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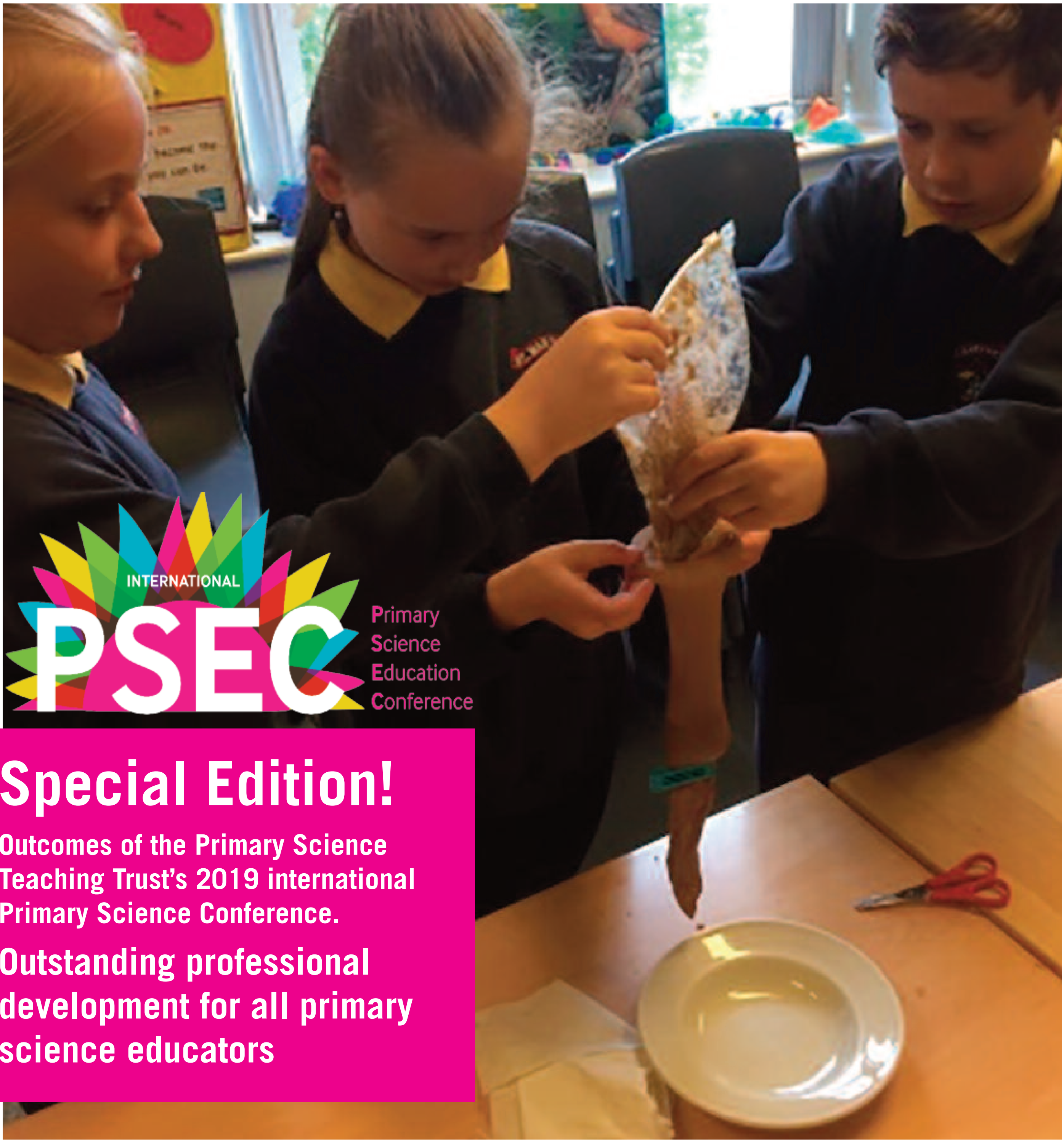

INTERNATIONAL PSEC Primary Science Education Conference

Special Edition!

Outcomes of the Primary Science Teaching Trust's 2019 international Primary Science Conference.

Outstanding professional development for all primary science educators

The Association for Science Education
Promoting Excellence in Science Teaching and Learning

why& how? PRIMARY SCIENCE TEACHING TRUST

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International PSEC Primary Science Education Conference

why & how? PRIMARY SCIENCE TEACHING TRUST

The Association for Science Education
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Why does the teaching of science at primary school matter?

● Dudley E. Shallcross

Abstract

Learning starts immediately at birth and a growing body of evidence shows that this learning is highly sophisticated from a very young age. If we believe that science is an important subject, it cannot be sidelined until secondary school. Looking into the future, science and technology will play an ever-increasing role in our lives and, in order to prepare young learners now for that future, we need to adopt the practices of the outstanding teachers. In this special issue, we reflect on a wide range of presentations and practice that were presented at the Primary Science Education Conference (PSEC) II.

