of] teaching pedagogies (Sharp *et al*, 2011), as well as the learning environment. For some children, the learning of conceptual science is a challenge – the scientific vocabulary, counter-intuitive concepts, abstract concepts, scientific misconceptions that have already formed, the overuse of worksheets, use of disengaging teaching strategies or learning facts, do nothing to engage children in science learning (Allen, 2014; Loxley *et al*, 2014).

Perception of risk – risk is a necessary and importance part of science education; we cannot wrap up our children in cotton wool! Children need to learn how to assess risk when working scientifically, recognising aspects that are both positive (engaging with risk encourages children to be adventurous, brave and innovative, whilst developing decision-making and thinking skills) and negative – risking the possibility of failure, accidents or injury (Sandseter, 2010; Bilton, Bento & Dias, 2017). Risk avoidance, underpinned by a culture of fear by some teachers concerning the safety of children, does nothing to enable children to learn to work safely whilst working scientifically; teachers should be supported in this by being given continuing professional development (CPD) on planning for risk in science lessons.

Teachers' Pedagogical Content Knowledge [PCK] (Shulman, 1986; 2015) is also important; the inexperienced or ineffectual teacher can focus too much on children having '*fun via exploration*' rather than take pedagogical approaches that promote understanding in science lessons. Of course, enjoying lessons is integral to engaging children in scientific learning – exploration and enquiry are crucial in developing process skills for children to construct their understanding of conceptual science. However, without a focus on scientific concepts, then the outcomes of enquiry will be just that – *fun*, without children progressing in their conceptual understanding of science. Sometimes during enquiry lessons, teachers can miss the opportunity to make explicit links between scientific concepts and the enquiry undertaken. This can happen for a variety of reasons, including time management issues; constraints in timetabling and resources; and a lack of pedagogical scientific content knowledge (Abrahams & Reiss, 2014).

It is argued that the status of primary science as a core subject has been eroded. This is not difficult to agree with when, on average, primary school children receive 5 hours of English and maths teaching per week in comparison to (at the most) 2 hours of science (Wellcome Trust, 2016). Cridland (2015) maintained that over half the teachers surveyed in the *Tomorrow's World* report [CBI] stated that they believed that the teaching of science in primary schools has become less of a priority. There are immense pressures on primary teachers to ensure that children perform in English and maths, as these are not only regularly monitored during 'Pupil Progress Meetings' and published in school league tables, but also inextricably linked to a class teacher's performance management! All of this, coupled with a lack of confidence for some primary teachers in subject knowledge of some areas of the science curriculum (Peacock & Sharp, 2014), as well as a shift in assessment procedures in primary schools (Roden & Ward, 2014), goes some way to account for scientific concepts not always being taught and assessed effectively in primary science lessons.

Resources – teachers who want to teach science via enquiry often find themselves very quickly challenged by the lack of resources available in schools to teach science effectively. The NFER Teacher Voice Survey (Wellcome Trust, 2016) found that, for the 805 primary teachers and leaders who took part in the survey from 740 different schools, the most important barrier to teaching or leading science was the lack of budget and resources. Recently I was invited to take part in a Science Week at an inner London primary school, where the children were incredibly excited about their week ahead; however, the frustrations of some teachers were clear when one teacher confessed that, during an investigation, measuring jugs were needed to measure the growth of yeast, but the school did not have one measuring jug – anywhere – across the school.

Therefore, Senior Management Teams (SLT) should provide the resources (money, physical resources) necessary for teachers to provide high quality science education; SLT should also make provision for effective CPD to support teachers' knowledge, understanding and skills in science so that they teach and assess the correct conceptual science to *all pupils* via enquiry, including providing for the more academically able pupils (Wellcome, 2014; CBI, 2015). CPD needs to ensure that teachers are clear on scientific misconceptions, how to identify and reconstruct them (effective pedagogical approaches), both in their own subject knowledge and that of the children they teach (Allen, 2014), which should improve teachers' confidence in teaching science effectively.

Ultimately: teachers, school leaders and governors need to be clear on the *aims of primary science education and what is achievable*; high expectations of outcomes in science education for *all* children in primary schools is not simply an expectation from the government, but what each and every child *deserves!*

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Teachers' perceptions of Inquiry-Based Science Education (IBSE) and the implications for gender equality in science education

• Tamjid Mujtaba • Sue Dale Tunnicliffe • Richard Sheldrake

Abstract

This paper explores the perceived effectiveness of teacher training covering inquiry-based science learning for primary school children in England. Teachers who initially took part in teacher training between 2011 and 2013 as part of the FP7 project Pri-Sci-Net were interviewed during spring and summer term 2014; teachers were asked to reflect on their students' reactions and engagement. Teachers' responses were thematically analysed, and the implications are discussed within the context of longer-term implications of primary science education on girls' attitudes and aspirations in science across their subsequent education.

Keywords: Gender, interviews, inquiry, professional development

Introduction

In England and in many other countries, there is a need for more students to study science in order to foster higher scientific and mathematical skills and to accordingly increase both individual and national prosperity (British Academy, 2015; OECD, 2015b). However, concerns remain over the relatively low numbers of students studying science subjects in further and higher education, and the low representation of girls studying science (Institute of Physics, 2014; Murphy & Whitelegg, 2006; Royal Society, 2006, 2011). Teachers have an important influence on students' engagement with science and their future choices: teachers can provide direct advice and support, show enthusiasm and help to foster the interest and engagement of students, and develop students' skills and experiences through various teaching and learning approaches (Murphy & Whitelegg, 2006; Reiss, 2004).

Attention has recently focused on primary school teaching to ensure that students' initial encounters with science can ideally be positive (CBI, 2015; Ofsted, 2013; Wellcome Trust, 2014). Fostering initial and continuing interest in science remains important, especially as declining attitudes towards science as students grow older have been considered a major cause of the low numbers of students studying science later in their careers, especially girls (Archer *et al*, 2010; DeWitt & Archer, 2015; DeWitt, Archer & Osborne, 2014; Murphy & Beggs, 2003; Murphy & Whitelegg, 2006; Royal Society, 2010, 2011).

Primary school students in England generally enjoy science, but have not necessarily seen themselves as becoming scientists; these students have perceived school science as less exciting than their ideas of 'real science', for example, and girls have had lower identification with some areas of science than boys (Archer *et al*, 2010). Similar results have been observed in other countries, where primary school students have enjoyed science and believed that they were good at it, although girls have expressed lower views than boys (Denessen, Vos, Hasselman & Louws, 2015). In another study outside of England, boys and girls have expressed similar attitudes towards a range of areas associated with science and everyday life, although slightly more boys than girls agreed that people need to be 'clever' to do science (Kirikkaya, 2011). While primary school students have considered science to involve investigation and recognise its benefit to society, they have not necessarily wanted to become scientists (Archer *et al*, 2010; Silver & Rushton, 2008). While they have enjoyed the practical and collaborative areas of science, their attitudes towards science and technology have been seen to decrease over time, and girls' enthusiasm for science has declined more than that of boys (Jarvis & Pell, 2002).

Teachers' attitudes and enthusiasm towards science have associated with primary school students' enjoyment in learning science, where female teachers' attitudes especially associate with those of girls (Denessen, Vos, Hasselman & Louws, 2015). In primary schools, teaching practices may variously facilitate girls to engage or disengage with science through implicit gender dynamics, for example where girls may begin to defer to boys and take less initiative in investigations. Working together in single sex groups, or offering students the freedom to choose how they work, has been seen to help avoid such issues (Cervoni & Ivinson, 2011). Variation across primary school students has nevertheless been seen, with some girls exhibiting strong involvement, confidence and assertion (Cervoni & Ivinson, 2011).

Wider research indicates how important it is for teachers to present science in a way that engages girls and encourages their learning and development. Students with a high interest in their science lessons were more likely to want to continue with non-compulsory physics, and having the opportunity to engage in more hands-on learning was positively associated with secondary school girls wanting to study non-compulsory physics (Mujtaba & Reiss, 2013). Problematically, compared to boys, girls reported: fewer opportunities to explore, discuss, and test their ideas in class; lower perceived support from teachers in helping them to learn physics; and lower levels of looking forward to and enjoying their physics classes. Girls were also less confident about their ability in physics tests (Mujtaba & Reiss, 2013). Interviews with girls across primary and secondary schools have nevertheless highlighted that girls of all ages were positive about their school science experiences, with the older girls mentioning physical and biological areas as among their favourites, and preferring problem-solving and hands-on activities; however, teachers were often blamed for when science was perceived as boring or irrelevant (Baker & Leary, 1995).

Overall, a large body of research explores students' attitudes and perceptions of science, often relying on quantitative surveys of secondary school students, although some also consider primary school students (DeWitt & Archer, 2015; DeWitt, Archer & Osborne, 2014; Mujtaba & Reiss, 2013). While these methods are extremely helpful in exploring the relative importance of different aspects of students' attitudes to science, more research is needed in order to determine what facilitates students' engagement with science at primary school level, especially for girls, and the impact of different teaching approaches, such as inquiry-based learning.

Within England and across Europe, the importance of practical work in science has been highlighted at primary and secondary levels, including through applying inquiry-based approaches of learning to help foster interest in science (Braund & Driver, 2005; European Commission, 2007; Ofsted, 2013; Osborne & Dillon, 2008). Inquiry-based learning of science broadly includes more focus on observation and experimentation, *facilitated* by teachers rather than purely focusing on the dissemination of knowledge *by* teachers, and on where students can identify and solve problems (European Commission, 2007; van Uum, Verhoeff & Peeters, 2016). Essentially, on a conceptual level, inquiry-based learning may involve students applying a scientific method or approach during their studies. Inquiry-based learning has indeed been associated with improved learning when reviewed across multiple studies (Furtak, Seidel, Iverson & Briggs, 2012; Minner, Levy & Century, 2010). In a practical context, for example, Thornton and Brunton (2010) have advocated that practitioners make use of the Reggio approach to improve students' learning at school; this approach is synonymous with inquiry-based education and suggests that pupils' creativity should also be supported through the learning environment. Within inquiry-based learning, research skills and student-centred learning are considered to be fundamental to developing pupils' self-reliance, independence and the ability to identify, investigate and solve problems. Through these approaches, children can actively construct their knowledge through practical activities scaffolded by teachers asking questions (Chin, 2006) and by facilitating open-ended discussions (Duggan & Gott, 2002). Given these various benefits, further research is still useful when considering the impact of inquiry-based learning on other areas such as students' interest and engagement with science, especially at primary school.