Introduction

The second international conference on the teaching of science at primary school level, hosted by the Primary Science Teaching Trust (PSTT) in Edinburgh in June 2019 (www.psec.org.uk), was by any standards a great success. The presentations and workshops were wide-ranging, with outstanding keynotes and presentations by teachers, many from the PSTT College (Shallcross *et al*, 2015). The presentations by teachers demonstrated cutting-edge innovation and research-informed practice (e.g. Trew *et al*, 2019, 2020). In this paper, I will refer to elements of the Conference and the wider work of PSTT and its stakeholders, to answer the question 'Why does the teaching of science at primary school matter?'.

It is often said that we should be preparing our young children for a future where careers in that future have not yet been imagined (something that one keynote speaker, Kate Bellingham, discussed). We can articulate key skills that any child might need in the future, such as problem-solving, communication, numeracy, team working, data synthesis and analysis (e.g. Rocard *et al*, 2007) and, although it is possible to impart these without reference to science, it is much easier to use the many opportunities that science provides. Children are curious about the world around them from a very early age (more on this later) and stimulating that curiosity is beneficial. The UK's industrial strategy (UK Industry Strategy, 2017) points the way forward for the near future (possibly up to the next 10 years), where the Grand Challenges identified are: Artificial Intelligence (AI) and a Data-driven Economy; Clean Growth; the Future of Mobility (including transporting goods and people); and addressing the issues of an Ageing Society. Our first keynote speaker, Professor Jim Al-Khalili from the University of Surrey, led us on a journey into a possible future and the role of AI in this. In the most recent wave of themes under the Grand Challenges Fund, we find, for example: accelerating detection of disease, self-driving cars, driving the electric revolution, the Faraday battery challenges, healthy ageing, precision medicine, industrial decarbonisation, manufacturing and future materials, robots for a safer world and smart sustainable plastic packaging. Primary school-aged children can understand many of these themes and the wider grand challenges to varying degrees, and the challenges would be an excellent stimulus for engaging with science for children and adults.

If we needed further reasons for engaging future generations in science, we only have to look at the United Nations 17 Sustainable Development Goals (Figure 1, https://sustainabledevelopment.un.org/#). Many of these goals require science, engineering and medical solutions, one of the most pressing being climate change, with associated impacts on food and water security and supplies, sustainable cities and the requirement for humans to produce affordable and clean energy and to consume and produce responsibly. Therefore, the need for future generations to be science-literate has never been clearer, and aspects of how we can engage and encourage young learners are contained in the STEM section of this special edition.

Why we cannot wait until secondary school

The Conference included presentations from Professors Laura Schulz from the Massachusetts

Institute of Technology, USA, and Paul Ramchandani from the University of Cambridge in the UK. Both Laura and Paul alerted the Conference to the rapid rate of development of young children from around 0-5 years, and how important interactions with parents, carers and other adults (and children) are during this rapid development phase (Ramchandani *et al*, 2013). Laura Schulz's research in early years has demonstrated that, during free play, pre-school children can distinguish between confounded and unconfounded evidence and can disambiguate confounding variables (Schulz & Bonawitz, 2007), something that is quite remarkable.

In a further study, Schulz's team demonstrated that 4-6 year-olds could systematically converge on solutions to problems, consistent with the ability to imagine the abstract properties of causal problems and their solutions – do we give our young children enough time and space to imagine? In a further study of 15 month-olds, Schulz and co-workers showed that infants make more attempts to achieve a goal when they see adults persist (Leonard *et al*, 2017). Laura stated that '*... in primary education, we teach children what we already know and* ***skills to find out more for themselves*** *and, in the fullness of time, they're going to maybe re-engineer the planet. It is the only thing that has ever done anything like that in the history of the universe. So it's quite remarkable'.* I think that the words highlighted in bold are key here: empowering young people with the skills of investigating and problem-solving. The early years phase is a very important time in primary school and those teachers who excel at the teaching of science at this level are so important, yet they are not valued as such.

Role of play

During the first PSEC, held in Belfast in 2016, Dr. Stuart Brown gave an excellent keynote talk on the role of play in learning and showed how a lack of play in childhood can cause problems in later life (Brown, 2010). Play was a common theme at this Conference, where Laura Schulz noted that '*Play is one of the biggest mysteries of learning. I think we don't have a real scientific answer. The smartest species play the most, so there's every reason to think that play enhances learning'.* However, can we do more to encourage 'playful learning' throughout primary school?

Professional learning and pedagogy

In this special edition, there is a section dedicated to professional learning, which includes contributions on co-teaching and lifelong learning. It is here that it is important to understand the role of this journal, *Journal of Emergent Science (JES)*, a joint venture from ASE and the PSTT. Access to primary research is becoming

Figure 1. The United Nations' 17 Sustainable Development Goals (see https://sustainabledevelopment.un.org/#).

easier through open access, but no easier to understand, sadly, for the class teacher, and yet that research could be informing practice. Equally, excellent publications such as ASE's *Primary Science* (which is also hosting a PSEC II special issue this year) provide a platform for teachers and practitioners to share ideas and tips on how to teach a subject. There is a chasm between this type of publication and research publishing, and it is here where *JES* wants to position itself, allowing teachers to report on action research that does inform fellow practitioners, but also gives researchers a platform from which to disseminate wider current research in an accessible way, as with the pedagogy section in this special issue.