In order to increase the number of people proficient in the sciences and to encourage more girls to pursue science in post-compulsory education, students' knowledge, skills and enthusiasm for science should be encouraged in the early years and primary education. In primary schools, teachers' approaches can link with students' interests and daily lives, and involve group work, often via hands-on and problem-solving approaches, although time for student-led inquiry has often been limited in the primary school years compared to pre-school education (Cremin, Glauert, Craft, Compton & Stylianidou, 2015). Specifically, an implementation of inquiry-science in primary schools in Northern Ireland increased students' engagement through their interest and enjoyment of the classes, and also increased their confidence and communication (Dunlop, Compton, Clarke & McKelvey-Martin, 2015). Similarly, in Ireland, primary school students' engagement with and attitudes towards learning science have been increased by hands-on and inquiry-based approaches (Smith, 2015).

In England, another study involved primary school teachers being trained in developing and applying open-ended science investigations for their students (Jarvis & Pell, 2002). Following the program, primary school girls expressed higher enthusiasm for independent investigative science (and were then more enthusiastic than boys), while boys expressed relatively unchanged enthusiasm (Jarvis & Pell, 2002). The training was essentially able to facilitate the enthusiasm of girls. Inquiry-based learning has also led to increases in primary school students asking questions (Gillies, Nichols, Burgh & Haynes, 2014). The wider processes within their discussions, involving the students' inquiries, representations of their ideas, and explanations for their reasoning, were considered to be important for learning and understanding science (Gillies, Nichols, Burgh & Haynes, 2014). Nevertheless, teachers' engagement in continuing professional development (CPD) does not necessarily require extensive changes in the delivery of science, and management of change is often difficult and slow (Spooner & Tunnicliffe, 1991).

Within this context, this article has two roles. Firstly, it outlines an implementation of inquiry-based training for teachers and the impact that teachers felt this training had on their classrooms at Key Stage 1 (Years 1-2, ages 5/6 to 6/7). Secondly, the findings are related to broader issues in science education, primarily whether a change in teachers' pedagogy can have a positive impact on students' attitudes to science and, more specifically and in the longer term, to girls' engagement with science. Within the context of primary education in England, it is useful to remember that at Key Stage 1 as well as at Key Stage 2 (ages 7/8 to 10/11), there are no compulsory teaching times set, although there is guidance available about the number of hours that teachers need to spend on each subject. Science is allocated approximately 7% of total teaching time at Key Stage 1, and 9% at Key Stage 2, while maths is allocated around 18% percent at both Key Stages, and English is allocated 24-36% at Key Stage 1 and 21-32% at Key Stage 2 (TES, 2016; QCA, 2002).

Methods

The training

The training referred to in this paper makes up part of the FP7 Pri-Sci-Net project funded by the European Commission. As part of the project, inquiry-based science learning tools were developed by a group of international science educators for use within primary schools. The activities were initially developed, selected and then were trialled for their adaptability. Comments from the trial were reported back to all European partners; for example, teachers in England highlighted preferences for clear activities for specific topics that could be applied within one session. The project partners then collectively worked on improving the trialled activities to be used within the main part of the project involving the training of teachers. Subsequently, the final activities that were used by teachers in England were those that best fitted their work plan at the time. Teachers did not wish to have data collection methods and valuation guidance, instead preferring to put together activities for lessons in accordance with their relevant needs or policies, such as concepts to convey, cross-curricular theses, assessment requirements and their schools' contexts. An example of one of the activities is given in Appendix 1.

Training within Pri-Sci-Net was developed for science teachers, covering the potential benefits of the methods and how they can be applied to their teaching. Training also involved encouraging teachers to use everyday classroom materials to demonstrate investigations and then foster student-led learning; the training essentially showed the teachers how to encourage students to think and do science. Information was disseminated throughout the primary science network to which we had access at the University, and groups of teachers in England were invited to attend a free training workshop, either in a local school or in the science department of a large university. Training in England was limited to one day, given that there were no funds for supply teacher cover. Similar events were also undertaken in other European partner countries, although, for increased contextualisation, the following results only consider teachers in England. The majority of the training sessions were provided in the summer terms between 2011 and 2013.

Forty teachers who had attended a training session were subsequently contacted to establish whether and how the training session had influenced their thinking and practice. Organising contact and gathering teachers' views was difficult, given the other demands on their time. Methods were adapted to maximise accessibility and accommodate teachers' other commitments: five teachers took part in recorded telephone interviews; ten teachers allowed notes to be taken in non-recorded conversations; and three teachers responded via online interview questions. Teachers' views were gathered between the spring and summer terms of 2014.

The teachers were from London and the south east of England. We asked teachers eight core questions:

Results

The responses were analysed by (thematic) content analysis (Cohen, Manion & Morrison, 2007): teachers' responses were read and initial themes were identified, consolidated and/or refined; responses were then re-read and coded against the final themes. The following themes emerged across the teachers' discussions of the effectiveness of the science inquiry-based learning activities: intrinsic motivation (interest); replicability; children's engagement; the relevance to curriculum; and support. Many of the teachers spoke about being interested or intrinsically motivated to try out the activities in their classrooms after having attended the training sessions. Teachers who had used the inquiry-based activities had done so because they felt that the activities were both replicable and relevant to the learning goals of England's science curriculum as set by the National Curriculum (Department for Education, 2013). All the teachers who tried out the activities within the classroom spoke about how engaged their students were, and believed that the activities were an engaging way for children to learn about scientific concepts. However, there were some problems with trying out (and possibly implementing) inquiry-based activities in the classroom: the reported barriers largely concerned the availability of school resources and senior management teams not allowing teachers the independence to decide what was the most appropriate way to teach science within their classrooms. It is interesting that teachers felt that there were barriers to the teaching of science and that they had not raised

THE INTERVIEW SCHEDULE

- Do you enjoy teaching science?
- Have you ever used Inquiry-Based Science techniques prior to the training given by the trainer?
- How easy or difficult did you find learning Inquiry-Based Science techniques as demonstrated to you by the trainer?
- Did you apply the techniques learned at the training day to your classroom?
- How did the children react to your Inquiry-Based Science lessons?
- Was the children's engagement with science any different to the way children reacted to traditional teaching methods?
- Research suggests that girls are less engaged with science lessons than boys. Did you notice any difference in girls' engagement with the Inquiry-Based Science lessons as compared to the use of more traditional methods?
- Were girls more engaged, less engaged, or was there no difference?

such issues for other subjects; this may be a generic issue within all primary schools in England, where limited time is allocated to science, particularly compared to English and mathematics.

Intrinsic motivation for teaching science

In total, almost all the teachers (94%, or 17 of 18) indicated that they enjoyed teaching science; this result was unsurprising as we had expected most people to enjoy their profession. This question was asked irrespective of what they thought about inquiry-based science techniques; there was no indication that those who did not enjoy their teaching were less engaged with learning new ways to teach their students (although, with the low number of teachers who expressed that they did not enjoy their work, this was not necessarily definitive).

We asked teachers to elaborate on why they enjoyed primary science teaching, and their responses resolved into core themes, specifically: wanting to make a difference, and enjoying science. As an illustrative quotation, one of the teachers stated: *'I have always wanted to be a teacher, nothing is more rewarding than knowing that, by the end of the year, before the children move on, they are armed with new skills and knowledge all down to my input…every once in a while I feel I have really made a difference, not so much in science but in the attitudes of young people… sometimes you know it's not about reaching key stage levels, its knowing that a kid wasn't interested in school and I made them interested'.*

Experience of inquiry-based science education

Teachers were asked if they had used inquiry-based science techniques previously. In total, a third of the sample (six teachers) reported having used such techniques before in various forms, while two thirds of the sample had not. It is possible, however, that teachers had various interpretations of inquiry-based learning; for example, working scientifically (as covered within the National Curriculum), or practical work in general, might be interpreted as inherently involving some degree of inquiry, while others might only consider inquiry-based learning as applying specific approaches, exercises or tools.

It was also important to establish how easy it was for teachers to understand how to teach inquiry-based science techniques. Reassuringly, a large majority of teachers (78%) felt that they were able to replicate what they had learnt in the workshops. It was possible that the limited provision of training (covering only one day) was relevant as a potential limiting factor. Some teachers cited that their students, rather than their knowledge of approaches, could be a limiting or deciding factor. For example, one teacher highlighted that: *'I don't think I will be able to easily replicate these findings; for one, I'd have to have faith in my students that they would be able to independently look for interactions between different parts of the investigation, I have trouble getting them to sit still and focus, let alone encourage them to lead their own investigations…is there a course on getting students to sit still?!'.*

In response to being explicitly asked *'Did you apply the techniques learned at the training day to your classroom?'*, around half the teachers reported that they had indeed applied aspects of the training. The training they applied were simple examples of how to use everyday materials found in classrooms for science lessons and apply them to inquiry-based science lessons (see Appendix 1 for an example), where students were directly involved in and directed their investigations and learning. Whilst the subject matter and teaching accessories/ equipment may have been the same as in traditional lessons, it was the way that the lesson was delivered that was the key difference. However, there were indications that lasting changes could perhaps be less clear, and potentially limited by the teachers' contexts. As an exemplar, one teacher responded that: *'Hey yes, of course! I left the course feeling really enthusiastic about teaching science in this way and even created my own version of an inquiry-based approach. However, it was simply an experiment on my part, kind of fun to see how receptive my class would be but, to kind of use it in a long term way, I would need support, learning materials, time to learn and the Head would have to be on board…a whole can of worms is opened when you want to go about changing things…there's the parents, could I teach something different than the way others are teaching without informing parents? I think the school would have to have a unified approach to the way lessons are taught. That doesn't mean I won't use these techniques and I intend on using them again, but for now I don't think I can adopt the approach as a bog-standard way of teaching'.*

Children's reactions to inquiry-based methods

Almost all teachers (94%, or 17 out of 18) reported that, when they implemented the inquiry-based lessons, their students appeared to be engaged with such teaching methods. The majority (61%, or 11 out of 18) reported that their students appeared to be more engaged with inquiry-based lessons compared to their usual teaching techniques. Caution needs to be applied as to what extent a few lessons had on student progress in science over a longer-term period; it was not possible to assess this within the limits of this research. Even so, the result is still encouraging, given the context that teachers were only provided with one day of training and had no further support in implementing inquiry-based learning. As an illustrative quotation, one teacher highlighted that: *'I was quite surprised to find [that one particular student] showed leadership skills in a positive way! Usually he is quite disruptive but, for once, rather than play the clown he led the group into thinking about cause and effect and even helped another group of students repeat the experiment. It is too early to say whether such teaching would have a profound effect on students, their learning and grasp of science, but what I can say is my class certainly were more involved and interested in the lesson than is the case generally…but then students are always more excited about practical experiments…who knows, it went well though'.* Another teacher remarked how she had not expected one of her female students to be so interested in science: *'Usually [the student] is quite good at getting her homework done and answering questions about anything other than science. I always thought she wasn't that interested actually. And then I repeat one of the activities I picked up off the Internet, following on from the workshop I decided to look things up online, and guess what, [she] was really interested in taking the lead. I paired the class up in no particular order and she was working with [a boy], but it was [she] who was, remarkably, leading their little investigation'.*

Girls' science engagement

The interviews involved highlighting that research suggests that girls are less engaged with science lessons than boys, and asked teachers to think about such issues within their own settings; teachers were then asked if they had noticed any difference in girls' engagement with the inquiry-based lessons compared to the use of more traditional methods (as being more engaged, less engaged, or with no difference having occurred). Half the teachers (50%) reported that girls within their inquiry-based science lessons were more engaged with the teaching as compared to using different teaching styles. As one teacher said: *'Actually I found that girls were more engaged in science, whether this was because we were doing an investigation or whether this was because I expected them to think for themselves, I don't know. What I can tell you is that if you want more girls to engage with science you do need to actively engage them with science – boys seem to take over sometimes and we as teachers can forget that the quiet ones in science are probably that way because of confidence'.*

Some teachers (22%) nevertheless considered that girls were less engaged with science using such approaches, whilst others (28%) reported that no difference in girls' engagement was apparent. It was possible that teachers were not always or easily able to determine their students' engagement, and preconceptions or prior experiences may have sometimes been relevant. As an example, one teacher commented that: *'Aren't girls at this age less interested in science because they prefer to be playing with other girls, are less hands-on than boys? [The teacher was then asked what she meant by "less hands-on"]…boys like breaking things and fixing things, at this age girls just want to draw pretty pictures. [The teacher was then asked if she was sure the inquiry-based lessons had no impact]…well, yes, I suppose girls did try and get more involved in the task'.*

Discussion

The responses from primary school teachers highlighted that inquiry-based learning was perceived to be easy to learn and apply; teachers perceived that their students reacted positively and, in half the cases considered, teachers believed that inquiry-based learning facilitated engagement from girls within their classes. Nevertheless, the sample was very small, students' views were not included, and teachers received only one day of training; more extensive training, undertaken over longer periods, is usually recommended in order to achieve lasting changes (European Commission, 2007; Osborne & Dillon, 2008). The responses from teachers highlighted that some indeed believed that further support would be necessary; this coheres with earlier research, which highlighted that inquiry-based learning relies on skills and knowledge from teachers and also from students in order to direct their own learning, requiring support for both teachers and students (Yoon, Joung & Kim, 2012).

In addition, the results highlighted that inquiry-based learning could potentially facilitate engagement between girls and science. Prior research has highlighted that girls often reported lower confidence than boys (OECD, 2015a), and it is possible that inquiry-based learning can help avoid confidence issues and similar factors becoming barriers to engagement, given the comments from teachers. Similarly, inquiry-based learning, through practically considering research questions and experimentation, may be perceived as more reflective of 'real science' by students. In prior research in England, primary school students have perceived differences between 'real science' and 'school science', which may potentially start a longer-term process of disenchantment or disengagement (Archer *et al*, 2010); similarly, research with students in the United States has highlighted that girls strive to make a connection to science and are able to see the relevance of science in their everyday lives, but are largely unable to come across such understandings in their science lessons (Buck, 2002). Girls do not always have positive perceptions of science and scientists, and have sometimes perceived that the work of a scientist has little relevance for social problems, and that scientists are isolated with little time for a social life (Miller, Slawinski Blessing & Schwartz, 2006). Engaging girls with science at primary school may help to diminish negative perceptions or stereotypes about scientists and about science itself.

Some comments from the teachers highlighted that it remains important to be mindful of and self-reflective about potential preconceptions about what students could or should do, and what students may or may not be interested in; for example, interest may not always be immediately apparent. Teachers can help foster students' own interest and engagement (Murphy & Whitelegg, 2006; Reiss, 2004), but parents and teachers may sometimes encourage boys' interest in science more than girls' interest (Jones & Wheatley, 1990), and teachers and their approaches can partially determine how science is perceived (Baker & Leary, 1995). Gender stereotypes or preconceptions may inadvertently ensure that gender differences and under-representation persists throughout science education (Institute of Physics, 2013, 2015). Research has suggested that some teachers do not encourage girls to try and understand science concepts to fit in with their own needs and understanding of the scientific world around them, and that traditional teaching approaches themselves do not necessarily help address such areas (Buck, 2002); girls often have to adapt to existing structures or preconceptions already in place within science education (Carlone & Johnson, 2007). Inquiry-based learning does not seek to push children to fit within a structure, but to use their own knowledge and skills to explore science and understand it using approaches with which they are comfortable, which may facilitate engagement and personal identification with science.

Our work has implications for teaching at Key Stage 1. Primary school students have associated 'doing science' and 'acting like a scientist' with hands-on activities and practical work, and have distinguished science in school from real science (Zhai, Jocz & Tan, 2014). In primary schools in England, differences between perceptions of science, scientists and students' perceptions of themselves have been considered relevant for girls who did not hold aspirations towards science: for example, notions of 'femininity' may be perceived to contrast with notions of 'being a scientist' in the sense of a career (Archer *et al*, 2013). Again in primary schools in England, students in Year 2 (age 6/7) have enjoyed science lessons and expressed a good understanding of what scientists do and how to be a scientist; students' attitudes appeared to have developed from books, visits to doctors/dentists, television and their parents' jobs, and notions that scientists are 'clever' (Turner & Ireson, 2010). By Year 6 (age 10/11), students were still positive about science and enjoyed science lessons, but expressed that they generally did not undertake science activities in leisure time and were not necessarily interested in science careers (Turner & Ireson, 2010). This decline in science interest could be addressed with classrooms adopting more student-led approaches to learning, for example, as our teachers had applied by implementing inquiry-based approaches. This also appeared to increase girls' confidence and engagement, according to our teacher interviews. However, the longer-term benefits of this approach need further investigation; we cannot conclude whether students' engagement and aspirations in science would continue.

On a wider level, the field of social psychology indicates that, when teachers teach students to set themselves goals, this has a positive impact on enhancing their cognitive efficacy, academic achievement and intrinsic interest in subjects (Bandura & Schunk, 1981; Schunk, 1989). Inquiry-based learning in science aims to achieve all these outcomes, although more research, including views from students, is required into the short-term and long-term effects of using a different way to teach science and taking part in more hands-on science activities.

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Appendix 1

IBSE TEACHER TRAINING ACTIVITY DESCRIPTION

Age range: 6-8 years

Title of activity: Magnetic force

Objective:
1. To investigate the strength of magnets.
2. To support pupils' measuring skills and observation techniques.

Equipment:
Everyday objects, both magnetic and not magnetic, a variety of magnets, ruler and worksheets.

Process:
1. Working in small groups, the pupils test a wide variety of objects for magnetic properties.
2. Within the groups, allocate roles – observers, recorders, planners.
3. Record their findings on the table – pupils can write or draw their observations.
4. Ask pupils to test their magnets – which is the stronger?
5. How will they do this? Pose the question and give time to investigate.
6. Record findings on the table.
7. How can we measure the strength?

Outcomes:
What have we learnt?
How might this be used in 'real life'?
What differences were there in the strengths of the magnets?

What do children think is inside a crab?

● Amauri B. Bartoszeck ● Sue Dale Tunnicliffe

Abstract

Children start learning about their internal anatomy from an early age, as they experience direct manifestations of some of it. They then tend to use themselves as a template for predicting the anatomy of other living organisms. The study of invertebrates is a very neglected area in pre-school and early primary school curricula. However, we believe that children from Southern Brazil nonetheless have a basic utilitarian knowledge of the internal anatomy of the crab, because crabmeat is a familiar part of their diet. In this study, a total of 433 children, 193 aged 5; 67 aged 10; and 173 aged 12, from 4 schools (3 public and 1 private) in an urban area of Southern Brazil, were asked to draw what they think is inside a mangrove swamp Brazilian crab. Analysis of the drawings of the children revealed a range of results illustrating what different age groups recognised as organs within the crab, although few drawings actually depicted organ systems.

The study showed that children have a poor understanding of the internal organs, and organ systems, of crabs, sometimes using their mammalian understanding of life functions, (e.g. 'lung' instead of 'gills', 'dog-bone' shapes to represent bones) as a template for explaining their understanding. The heart and brain were the organs most represented by both genders in all the participating age ranges. The digestive and respiratory organ systems were only represented in the drawings of the 12 year-old pupils.