The teachers

It was incredible to see so many PSTT Fellows (Shallcross *et al*, 2015) present their work at the Conference and is a testament to the excellence of science teaching at primary school level in the UK. Outstanding teachers empowered with a dynamic curriculum encourage investigation, questioning and discussion, exemplified by the *Thinking, Talking and Doing Science* project (Mant *et al*, 2007), a project that was originally funded by AZSTT. The innovation, pedagogy and content knowledge of the teachers who presented were incredible.

Future prospects

Data science, machine learning and artificial intelligence are all terms that are discussed now and will be commonplace in the future. Will our current cohort of primary-aged children be ready for this when they leave school? Yes, if they are provided with the tools of investigation, synthesis, evaluation and reflection from an early age and, given the excellent presentations at PSEC II, there is every reason to believe that the UK will be at the forefront of education, recognising the vital role played at primary school.

Acknowledgments

PSEC II would not have happened without the efforts of many people, including Ali Eley, Colette MacKie, Sue Martin, PSTT Fellows and stakeholders (most notably SSERC) and the many others who attended and contributed from the UK and especially from overseas. However, the PSTT Trustees should take pride of place for backing the Conference and this paper is dedicated to the outgoing chair of Trustees, Dr. Mike Rance, who has been an incredible supporter of the teaching of science at primary school for many years.

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Practitioners as lifelong learners: a collaborative approach to professional learning in Scotland

● Lise McCaffery

Abstract

In Scotland, the national model of professional learning highlights the importance of education professionals as lifelong learners across the education system. Agreement on the national model of professional learning was reached through collaboration across sectors including education, universities and teacher professional associations, and builds on national and international research into effective professional learning and teacher professionalism (GTCS, 2017; Hargreaves & Fullan, 2012; Timperley, 2008). In this paper, the evolution of this co-constructed national model is shared, with three examples of the model actively influencing science and wider learning and teaching at school, local, regional and system level.

Keywords: Professional learning, teacher development, CPD, Scotland

In Scotland, the national model of professional learning highlights the importance of education professionals as lifelong learners across the education system. In this article, Education Scotland explores the model alongside some other system-wide strategies in Scotland that support science learning and teaching and provide practitioners with further reading and online support resources.

Collaborating to construct the national model

Education Scotland (a Scottish Government executive agency charged with supporting quality and improvement in Scottish education) has strategic responsibility for professional learning and leadership. It has led work with partners and stakeholders to agree a national model of professional learning, which builds on national and international research (Timperley, 2008; Hargreaves & Fullan, 2012, amongst others) and the work of the General Teaching Council for Scotland. In 2017, the Strategic Board for Teacher Education, the body that oversees and evaluates reforms to teacher education in Scotland, established a Short-Life Working Group on Professional Learning. To support the work of the group, the Scottish College for Educational Leadership (SCEL) commissioned a scoping study on professional learning, gathering the views of over 600 teachers from 30 local authorities regarding their aspirations for their own professional learning (Scottish Government, 2018).

The group then made 16 recommendations across four themes:

- communicating a consistent professional learning model;
- improving access to professional learning resources;
- accreditation and endorsement of professional learning; and
- developing professional learning partnerships.

Education Scotland then led on the work to take forward these recommendations. Agreement on the national model of professional learning (Figure 1) was reached through collaboration across sectors including education, universities and teacher professional associations.

For example, as part of Education Scotland's work engaging the wider system around this model, we delivered a seminar at the International Primary Science Education Conference held in Edinburgh in June 2019. During the session, primary science teachers were encouraged to reflect on the last time that they experienced professional learning (or CPD, continuing professional development) that deepened their knowledge and understanding, challenged their thinking and was collaborative in nature. They also considered the extent to which time and space for professional learning was protected in their setting.

Figure 1. National model of professional learning in Scotland.

Education professionals engage in professional learning to stimulate thinking and to ensure that practice is critically informed and up-to-date. Whether that learning is with colleagues in their setting, or with external providers, the model of professional learning (Figure 1) identifies the key principles and features of effective learning that build capacity and promote collaborative practices. These principles build on the concept of teacher professional capital and the elements of 'human capital', 'social capital' and 'decisional capital' (Hargreaves & Fullan, 2012).

At the heart of the model is the relationship between the learning of the education professional and the learning of those they support. '*Teachers who are engaged in cycles of effective professional learning take greater responsibility for the learning of all students […], as they discover that their new professional knowledge and practice are having a positive impact on their students, they begin to feel more effective as teachers'* (Timperley, 2008, p.9). Having a national model that emphasises the importance of high-quality professional learning for practitioners will ultimately impact on outcomes for children, young people and adult learners.

The model identifies that professional learning should be:

- Challenging, and develop thinking, knowledge, skills and understanding;
- Underpinned by developing skills of enquiry and criticality; and
- Interactive, reflective and involve learning with and from others.

Professional learning should be informed and supported by professional standards and education policy. The General Teaching Council for Scotland in its paper *Teacher Professionalism and Professional Learning in Scotland* states that '*teachers and school leaders should be empowered, enquiring, collaborative professionals who are well-informed to make the best decisions for our children and young people'* (2017, p.1). Enquiry '*establishes and maintains a rhythm of learning, change and innovation'* (OECD, 2016, p.5).