Keywords: Crab, internal organs, drawings, children

Introduction

The process of developing scientific literacy, together with the literacy skills of writing and reading, is a complex one for most early years pupils. One aspect of scientific literacy is to achieve a basic understanding of biological forms and the function of organisms with respect to the environment. As children are part of the biological domain, and experience living aspects in the environment directly, such as breathing and eating, they tend to use their personal understanding when examining other biological forms. This is unlike the way children relate to the physical domain, to which they are extraneous.

There are many ways of gathering information about students' understandings of scientific phenomena. However, despite the richness and variety of the methods used by science educators, most of these methods tend to rely on students either talking or writing about science. Such methods include oral interviewing of students, gathering their written responses, recording their spontaneous conversations and encouraging them to construct written concept maps. As Cox (1992) wrote, a child´s drawing is a way in which s/he may choose to represent his/her inner mind representation of reality. Mental models are representations of information and experiences that the child may have from the outside world (Rapp, 2007). A mental model is a graphic representation of an object or events formed by the mental activity of a child or adult. The process of forming and constructing models is a mental activity of an individual or group (Duit & Glynn, 1996). A mental model is the person's personal knowledge of the phenomenon – in the case of this article, a specific animal species, and will have similarities to and differences from the scientifically accepted knowledge, which in this case includes the taxonomic position of the animal, its significant morphological features, etc.

Living organisms have an important place in children's lives. Children learn about animals and plants from their earliest moments. When children deal with living organisms, they experience countless opportunities for understanding the natural world around them; for instance, how invertebrates differ in form, how animals adapt to habitats, and this contributes to their science learning (Abramson, 1990; Tunnicliffe, 2013; Bartoszeck *et al*, 2014).

Children come to their biology education experience with existing mental models of living things encountered in their formal studies in school, outside of school, at home, or elsewhere during leisure activities. Such mental models may be viewed as representations of an object or an event.

The body forms of invertebrates are relatively unfamiliar to young children, compared to the more familiar shapes of vertebrates, which can be mapped more easily in comparison to a child's own body. Furthermore, children often express distaste when faced with invertebrates (possibly because of the unfamiliarity of their external morphology and behaviour, especially when compared to human beings). Even so, some invertebrates do attract the curiosity of some children (Kellert, 1993). Such experiences may contribute to further science understanding.

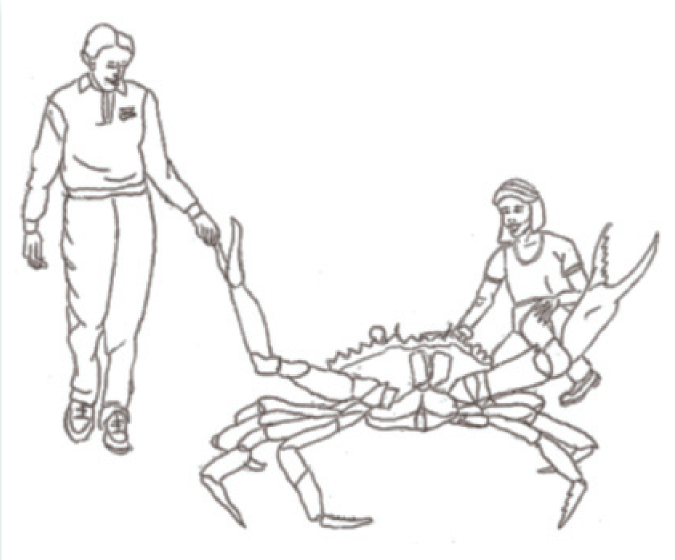
Research into children´s ideas about the internal organisation of organs and organ systems in vertebrates is more common (see Bartoszeck *et al*, 2011b). There is relatively little study on the understanding held by children of the internal anatomy of invertebrates, although there has been some research carried out on the analysis of drawings constructed by learners (Rybska *et al*, 2014; Tunnicliffe, 2015a). Through eliciting their mental models as expressed in drawings, we can learn something of the students' understanding.

Mental models manifested by means of drawings, i.e. the expressed model, can be a child´s fantasy, a child's exploration or an account of what is on his/her mind at that moment. Children's drawings are not intended to be photographs or exact reproductions, but are instead amateur illustrations representing objects and organisms belonging to the environment around them (Anning & Ring, 2004; Cox, 2005). Moreover, the interpretation of traditional drawings depends on the pupil's possession of visuospatial skills.

Occurrence of crabs

The subtropical Brazilian crab (*Neohelice granulata* Dana, 1851) lives in near-vertical tunnels in mangrove swamps, or among rocks near rivers and the coast. The crabs may be located in their burrows close to tree roots, and some climb onto tree branches growing in the swamps.

Figure 1: Artistic illustration of a crab presented in a children's picture book.



During January and February each year, low-income families work hard to collect this species of edible crab to sell to fishmongers and local restaurants as a source of income. Children living in towns away from the sea or lakeside beaches do not see crabs every day. However, when families buy fish at the market or from fishmongers, children have an opportunity to see these invertebrates, which are also used by restaurants, with shrimps and river crabs appearing in dishes such as Spanish paella. These children may also encounter crabs during summer vacations when their families rent beach houses at Paraná (Guaratuba) or Santa Catarina (Camboriú).

Children acquire a second-hand familiarity with organisms from seeing images in the media, video, TV and books. In Brazilian children's picture books (suggested reading to the age range of 3-4 to 10-12 year-olds) about the Brazilian crab, the narratives only mention activities that occur in the mangrove swamp in which the animal lives. Recent research stresses that children's learning, as well as a transfer of information to the real world, may occur when encountered in picture books, even for the youngest children (Bruguiére, 2015), although such images may give an unrealistic impression of the organism, for instance where the size of the animal is enlarged. Furthermore, such drawings only provide a view of the external morphology.

Drawings as a source of children's ideas

This investigation sought to examine how young children aged 5, 10 and 12 represent the internal anatomy of a Brazilian crab by means of a drawing.

In this study, the drawings are products of the child's imagination kept in his/her memory. There is a tendency for children to apply the knowledge they may have of the internal anatomy of their bodies and apply such informal knowledge to other organisms. Moreover, drawings, i.e. the expressed model, channel graphic information and communicate children's ideas or development of concepts, sometimes in alternative and confusing ways.

The research question of the study was:

What do Brazilian primary school children understand about the internal anatomy of crabs?

Methodology

This study sought to elicit the understanding of pupils aged 5 (n=193), 10 (n=67) and 12 (n=173) when representing the inside anatomy of a crab, from drawings made. Such knowledge was elicited though the drawings made by the children from their mental models and identified by them on their drawings, by labelling or having an adult annotate the drawings according to the child's direction. These data were collected during school time.

An exemplar of a subtropical crab (*Neohelice granulata* Dana, 1851), taxidermically prepared by a technician from the Department of Zoology, University of Paraná, was shown to pupils attending the kindergarten, and primary school 4th grade and 6th grade respectively. Study of the internal structures of a crab does not form part of the 5 year-olds' curriculum, as the focus is on external parts of the human body, the names of animals, everyday plants, or seasons of the year. This species of crab is mainly used in practical classes when teaching about crustacea in the last year of secondary school, when pupils are 15 years old, and also during undergraduate biology courses.

At the beginning of the session, the first researcher asked the class if they knew what a crab was, before showing the preserved specimen of a real crab (*caranguejo* in Portuguese). The children informed the researcher verbally and the number claiming that they knew was noted. Most said that they knew what a crab is and that they were familiar with the invertebrate, as families boil them in large pots during summer gatherings (in January and February) to eat the flesh inside the claws and legs, flavoured with tasty spices and enjoyed with cold beer.

Fieldwork was then carried out in southern Brazil, in the Paraná State capital, Curitiba, in 3 kindergartens (one private and the others state-funded) and a public primary school. Pupils in each age range were asked on separate occasions to draw, using a black pencil, what they thought was inside the crab when it was alive. Pupils were told to write their first names and age at the top of an A4 blank sheet of paper to allow for easy processing of data. The teacher wrote labels on the drawings for the 5 year-olds when requested, but only the exact words and in places as dictated and pointed out by the children. The fieldwork was conducted in whole class settings. Children were given 10-15 minutes to complete each drawing.

Ethics permission

Permission to conduct this study was provided by the headteachers and teachers in the participating schools. All data were collected subject to the full consent of parents and principals of all educational institutions involved. Consent forms were collected by the school co-ordinator and only the drawings by children whose consent forms had being signed by parents were included in this study.

Analysis of the drawings

The analysis involved used the basic rubric scale protocol devised by Tunnicliffe and Reiss (2001) for scoring drawings of the internal anatomy (although for vertebrates, adapted for invertebrates, in this case the crab) and used appropriately according to the class of animals, e.g. Tunnicliffe (2015), in which the researchers described stages of development of the understanding of organs and organ systems (see Tables 1 and 2). Each occurrence was coded with either a lower or upper case letter, indicating which organ was represented and the organ system at least once; for instance, 'digestive system d= for an organ'; or 'digestive system

D= tube from mouth to anus' (Reiss & Tunnicliffe, 2001). Exemplars of drawings and grades allocated are shown in Figures 2 to 6.

The researchers agreed on a definition of particular organs belonging to a system to complete the rubric scale below.

Table 1. Organ and organ system scoring rubric scale.

Level 1	No internal recognisable organs.
Level 2	One or more internal organs shown at random.
Level 3	One internal organ (e.g. heart) in appropriate position.
Level 4	Two or more internal organs (stomach, gills) in appropriate position but no extensive relationships indicated between them.
Level 5	One organ system indicated (e.g. gut connecting mouth to anus)
Level 6	Two or three major organ systems indicated (e.g. digestive, circulatory).
Level 7	Four or more organ systems indicated.

(Adapted from Reiss and Tunnicliffe, 2001).