Leadership of and for learning, across all levels of education, is essential to ensure that learning is well supported, promoted and sustained. '*Professional learning is strongly shaped by the context in which the teacher practises. This context is usually the classroom, which, in turn, is strongly influenced by the wider school culture and the community and society in which the school is situated'* (Timperley, 2008, p.6). The model encourages all those involved in teaching and learning – be it at classroom or Headteacher level – to consider themselves as leaders of and for learning and to create the culture for ongoing and sustained professional learning within their setting.

Embedding the model across the system using a process of endorsement

For those planning professional learning, the model can be used to stimulate thought around deepening the learning and the approaches used to do so. Through Education Scotland endorsement, external programmes that demonstrate how they reflect the national model can be identified as examples of high-quality professional learning.

These endorsed programmes sit on Education Scotland's website, meaning that practitioners can feel confident in choosing options to support their own development and that of their staff.

An example of this is provided by Juliet Lunnis, who leads Edinburgh City Council's 'Edinburgh Learns: Inspiring Teacher Enquiry Programme', which was recently endorsed by Education Scotland.
'The programme supports practitioners to critically reflect on their values, strengths and pedagogy, then develop skills to lead teaching and learning improvements in their establishments.

'Going through Education Scotland endorsement and reflecting on the national model of professional learning ensured we were rigorous in the process of producing a coherent, high-quality and valuable course.

'Edinburgh Learns now aims to achieve GTCS Professional Recognition status for Inspiring Teacher Enquiry and has plans to apply for Education Scotland endorsement for a number of their other courses.'

Outlined below are three examples of the model in action actively influencing practice. The first focuses on teachers supporting teachers' professional learning within their setting, the second looks at how the model has influenced national strategy around STEM professional learning, and the third how the model is being used to encourage practitioners to question and challenge practice around gender balance in education.

❐ Example 1: using the model as a shared tool in schools

Dougie Gillespie is Principal Teacher of Career Long Professional Learning at Hillhead Secondary School in Glasgow. He describes how having a national model has helped to shape the school's thinking around its own professional development and has tied in with his own further professional reading. In this section he explains how he has engaged with the model. *'Teacher growth is closely related to pupil growth. Probably nothing within a school has more impact on students in terms of skills development, self-confidence or classroom behaviour than the personal and professional growth of their teachers'* (Barth, 1990, p.49).
As Dougie views it, *'Barth's quote perfectly summarises the use of the national model of professional learning at Hillhead Secondary School. The model views the teacher as the learner, at the centre, and we look at the impact of this upon the pupils.*

'All teaching staff are members of Teacher Learning Communities. These are led by volunteers who attend training and deliver sessions to the members of their community. This provides the foundation for enquiry at Hillhead, engaging with professional reading and working as a collaborative to challenge ideas.

'Our Maths Department engages further with professional literature during department meetings, developing the Mastery approach. There is a confidence in taking a risk, with staff feeling supported through being given space and respect to explore new learning and make professional judgements.

'The national model of professional learning acts as a planning tool for all of our professional learning. We ensure that any in-house event is well-led, tailored to the [General Teaching Council for Scotland] professional standards, allows staff to work together to deepen their knowledge, and is well-resourced with all book titles purchased and added to our extensive library. All of this, of course, to provide more positive learning experiences for our pupils.'

Hillhead High School is an example of the growing number of teachers working collaboratively to inform their practice.
This is being replicated at: local level (through informal groups such as the Teachers Enquiry Network (TEN) in East Lothian and Mid Lothian); regional level (through programmes such as the Collaborative Enquiry Networks in the West Partnership); and nationally (through organisations such as the Scottish Professional Learning Network and Education Scotland's own Professional Learning and Leadership programmes).

❐ Example 2: enhancing professional learning through the STEM Grants Programme

In 2018, Education Scotland launched a grants programme funded by the Scottish Government. The aim of this programme is to enhance provision of local, regional and national STEM-related professional learning and supports the implementation of key commitments within the STEM Education and Training Strategy (Scottish Government, 2017) and the *Making Maths Count Report* (Scottish Government, 2016).

The new STEM Grants Programme seeks to support early learning and childcare practitioners, community learning and development practitioners, teachers and school technicians. Round one of funding in the 2017/18 academic year awarded £187,000 to support 24 projects throughout Scotland. The programme was extended in Round two, with £1.3 million being made available through the grants programme to give funding for providers delivering on a regional or national basis, as well as introducing a new Leadership and Collegiate Professional Learning Fund. This new fund was created to enable collaborative professional learning across sectors, within school clusters or to support practitioner networks. All of which works to link national strategy and funding to the key principles and themes of the national model of professional learning.

Ninety-seven professional learning programmes have been awarded funding in 2019/20 and a further forty-one professional learning programmes will be supported through the Regional and National Partner Fund.

The aim of both funding streams is to support interdisciplinary approaches to STEM and subject-specific support to each of the STEM-related disciplines, including numeracy and mathematics, sciences, technologies, digital learning and teaching, and engineering. However, the design of the Leadership and Collegiate Professional Learning Fund places an emphasis on supporting schools in taking forward their own partnership plans in building capacity through professional learning: *'[I]f teachers are to change, they need to participate in a professional learning community* ***that is focused on becoming responsive to students****, because such a community gives teachers opportunities to process new information while helping them keep their eyes on the goal'* (Timperley, 2008, p.19). The STEM Grants Programme facilitates the *'leadership of and for learning'* from the national model with practitioners planning collaboratively across sectors. Funding going directly to schools will allow the flexibility in planning for that time and space to build these professional learning communities.

❐ Example 3: Using the model: critically reflecting on improving the gender balance in STEM and beyond

Reflecting on and challenging your practice is one of the key principles and features of the national model of professional learning – 'learning by enquiring'. Barriers to science qualifications and careers for certain groups are well documented (Archer *et al*, 2013) and the younger we can start to address these barriers (in primary education, if not earlier), the better. Increasingly, research (Koenig, 2018; Kurtz-Costes *et al*, 2014) shows that the best way to combat the negative effects of gender stereotyping on young people is through an embedded and sustained approach to raising gender bias awareness. Based on this growing evidence base to address gender biases and stereotyping across education, the Scottish Government has funded the *Improving Gender Balances and Equalities* team.

This team offers training on gender, stereotypes and unconscious bias, underpinned by principles of the national model of professional learning. The team aims to support all practitioners in Scotland over the next four years to critically reflect on their own biases and how they impact on their practices in the classroom, on their structures and planning within schools, and on their wider learning community.

As with all professional learning, training can often be simply the first step on a journey. Further reflection, professional dialogue and collaborative planning and practices will need to be put in place in schools, early learning and childcare centres and community learning to truly challenge gender imbalances in education.

The Improving Gender Balance pilot: countering self-selection in clubs:

One secondary school in Scotland was keen to find ways to enable all their students to experience the fun and reward of STEM challenges, but found that asking for volunteers meant that a lot of the young people ruled themselves out.

'We've had a long tradition of having a science club that has been very successful and won awards, and various extra-curricular activities. But, when we look at who engages, it tends to be the same self-selecting group of pupils.

'We realised that a number of our pupils were very, very good, had the right skills to do well at these sort of events and would enjoy them, but wouldn't go to the traditional lunchtime or after-school clubs to take part.

'One of our approaches was to select a large STEM challenge (Shell's 'The Bright Ideas Challenge') and run it for the whole of S2 (ages 12–14). Every S2 pupil got to take part in it and then only after they'd all experienced it did we ask for groups of volunteers to continue with it further. We ended up with mixed gender groups, which we wouldn't normally have had. Speaking to the girls who had been involved, they wouldn't have volunteered normally to take part. It gave them the opportunity to experience STEM in action' (Institute of Physics, 2018, p.23).

Further case studies can be found in the *Improving Gender Balance* report (Institute of Physics, 2018). In the *Improving Gender Balance*

Figure 2. Tackling common misconceptions.

toolkit, practitioners, school and system leaders are asked to critically reflect on the statements in Figure 2. To what extent do they challenge assumptions about gender in education?

How do schools' policies and practices work to break down gender, and other, barriers for learners? There is an ethical prerogative to taking an enquiry stance to improve outcomes for children, young people and adult learners.

Alongside delivering training, the *Improving Gender Balance and Equalities* team works with schools and early learning providers to expand and embed the approaches, including developing a gender champion network and a gender schools award to grow and spread best practice. For a literature review of the *Improving Gender Balance and Equalities* work, see Education Scotland (2019), and practical resources to support this journey of understanding are freely available on the Education Scotland website (see link below).

Questions to consider for developing professional learning

In the past twelve months, how many teachers and practitioners can say that they have experienced professional learning that **deepened** their knowledge and understanding, **challenged** their thinking and was **collaborative** in nature? Is the time and space for their learning protected in their setting? Primary science practitioners *teach* enquiry skills; how often do they have an opportunity to *enquire* into their own practice?

For those designing professional learning opportunities, some challenge questions are posed: How much do programmes rely on the 'sage from the stage' approach? How often is the experience, knowledge and skills of participants utilised to co-create new shared knowledge?

The national model provides a further focus to move professional learning forward in Scotland and to pose questions for the wider education world. To learn more about the model, and for supporting documents, please visit: https://professionallearning.education.gov.scot/

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The SSERC Primary Cluster Programme in Science and Technology – Impact on teaching and learning

● Kath Crawford ● Kevin Lowden. ● Stuart Hall ● Euan Mitchell
● Teresa McErlean ● Hayley Sherrard ● Lynn Daley

Abstract

This paper considers the findings of a recent multi-method research project that assessed the impact of a national Career Long Professional Learning (CLPL) programme, which suggest that teacher CLPL, particular in science and technology education, is particularly effective when it adopts a collaborative mentoring approach deployed across school clusters. This model is underpinned by collaborative professional dialogue, action research and a focus on promoting teachers' confidence and expertise in science and technology using practical skills as a vehicle. We examine the model adopted by the programme, drawing on research evidence in the literature on effective professional learning for teachers and, in particular, apply Desimone's (2009) conceptual framework. The paper identifies key components of the programme responsible for its effectiveness and concludes by reflecting on the implications of the findings for tackling the challenge of promoting science literacy and attainment.