Table 2. Organs belonging to an organ system.

Nervous system	Cerebroid ganglia, supraesophageal ganglion, circumesophageal ganglion, thoraxic ganglion, abdominal nerve, optic nerve, nerves
Digestive system	Cardiac stomach, hepatopancreas, middle (small) intestine, posterior (large) intestine, cecum, anus
Circulatory system	Heart, lateral right branch blood vessel, lateral left branch blood vessel
Muscular system	Muscles in the legs and claws
Excretory system	Bladder, kidney, vas deferens, excretory hole
Respiratory system	Branchial chamber, gills, openings to the outside
Reproductive system	Testis, deferens channel, ejaculator channel, penial papilae, ovary branches right and left, spermatecae

(Adapted from Felgenhauer, 1992).

Figure 2: A drawing by a 5 year-old boy, which scored as level 4 according to the grades in Table 1.

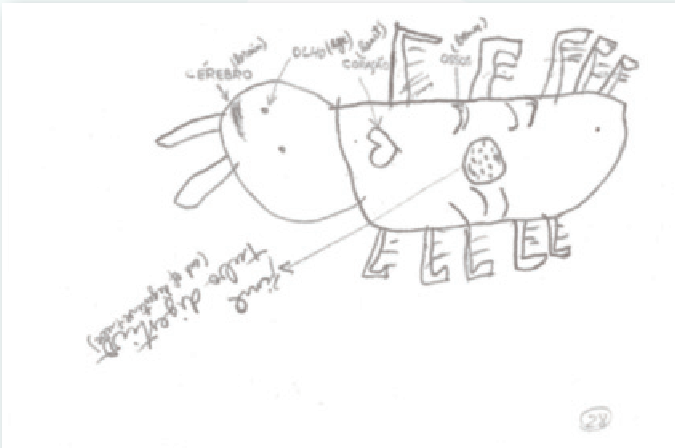


Figure 3: A drawing by a 5 year-old girl, which scored as level 4 according to the grades in Table 1.

Figure 4: A drawing by a 10 year-old boy, which scored as level 4 according to the grades in Table 1.

Figure 5: A drawing by a 10 year-old girl, which scored as level 5 according to the grades in Table 1.

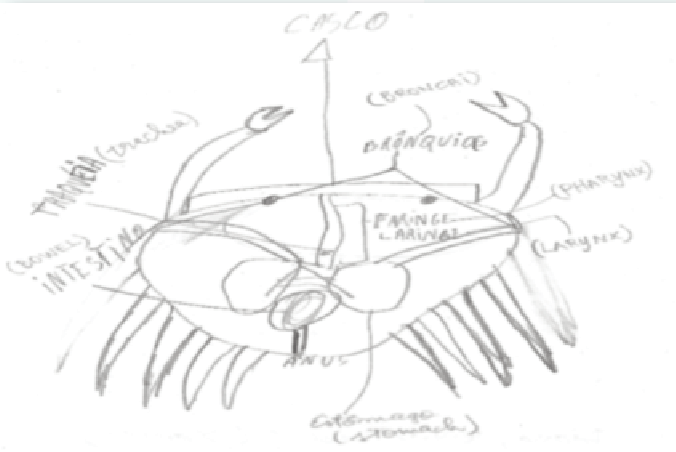
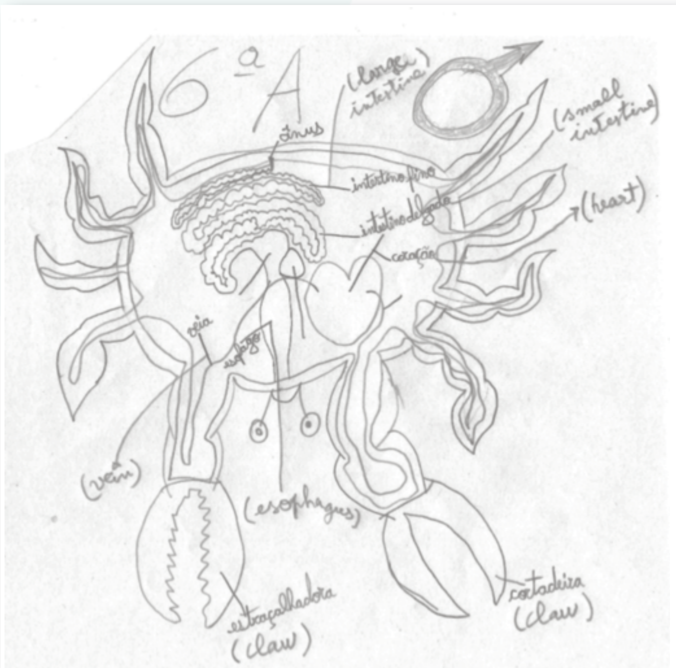


Figure 6: A drawing by a 12 year-old boy, which scored as level 5 according to the grades in Table 1.



Findings

The significance of the age of the pupils

The older children knew more of the internal organs of crabs and just a few pupils understood an organ system (see Tables 3 and 4). The most represented organ in the drawings for the 5-year age range was the heart (85% – about the same percentage for both genders), followed by the brain (35% – about the same percentage for both genders); the least represented were the kidney and bladder. A similar trend was identified for the 10 year-old pupils, who represented the heart (55% – about the same percentage for both genders) and the brain (43% – about the same percentage for both genders), whereas the 12 year-olds represented the heart (47% – about the same for both genders) and the gills (40% – for both genders). The respiratory system was the least represented in all the drawings (1%), while more students drew the digestive system (30%). Further analysis confirmed that older pupils attained higher levels than younger ones.

The data scores of 5 year-old children shown in Table 4 indicate that more girls than boys drew organs. The percentage of organs represented in the drawings by 5 year-olds varied. The least drawn was the kidney (1%, both genders) and the most common was the heart (83.0%). 20% drew the stomach and 32% drew the brain, in both cases with no specific gender difference.

The largest number of respondents' drawings scored at level 4 (see Table 1) and the second largest at level 2 ('one or more internal organs shown at random'). However, more girls in this age group knew something about internal organs inside a crab. Their knowledge about their own internal anatomy from their personal experience appears to have served as a guide to what they thought should be present. The girls, in fact, could identify an organ necessary for life functions.

The largest percentage of boys aged 10 years scored at level 4 (see Table 1), with the second largest group being at level 2.

The least drawn organ by the 10 year-olds was blood vessels (1.5%, both genders) while the most drawn were the heart (55%) and brain (43%), similar for both genders. The children also drew gills (29%) and lungs (20%), also represented equivalently by both genders.

Table 3: Table of knowledge of individual organs (levels defined in Table 1) for each year group and the total responses obtained.

	Age 5 n = 193	%	Age 10 n= 65	%	Age 12 n = 171	%	Total per organ n=429	%
Brain	67	35	28	43	48	33	143	33
Heart	159	82	36	55	81	47	276	64
Blood vessels	35	18	1	2	0	0	36	8
Spleen	0	0	0	0	2	1	2	1
Bowel (intestines)	0	0	11	17	28	16	39	9
Stomach	48	25	25	39	41	24	114	27
Lungs	19	0	13	20	18	11	50	12
Gills	0	0	19	29	57	33	76	18
Muscles	28	15	7	11	9	5	44	10
Bladder	5	6	4	6	3	2	12	3
Kidney	2	1	4	6	6	4	12	3
Liver	0	0	12	19	15	9	27	6

Table 4. Number and percentage of children drawing organs by gender and year group.

Gender Totals	Age 5 n = 193	% Age 5	Age 10 n = 67	% Age 10	Age 12 N=173	% Age 12
Boys (218) (50.%)	90	47	33	49	95	55
Girls (215) (50%)	103	53	34	51	78	45
Total	**193**	**100**	**67**	**100**	**173**	**100**

Table 5. Number and percentage of children drawing organ systems by gender and year group.

	Boys n=90	Girls N=103	Boys N =33	Girls N=34	Boys N=95	Girls N=78
Digestive system	0.0	0.0	0.0	0.0	7 (4.09%)	35(20.47%)
Respiratory system	0.0	0.0	0.0	0.0	0.0	2/ 1.17%
Urogenital system	0.0	0.0	0.0	0.0	0,0	4/2.34%

The data from the drawings of the 12 year-old age range show that the least represented organs were the respiratory and urogenital systems, spleen and bladder (range of 1.1% to 2.3%), and the most represented were the heart (47.5%), gills (23.4%) and brain (26.0%), almost equally across both genders. The kidney, muscle, liver, lung, bowel, stomach and digestive system were represented in the range of 3.5% to 28.0%, almost equivalently by both genders.

The levels attained by the children across age and gender showed a modest growth in mean level across both age and gender, with the one

Table 6. Mean levels attained by children across gender and age.

Age	Boys		Girls	
	Mean	N	Mean	N
5	2.84	91	2.69	103
10	3.18	33	2.75	34
12	3.04	95	3.18	78
N total		219		215

exception of 10 year-old boys who were at a higher level than the 12 year-old boys.

Most of the drawings of kindergarten children (age 5) achieved level 2 and/or level 4, with girls having higher percentages. The most frequently represented organ on the drawings was the heart (85%), followed by the brain (35%), and the least frequently represented organs were the kidney and bladder. Boys and girls represented almost the same percentage for the same organs.

The majority of the elementary school children (age 10) achieved level 4. The most frequently represented organs by the 10 year-olds were the heart and brain and the least represented the kidney and gills. On the other hand, the 12 year-olds achieved level 5. The most frequently represented organ system was the digestive system and a few represented the respiratory system. A number of the 12 year-olds did also represent the heart and gills.

A typical misunderstanding of internal organs in invertebrates that was demonstrated in the drawings was the gaseous exchange system. In most of the drawings of the respiratory system of the crab, pupils included the lung, which is typical of vertebrates and not the plume-like gills that the crab possesses to breathe. This shows how the pupils used knowledge about themselves as a template for what all animals need to live.