Surveys of >12000 pupils have shown, inter alia, that the programme encourages the preservation of positive pupil attitudes towards science.

Keywords: Professional learning, primary science and technology, teacher mentors, collaborative enquiry

Background

Publication of the TIMSS report (Martin *et al*, 2008) was something of a wake-up call to the education community in that Scotland's relative position was perceived to be weaker than had previously been the case. A series of recommendations followed on from the TIMSS report (Donaldson, 2010). In relation to the work discussed here, three of Donaldson's recommendations are particularly noteworthy:

- ❒ *Recommendation 33 – The balance of CPD[1] activities should continue to shift from set-piece events to more local, team-based approaches that centre around self-evaluation and professional collaboration and achieve an appropriate blend of tailored individual development and school improvement.*
- ❒ *Recommendation 34 – Teachers and schools should plan and evaluate CPD more directly on its intended impact on young people's progress and achievements.*
- ❒ *Recommendation 42 – Teachers should have access to high quality CPD for their subject and other specialist responsibilities.*

The need for high quality, effective professional development to support teachers of primary science and technology was further highlighted in a report (SEEAG, 2012), which concluded that the majority of primary teachers in Scotland lacked confidence in teaching about science.

In 2012, the Scottish Government invited SSERC to plan a professional development programme that would address some of the concerns about the quality of science provision in the primary sector. The SSERC Primary Cluster Programme in Science and Technology (PCP) was developed to pilot a systematised approach to CLPL that would offer *all* primary teachers opportunities, within an existing learning community, to raise their levels of confidence and expertise in science and technology, thus providing a better experience for, and engagement from, their pupils.

PCP aims to address the challenge of how to make available a programme of effective CLPL that offers opportunities to *all* primary teachers within specified communities to improve their levels of confidence and expertise. Within Local Authorities in Scotland, schools are usually associated in groups and, most frequently, these consist of several primary schools and their associated secondary schools. Whilst the names of the local groups vary (e.g. Associated School Group, Learning Community, Cluster etc.), the groups of schools that have taken part in PCP are referred to as clusters. The first tranche of clusters joined the programme in September 2012.

Aims of PCP

Through PCP, SSERC seeks to:

- provide opportunities for every primary teacher within the selected school clusters to raise their levels of confidence and expertise in science and technology, thereby increasing pupil engagement in, attitude towards, understanding and knowledge of science and higher-order problem-solving skills;
- develop further the range of pedagogic and assessment skills of all primary teachers within the clusters in science and technology contexts;
- develop further the individual professional practice of participants;
- establish collegiality between schools within a cluster and, where appropriate, between clusters; and
- lead to greater engagement of learners and increased aspirations to pursue a career in science, technology or engineering.

Programme outline

Several months before participation in the programme, initial contact is made at a high level with a Local Authority (LA) and, at that point, the LA is invited to make a commitment in relation to its participation over a two-year period. There follows significant liaison between SSERC senior management and the Quality Improvement Officer (QIO), or equivalent, in the LA to discuss requirements for participation; such discussions include the need for any participating cluster to have science and technology on its cluster improvement plan. Since 2015/16, SSERC has additionally requested that a LA nominates a cluster whose schools have a significant proportion of pupils from areas of deprivation, as measured by the Scottish Index of Multiple Deprivation. Once nominated, SSERC personnel meet with the Cluster Management Group (CMG) and QIO to agree the level of their support required. The CMG nominates mentors who must have a keen interest in science and technology, although they do not need to have a background therein. Each cluster selects several teachers who will assume the role of 'mentor'.

The role of a mentor, which is explored further in the next article, includes working with other mentors to assess the science and technology CLPL needs of teachers in their cluster and to design and implement a programme of experiential CLPL[2], tailored to address these identified needs.

Figure 1 portrays the sequence of activities that occur within PCP.

The PCP provides opportunities for CLPL at two levels:

- Mentors initially participate in immersive, experiential, residential CLPL (3 days' duration) to help raise their levels of confidence and expertise. During this phase, mentors are provided with resources (electronic and physical) and will continue to be able to access further advice and guidance from SSERC personnel; and
- Non-residential, experiential CLPL for all teachers in the cluster via programmes designed and organised by cluster mentors.

Mentors carry out a needs analysis of the CLPL required by teachers across the cluster, then design and start to implement a tailored programme of CLPL. Later in the implementation phase, mentors participate in a second, immersive, residential event (generally nine months after the first).

At this second residential mentor cluster, groups, *inter alia*, highlight the progress and impact of their work with teachers and pupils. During the following academic year, clusters are eligible to receive support through the Sustain and Extend Programme available through a financial contribution from the Primary Science Teaching Trust (PSTT).

Grants from the Edina Trust allow all schools that participate in PCP an opportunity to acquire classroom resources that complement the CLPL.

Thus, PCP provides:

- CLPL for mentors and teachers;
- resources for CLPL; and
- classroom resources.