Discussion and conclusions

Three previous cross-sectional studies of children's understanding of other invertebrate species, which discussed how children's drawings of internal anatomy developed, establishing basic transitory categories (Rybska *et al*, 2014; Tunnicliffe, 2015a), were identified. Although older children attained higher levels than the younger ones when comparing the levels achieved, very few of the children's drawings attained either levels 5 or 6 – similar to what was found for the understanding of the internal anatomy of the human body.

We recognise that only collecting drawings in this study could be considered as a limitation. We are also aware that the research could have been enhanced with additional interviews, at least with a few children, as children would most probably be able to explain their understanding of the internal structures of the crab that they drew. Previous experience, in the case of a study on butterflies, has shown that one can attribute meaning better from interviews and drawings carried out under the supervision of the teacher.

Capturing the expressed models, i.e. representations of scientific phenomena such as the internal anatomy of invertebrates and how they develop and extend throughout other educational settings in Brazil, can be a collaborative goal and a subject for future investigations. Such research can provide insights and direction for new didactic interventions to science teachers, for example using the local invertebrate species, the river crayfish (*Aegla platensis*) for dissection under the stereomicroscope. This approach highlights the importance of the practice of 'observing with meaning', which can be taught from pre-school level.

The information about children's views of the internal structure information was obtained from a sample of children that was not representative of children in Brazil of these three ages. Nonetheless, the study did provide insights into children's conceptions of inner structures and how they use themselves as a template, which has been shown in previous investigations (Reiss & Tunnicliffe, 2001). Making a drawing of structures that they presume are inside this invertebrate can be considered as a spontaneous concept, which could be developed into a more scientific concept through formal learning at school, and using other species as a first step.

The data also revealed that children had no knowledge of the mechanism for respiration in crabs, which is not a lung-based system as in the case of mammals. However, it did show that children were aware that the organisms needed 'lungs', presumably to breathe.

Children's interactions with organisms in school activities, especially during practical classes with invertebrates, can potentially improve the understanding of the internal anatomy of organisms. A variety of practical work at school can also contribute to a good grasp of the internal structures of invertebrates (Blanquet, 2010). It is claimed that children are initially able to construct visual representations of their ideas, which develop, and they achieve a higher level of understanding as they grow older. Another pedagogical approach that can be adopted involves the manufacturing of models made from plastic tubes and food containers representing, in 3D, the inner structures of invertebrate species, particularly organ systems such as the excretory system.

School authorities can also encourage schools to undertake visits to natural history museums and science centres in Brazil, especially those that do not charge fees, as this could increase children's biological understanding. Brazilian textbooks for the 10-12 age range cover mainly the external anatomy of crustacea and a few words on gill respiration and pigments in the blood. They do not mention the circulatory or other organ systems. Nonetheless, probing children's thinking about the internal organs and systems of crustaceans can be a starting point for more effective teaching in the classroom. This requires that science teachers are able to elicit children's existing biological knowledge, and to promote ways to enable the construction of new knowledge.

Educational implications

This study has educational implications for science teachers from pre-school onwards:

- Teachers, in our opinion, need to analyse pupils' big ideas in biology, such as, for example, the vital life systems, e.g. respiration and excretion, which vary across differing phyla of organisms, and contrasting ways in which lungs and gills function;
- More emphasis should be given during pre-service training courses to everyday invertebrates;
- Children's fictional narrative books on the crab can be used as a way to familiarise young readers with different invertebrates, besides the traditional ones;
- Freshwater crabs should be obtained from the fishmonger to dissect on trays in the classroom, unless under threat of extinction;
- The relevant everyday experiences of the children out of school, such as cooking and eating crabs, could be utilised;
- Schools can introduce activities, as mentioned previously, which use children's predictions and their ideas about the internal anatomy of different organisms to promote learning;
- A colour atlas of animal internal anatomy and biological models can be used to help during practical classes; and
- Teachers can organise visits to natural history museums, which offer rich informal learning experiences.

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Outdoor learning, science trails and inquiry: an introduction

● **Amanda McCrory**

Increasing evidence points to how learning outside the classroom has the potential to enrich all who take part: '*The benefits of the outdoor classroom are clearly not confined to students alone. Teachers noted improved relationships with students, personal development in their teaching and … job satisfaction*' (Dillon *et al*, 2005; Natural England, 2012; Natural Connections Demonstrations Project, 2016) and can help to combat under-achievement: '*Outdoor learning may be particularly beneficial for children who struggle to maintain concentration in more formal classroom settings and actively seek out ways to introduce direct experience into their learning*' (Waite, 2010).

The ASE (2016) is committed '*to promoting fieldwork as an effective and inspirational way*' for children to learn science. There are now many projects that provide opportunities for children to learn outdoors, and Continuing Professional Development (CPD) opportunities for teachers to learn how to facilitate effective learning outside the classroom. A good example of this is the 'Teach Outdoors – Learning Through Discovery' project (2016), which aims to raise standards through outdoor learning. Leaders of the project argue that the benefits of learning through discovery are wide-reaching, which include:

- increased pupil engagement as children are involved in experiences first hand;
- improvement of behaviour for those with behavioural issues through giving children opportunities to be responsible and earn the trust of their peers and adults;
- children being active rather than passive learners whilst learning lifelong skills;
- improved emotional wellbeing and confidence;
- risk assessment opportunities; children are given opportunities to assess risk whilst being taught strategies to identify dangers and stay safe; and
- improvement in physical fitness. (Teach Outdoors – Learning Through Discovery, 2016)

In this issue, articles (Bartoszeck & Tunnicliffe, 2017; Morgan, Franklin & Shallcross, 2017; Mujtaba, Tunnicliffe & Sheldrake, 2017) and the book review (Bilto, Bento & Dias, 2017) all focus on the importance of providing children with opportunities for outdoor learning and inquiry. Authors discuss how teachers and facilitators can engage children in meaningful learning experiences that contextualise science via the environment. One interesting way of achieving this is to plan opportunities for children to undertake science trails, which can take place almost anywhere and, therefore, capitalise on any environment. Maths and science trails have been used in schools for a number of years to engage children in learning maths and science outside the classroom, but what specifically is a 'Maths or Science Trail'?

A 'Maths or Science Trail' can be developed by children and teachers to stimulate maths or science conceptual understanding, whilst practising inquiry skills such as problem-solving, observation, questioning and pattern-seeking, in a setting local to a school. Children and teachers actively take a pre-planned walk around a chosen outdoor environment to explore and investigate a particular concept or topic within maths or science.

An example of a simple maths trail would be to ask children to look for numbers or shapes in their local environment. Science trails can provide students with opportunities to explore a topic and uncover the science behind that topic. For example, when learning about trees (Year 1, Key Stage 1, (age 6) Science National Curriculum – to learn about coniferous and deciduous trees) children can explore the local environment to compare the locations and types of plants found there, then use their observations and scientific knowledge to explain why certain plants are suited to certain locations.

Maths and science trails not only can take place in the local environment, but, in fact, anywhere outside the classroom. For example, the Science Museum in London provides a number of well-thought-through science trails where children can explore the galleries and objects that the museum has to offer. One science trail that is particularly engaging is called 'Spectacular Space', in which children are encouraged to engage with a number of objects to uncover the science and stories behind them. For example, one object on the trail is the Apollo 10 Mission command module – children are asked to examine the module and find evidence to demonstrate that the module actually went into space! On close inspection, using their observation skills, children discover that the underside is burned and charred where it re-entered the Earth's atmosphere. Next, the children are asked to take a pen and a piece of paper and drop them from the same height to investigate which will hit the ground first. They are then asked to explain why this happens (using their understanding of air resistance and surface area) before being informed that the investigation they just did was done on the Moon, but with a different outcome – both objects hitting the floor at the same time; children are asked to explain why, promoting abstract thinking skills. Therefore, we can see that the activities to which the children are exposed throughout the science trail are designed to encourage the children to use and improve their scientific knowledge and understanding whilst practising their inquiry skills.

The following interesting article by Morgan, Franklin and Shallcross (2017) discusses the use of science trails to investigate physics with children in the Early Years Foundation Stage and Key Stage 1 (age 5-7), giving readers ideas of how they themselves can use science trails with the children whom they teach.

For Key Reports and References, please see:
https://www.ase.org.uk/resources/outdoor-science/
http://publications.naturalengland.org.uk/publication/6636651036540928
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Let's go and investigate physics outdoors at Foundation and Key Stage 1 level (4-7 year olds)

● Jeannette Morgan ● Sophie D. Franklin ● Dudley E. Shallcross

Abstract

Outdoor science trails can be used to explore a wide range of topics in science at primary school level, but are often viewed as being relevant to the more environmental and biological topics. Here we describe some science trails developed for children aged 5-7 that prompt the children to think about electricity, energy, sound and light. The use of discussion before, during and after the trail and the importance of planning are described. Having undertaken the trails and built up a range of experiences and photographs, these young learners were better equipped to understand topics such as electrical circuits.

Keywords: Electricity, sound, light, heat, outdoors

Introduction

Research suggests (e.g. DeWitt & Hohenstein, 2010) that visits to science centres and museums encourage teachers to engage in more open-ended questions and allow students to exert more control over experiences that can lead to affective and cognitive gains. In an outdoor setting, children have even more freedom, potentially, to explore and investigate their surroundings. It is often reported that children are more enthusiastic on such outdoor trips than in a classroom setting and, provided that suitable support, scaffolding and time is given, these students can engage in deep level learning. One key aspect that facilitates this is allowing discussion and talk-based activities either at the site or back in the classroom, where this is most effective when some rules for discussion have been established (e.g. Mercer *et al*, 2004).

We experience 'forces' constantly and yet they are difficult to see and understand for many types of learners, not just the young learners addressed in this paper (e.g. Danielsson & Warwick, 2014). We use electricity on a daily basis, in the UK at least, but what is it (e.g. Summers *et al*, 1998)? We observe the change in light levels on a daily, seasonal and yearly basis and use light and sound to explore the world around us, but what do we know about these important science concepts (e.g. Parker & Heywood, 1998)? We note that these science concepts (energy, light and sound) are often associated with physics and so we have grouped them together under that banner, but other groupings of topics in science would work equally well and science trails can be devised for a wide range of topics and concepts. Here, we want to show how topics associated with physics can be explored outdoors. In the 'Let's go Science Trails' project, we have used the outdoor environment to identify and develop children's emergent science understanding and investigative skills in a range of science topics and, in this particular study, we have focused on children aged approximately 5-7 years.

It has already been noted that the outdoor environment provides and encourages pupils' engagement and investigative learning and has a positive effect on teacher-child relationships and pupil attendance (e.g. Dillon *et al*, 2006).

There is a positive correlation between time spent outdoors and general health and wellbeing, and the fostering of responsible attitudes to the environment (Vitale, 2011). Indeed, Ofsted (2008) notes that a well-planned and implemented outdoor learning experience makes a significant contribution to raising standards and improving pupils' personal, social and emotional development. The outdoor environment has also been shown to promote learning, in particular amongst students who are native speakers, and to be an excellent stimulus for class discussion (e.g. Osborne, 2010). Irrespective of whether the school is based in an urban or rural location, the outdoor environment can be used to develop science understanding and investigative skills.

The development of a science trail

The 'Science Trail' concept is a culmination of the experience of several highly experienced primary school teachers of science who have seen the many benefits of investigating topics using the outdoor environment. Much planning is needed to develop a trail and refinements and adaptations will always take place but, in summary, all trails described in this study follow the same development, format and implementation.

First, a particular topic or science concept is chosen as well as the age range that will undertake the trail. Second, appropriate locations are identified where the pupils will encounter many real world examples of this topic. Third, teachers investigate the potential trail themselves to enable pre-trail materials to be developed (e.g. stimuli such as photographs), complete a health and safety analysis and identify resources needed to prepare for the trail, while on the trail and then back in the classroom.

Electricity

During the primary school years, pupils will look at electrical circuits, but what do they know about electricity in the (England education system) early years and at Key Stage 1 (approximately ages 4-7)? In the classroom, before the trail was undertaken (the timing varied from school to school and group to group, but was typically during the week before the trail), the teacher and pupils discussed the uses of electricity, what electricity might be and that it can be used to produce light, sound, movement and heat (or a change in temperature). On this science trail, the pupils were divided into groups and asked to find electrical appliances that produced sound, produced light, caused movement, or produced heat or a change in temperature. The results from these investigations are summarised in Table 1.

Table 1 shows that the sets of electrical appliances that were identified under the different categories were different, and only one item, the coffee machine in the food store, was reported to have produced sound, light, movement and heat. It had a light on the panel and produced hot drinks, which is why the children agreed that it was generating heat, and the cup dropped down, which was why they reported that it produced movement. The number of electrical appliances that were thought to produce heat and light was much smaller than the number for the other two categories.

Table 1. Items identified by children that use electricity and produce sound, light, movement or heat.

	Dry Cleaners	Food Shop	Launderette
Sound	Alarm Vacuum cleaner Till (Ticking) clock Fan Sewing machine Radio	Conveyor belt Fridge Till Printer Coffee machine Lottery machine	Tumble dryer Washing machine Change machine (Ticking) clock
Light	Lights	Light at till Coffee machine	Lights
Heat	Vacuum cleaner	Coffee machine	Tumble dryer
Movement	Fan Vacuum cleaner Till (Ticking) clock Sewing machine	Conveyor belt Coffee machine Till Printer Lottery machine	Tumble dryer Washing machine Change machine (Ticking) clock

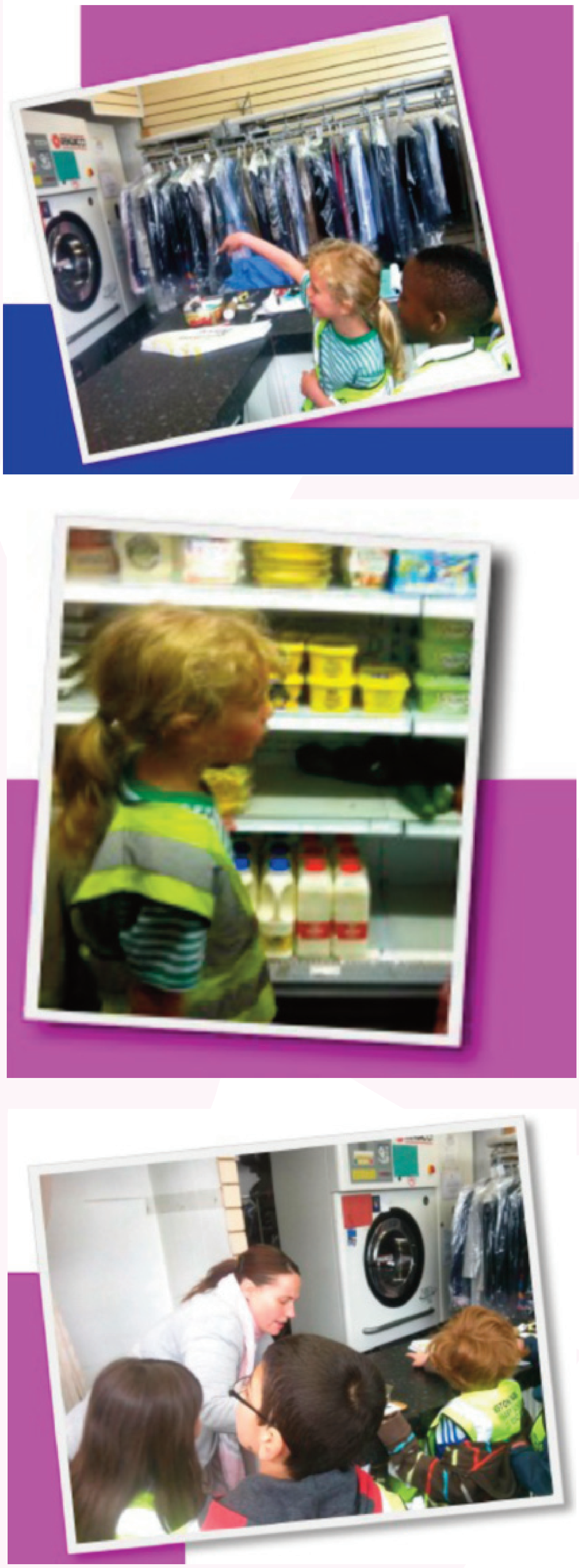
Apart from lights themselves, only the coffee machine was recorded as a producer of light. Only three items were recorded as producing heat: the coffee machine, the tumble dryer (because it warmed up the clothes), and some children knew that vacuum cleaners produced heat (from experiences at home). However, one of the drawbacks of the trail was the adherence to health and safety, in that touching potentially hot objects was prevented and so the children did not have an easy way to determine whether heat was being generated. So, just these three items were recorded as producing heat. Back in the classroom(s), there was much discussion about whether some of the other electrical items produced heat and light. The children remembered that it was warm in both the dry cleaners and the launderette, and a very interesting discussion followed: although most children assumed that the heating was on in both shops, there were a few children who thought that it was warmer because the shops were much smaller than the food shop. It may be that some children thought that some or all of the machines were generating heat, but they did not make that connection in the discussion or did not want to suggest this out loud. Some did know that the vacuum cleaner was warm to the touch.

However, children remembered that the food shop had parts that were warmer and certainly parts that were cold *('where the ice cream was')* and said that the fridges were making those parts colder. Some children then started a discussion about why some of the fridges were open and some had sliding doors, and a few noted that the food that was in the 'closed' fridges was colder. Although not all the children would have used the word 'energy', most had a concept that electricity was essential to the operation of the appliance and that it generated sound, light, heat or movement, or combinations of these. The children went on two other trails to investigate sound and light in more detail.

Sound

The sound trail saw the children embark on a trail that incorporated the environs of the school and also a local park or equivalent location. The children were asked to record the various sounds that they could hear and to identify, if they could, the source of the sound. The children had sound meters with them, which recorded decibel levels.

Figure 1. Key Stage 1 children (aged 5-7) investigating electrical appliances in a row of shops in their local environment.



In the park
These young learners were able to identify a number of sounds arising from animals, dogs barking, birds making a variety of noises and insects buzzing, for example. Other sounds that they were able to identify included the wind rustling through leaves, people talking, cars driving by, music from a person's music player, someone playing tennis, a splashing fountain, a street-cleaning cart, and the noise from a train.

Around the school and on the High Street
There were many sounds identified, including from an ambulance, buses, traffic lights bleeping, someone banging on a glass window and people talking. The children used the sound meters and these confirmed the children's ideas that the environs of the school and High Street were noisier than the park and, in certain places, much noisier than the park. Through discussion, the children categorised the sounds into those caused by humans and those that are not, and noted that the only place that they heard non-human sounds was in the park. Some children suggested that it was so noisy on the High Street that they probably couldn't hear any animals and that, apart from dogs, most animals would avoid the High Street. A later in-class discussion investigated how sound is generated and, given access to resources in the class, the children identified a range of musical instruments. There was evidence that children were thinking about why these instruments generated sound.

Figure 2. Key Stage 1 children (aged 5-7) investigating sound in a variety of outdoor settings using a sound meter.

Light
Some children also investigated light on the same or similar trails but, rather than look at objects that produce light, they were asked to record places where there were different light levels and had a light meter to help them. In the park, several groups of children noted (using the light meter recordings of lux) how much darker it was in the shady part of the park under the trees and how it was quieter there too. Here were examples where the use of meters added greatly to the exploration and discussion. With help, the children could use the meters to demonstrate how dark or how quiet an area was compared with another. On the High Street, they noticed that some parts were in shadow (from tall buildings), but there was no obvious change in noise levels along the street compared with the park. The children discussed the differences and concluded that, in the park where it is darker, animals are quieter so that they can hear other animals and that they need to use their hearing more because it is hard to see.