Evaluation

The Robert Owen Centre at the University of Glasgow was commissioned to evaluate the effectiveness of the SSERC PCP. The findings from the final evaluation of the latest phase of the PCP have recently been made available (Lowden *et al*, 2019). The main aims of the evaluation were to:

- gauge the standard of the CLPL and satisfaction rates regarding the CLPL across the participating LAs;
- collect data on mentors' needs, aspirations and plans, and assess the impact from the perspective of mentors, teachers, Headteachers and other relevant key stakeholder groups;
- collect data from pupils to contribute to assessing the impact of the Programme; and
- use the emerging findings to inform and refine the development of the Programme and to feed into the knowledge exchange process with SSERC's LA members and other relevant professional bodies.

In the evaluation (Lowden *et al*, 2019), a range of research methods was used including:

- surveys of all teachers involved, teacher mentors, *all* Headteachers/senior management in involved clusters/LAs;

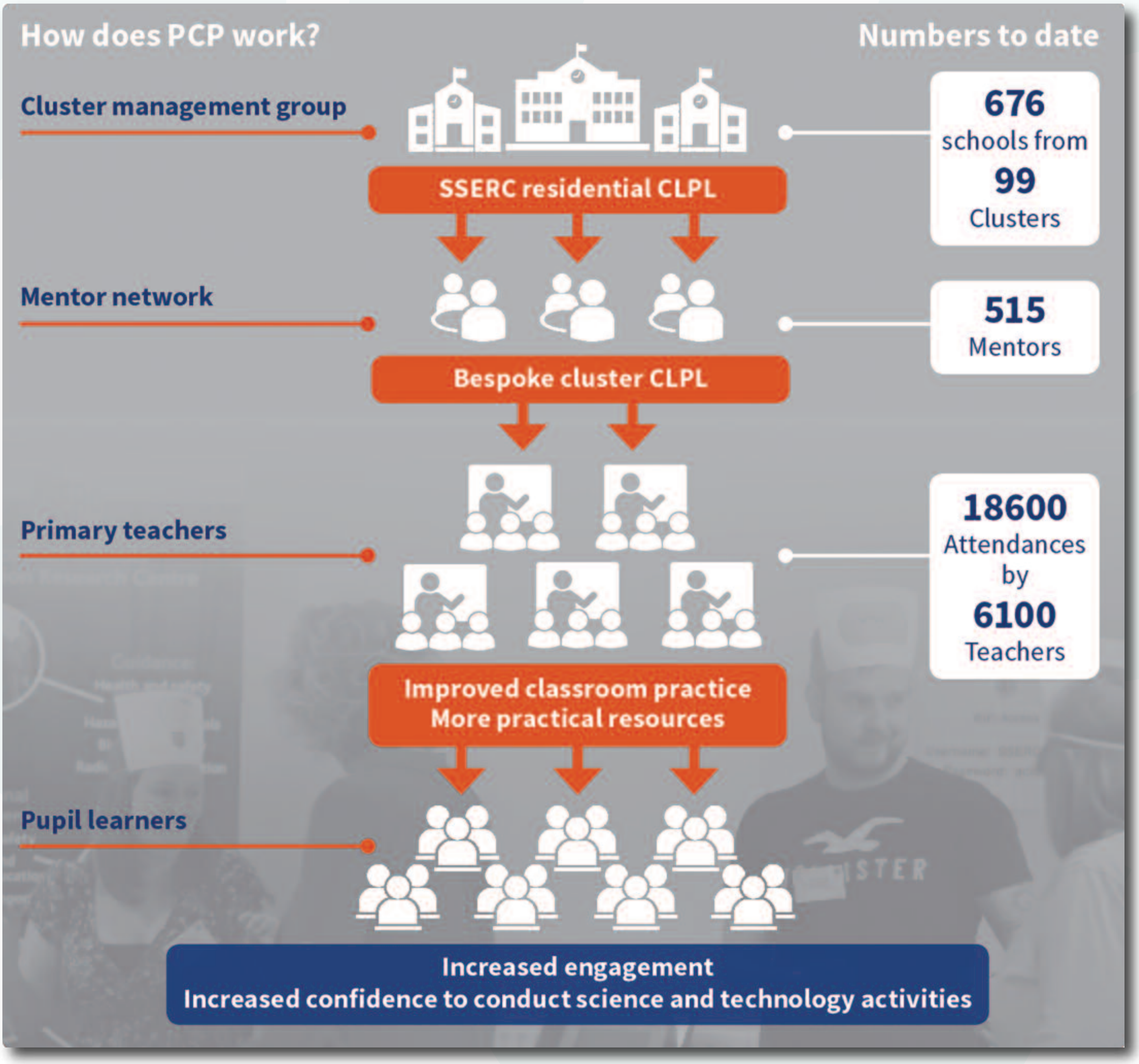

Figure 1. Overview of PCP with data on participation and level of involvement – April 2012-March 2019.

- focus groups with mentors;
- mentors' reflective diaries; and
- observation of SSERC and SSERC-approved CLPL events.

Results from the evaluation indicated that, by the end of the first phase (April 2012-March 2018), PCP had been successful in achieving the programme's aims. In addition, it was recognised that the Programme also empowered mentors to:

- adopt a collaborative action research model to inform practice and provide CLPL sessions;
- provide support and guidance between staff in school and across cluster schools; and
- facilitate a network that has shared ideas and expertise, and influence the direction of appropriate CLPL.