Summary
The various trails proved to be a very positive experience for the early years and Key Stage 1 students. Firstly, they were more aware of electricity, sound, light and energy in the world around them and started to sort these into natural and human-made sources. Secondly, given training, the use of meters was a positive, as students could demonstrate and quantify to themselves that there was a difference in the amount of sound and light from one place to another. Thirdly, they started to make some interesting connections at various parts of the trail, for example, that darker places in the park that were shaded by trees were also much quieter. Fourthly, there were the beginnings of the idea that electrical appliances generate heat, but further (safe) experiments are required to show this. As important, the teachers themselves found that this activity built their confidence. They worked on trails together and, with several schools contributing, had feedback and trialling of the trails by other children and their teachers. Early years

and Key Stage 1 science can be difficult to teach, but using the trail idea provides an opportunity for children to make connections, stimulates good science discussions and can determine what the children already know.

Acknowledgements

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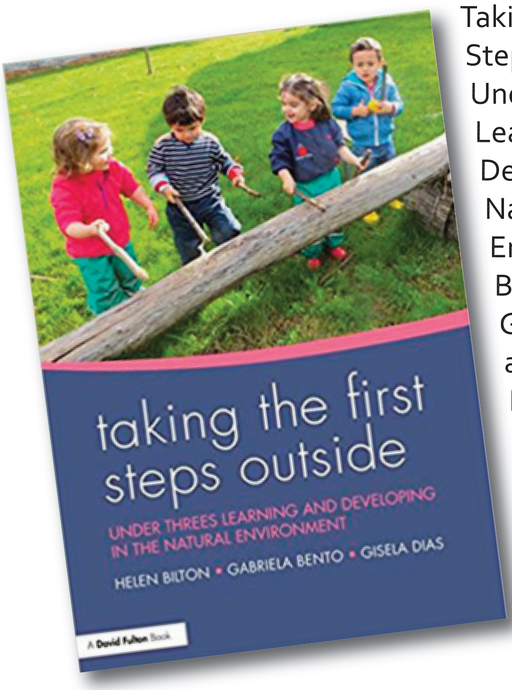
Resource Review

Taking the First Steps Outside – Under Threes Learning in the Natural Environment



Taking the First Steps Outside – Under Threes Learning and Developing in the Natural Environment By Helen Bilto, Gabriela Bento and Gisela Dias. Published in 2017 by Routledge, Abingdon, UK, price £21.99 (Pbk). ISBN 978 1 13891 989 1

This interesting, informative and highly accessible book – the result of a recent research project undertaken in Portugal – is beautifully illustrated with photographs of children exploring and engaging with the outdoor environment, complementing and illuminating for the reader the detailed descriptions of the real events described in the book.

Written by three experts in the field of early childhood education – Helen Bilto, Associate Professor of Education at the University of Reading, UK; Gabriela Bento, an educational psychologist and PhD student at the University of Aveiro, Portugal; and Gisela Dias, an experienced early childhood teacher in Portugal – this book demonstrates how children under three can benefit from exploring the natural outdoor environment, whilst providing teachers and facilitators working in educational settings for the under-threes with a variety of pedagogical approaches to learning outside.

The authors argue that, although there has been a longstanding tradition for children over three to play and learn using outdoor environments, e.g. the playground or garden in educational settings, this tradition, in Portugal, has not necessarily extended to younger children in the school nursery. The dominant reason for this, the authors assert, is a perception that children under three can be problematic in relation to their behaviour. For example, they cite the idea of the 'terrible twos' (which the authors argue is a myth), a time when two year-olds can become extremely angry, frustrated and upset, often resulting in temper tantrums because they do not have the ability to perform many of their desired outcomes. This book claims that there are indeed many myths about one- and two year-olds, which it sets out to dispel – the point made about young children needing to be constantly entertained is powerfully eliminated in the authors' critical discussion of the negative consequences of over-stimulation and the importance of young children being given time to enjoy Nature quietly and in contemplation. The authors assert that encouraging self-regulation during childhood encourages young children to be self-motivated without needing constant external reinforcement.

The authors are also concerned with a growing trend of children spending more time on electronic devices and less time outside and argue that the outside is an all-encompassing learning environment, affording young children the opportunity to learn and practise life skills such as perseverance, overcoming adversity and fear, whilst benefitting from collaborative learning.

In terms of science education, this book focuses on how to use the outdoor environment to elicit and maintain curiosity whilst giving young children opportunities to observe, explore and question, as they develop a love for the natural world as well as their language and thinking skills.

Insights into the crucial role of the adult are given; adults observing and reflecting upon children's learning is high on the agenda. It is clear that the authors believe that adults should not feel the need to teach or over-stimulate the children in their care with constant activities; this is not simply sage advice but a change in pedagogical approach for the teachers involved in the project. Necessary changes in educational practices are highlighted; reasons for these, how these were achieved and theoretical underpinnings are discussed. The book also provides clear advice on choosing the right resources to create an effective enabling outdoor learning environment for young children, and guidance on how to undertake a research project for children under three – a welcome chapter in the book, which will hopefully inspire nursery practitioners, or indeed any reader of the book interested in education, to undertake action research or become involved in a research project.

However, for me, the power of this book lies in the focus on what the authors call 'risky play' to promote challenging and positive opportunities in the natural environment. In today's political climate, teachers and facilitators are held highly to account, and rightly so – all children deserving the absolute best education undertaken in a safe and stimulating environment; however, this can, as the authors rightly argue, create a strong risk avoidance approach to prioritise children's protection and security. I would agree with the authors' premise that '*absolute safety is not possible or desirable – it is not possible to keep children in a bubble-wrapped environment'* (2017:63). Therefore, 'risky play' is an important trigger for children's social and cognitive development, responding to a child's need for stimulation of all the senses, and encouraging a child's natural curiosity. Moreover, the authors strongly argue that, without risks, children are not given the opportunity to develop the attitude of persistence that is needed to not only develop problem-solving skills but also to undertake challenge; when children seek challenge, the authors note that they become creative in learning the best strategies through which to solve them.

It is important to note that this book is centred on a research project undertaken in Portugal, where the authors state that early childhood education is still too centred on what happens inside the nursery. Portugal also clearly has a different curriculum to that in the UK. However, all the activities and pedagogical approaches suggested would fit well into delivering the EYFS curriculum and what many teachers in the EYFS setting already do; the ideas presented are inspiring.

Furthermore, the premise that the nursery teacher is a facilitator of outdoor learning fits well with the idea of teacher-initiated activities, leading into child-initiated exploration incorporating observation and problem-solving: a clear reflection of good practice in teaching science to young children. Therefore, all educators in the field of early years education would certainly benefit from reading this book, but I would also go as far as to say that this book could inspire teachers and science co-ordinators of older children within the primary-age range to utilise the outdoor environment more when undertaking scientific enquiry.

Amanda McCrory

Contributing to JES

About the journal

The *Journal of Emergent Science (JES)* was launched in early 2011 as a biannual e-journal, a joint venture between ASE and the Emergent Science Network and hosted on the ASE website. The first nine editions were co-ordinated by the founding editors, Jane Johnston and Sue Dale Tunnicliffe, and were the copyright of the Emergent Science Network. The journal filled an existing gap in the national and international market and complemented the ASE journal, *Primary Science*, in that it focused on research and the implications of research on practice and provision, reported on current research and provided reviews of research. From Edition 9 in 2015, *JES* became an 'open-access' e-journal and a new and stronger Editorial Board was established. From Edition 10, the copyright of *JES* has been transferred to ASE and the journal is now supported by the Primary Science Teaching Trust (PSTT).

Throughout the changes to *JES*, the focus and remit remain the same. *JES* focuses on science (including health, technology and engineering) for young children from birth to 11 years of age. The key features of the journal are that it:

- is child-centred;
- focuses on scientific development of children from birth to 11 years of age, considering the transitions from one stage to the next;
- contains easily accessible yet rigorous support for the development of professional skills;
- focuses on effective early years science practice and leadership;
- considers the implications of research into emergent science practice and provision;
- contains exemplars of good learning and development firmly based in good practice;
- supports analysis and evaluation of professional practice.

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The Editorial Board of the journal is composed of ASE members and PSTT Fellows, including teachers and academics with national and international experience. Contributors should bear in mind that the readership is both national UK and international and also that they should consider the implications of their research on practice and provision in the early years.

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Articles submitted to *JES* should not be under consideration by any other journal, or have been published elsewhere, although previously published research may be submitted having been rewritten to facilitate access by professionals in the early years and with clear implications of the research on policy, practice and provision.

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The contributions should be presented as a word document (not a pdf) with double spacing and with 2cm margins.

- The first page should include the name(s) of author(s), postal and e-mail address(s) for contact.

- Page 2 should comprise of a 150-word abstract and up to five keywords.
- Names and affiliations should not be included on any page other than page 1 to facilitate anonymous refereeing.
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- UK and not USA spelling is used i.e. colour not color; behaviour not behavior; programme not program; centre not center; analyse not analyze, etc.
- Single 'quotes' are used for quotations.
- Abbreviations and acronyms should be avoided. Where acronyms are used they should be spelled out the first time they are introduced in text or references. Thereafter the acronym can be used if appropriate.
- Children's ages should be used and not only grades or years of schooling to promote international understanding.
- References should be cited in the text first alphabetically, then by date, thus: (Vygotsky, 1962) and listed in alphabetical order in the reference section at the end of the paper. Authors should follow APA style (Author-date). If there are three, four or five authors, the first name and *et al* can be used. In the reference list all references should be set out in alphabetical order

Guidance on referencing

Book

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Manuscripts are sent for blind peer-review to two members of the Editorial Board and/or guest reviewers. The review process generally requires three months. The receipt of submitted manuscripts will be acknowledged. Papers will then be passed onto one of the Editors, from whom a decision and reviewers' comments will be received when the peer-review has been completed.

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