There was consensus across mentors, senior management and other teachers in the schools regarding the CLPL Programme's high level of impact. Almost all respondents in these groups agreed that the Programme had provided consistently high quality relevant CLPL that had had a positive impact across the range of evaluation criteria detailed above. Moreover, it was clear from the evaluation findings that the PCP was addressing key recommendations from Donaldson (Donaldson, 2010) by encouraging more locally based professional CPD, where teachers and schools planned CPD collaboratively to better meet the subject development needs of teachers and consequently enhance the progress and achievement of pupils.

The Scottish Government, as principal funders of PCP, were keen to gather evidence on whether there was impact on learners in the clusters, particularly regarding learners' self-efficacy, engagement and views on science. To meet this requirement, a strand of the evaluation focused on gathering pupil data and, from the autumn of 2015, both pre- and post-CLPL programme pupil surveys were conducted (P2–P7, ages 5-11). Baseline and follow-up surveys of pupils took place in the same year as teachers from their school were involved in the PCP CLPL. In the final three years of Phase 1, the evaluation collected baseline and follow-up questionnaires from almost 12,000 pupils.

Impact

There is substantial research literature and professional advice on what constitutes effective professional learning and development for teachers, and possible models for implementation to enhance effectiveness (see, for example, Joyce & Showers, 2002). Our approach, with teacher mentors supporting their cluster schools at its core, is grounded in research evidence and the wider literature (Duncombe & Armour, 2004; Smith & Nadelson, 2016). Hargreaves' (2005) research identified the value of mentoring and coaching in providing a 'critical friend' to support teachers' professional development.

We recognise that the PCP has, within its structure and *modus operandi*, a range of elements that are described in the literature as best practice. The delivery and ethos of PCP parallels the observations of Desimone (2009) in which she argues that '*there is an empirical research base to*

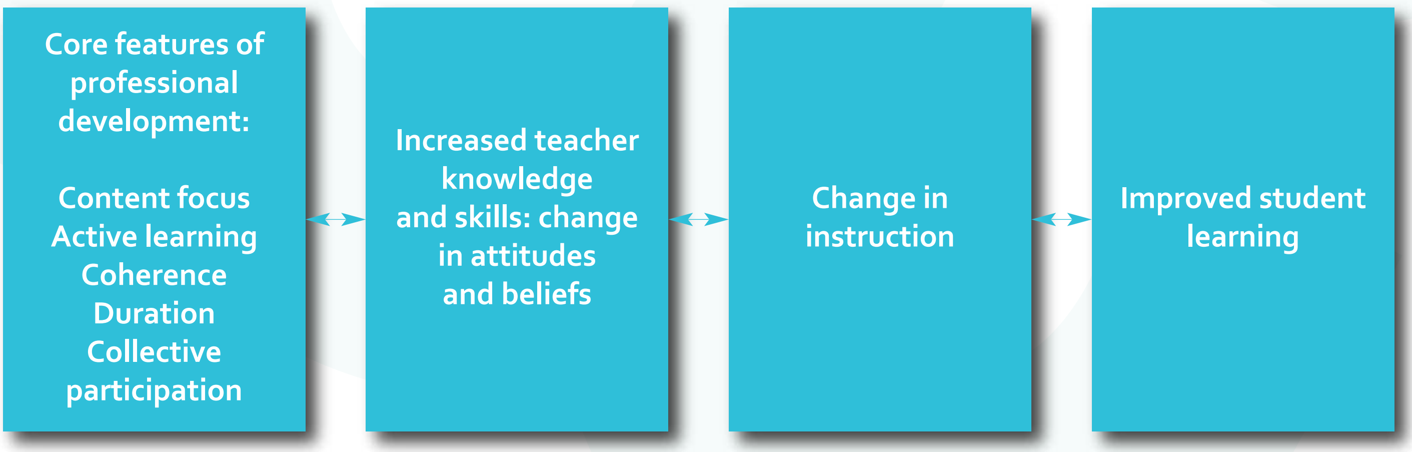

Figure 2. Proposed core conceptual framework for studying the effect of professional development on teachers and students (taken from Desimone, 2009).

support the identification of a core set of features of effective professional development' (Figure 2).

Our view is that the PCP displays most, if not all, of the elements for effective CLPL as described by Desimone (2008). It is appropriate, therefore, for us to consider 'improved students' learning'.

Reviewing the findings from the pupil survey, we conclude that the majority of pupils in the study are enthusiastic about school and about the subjects they study. After PE and ICT, science was ranked third most popular subject for all pupils. There was some evidence to suggest that, over a year, the enthusiasm of both P2 (ages 5/6) -P4 (ages 7/8), and P5 (ages 8/9) - P7 (ages 10/11) pupils towards school and all their subjects began to decrease. Pupil responses from the P5 - P7 group showed relatively positive attitudes towards science, with substantial numbers indicating their enthusiasm for science education in school and an interest in pursuing science beyond school. A majority of pupils in both the P2 - P4 and P5 - P7 cohorts enjoyed taking part in a range of science-related activities. *Doing experiments in class* and *Going to the science museum or science centre* were particularly popular across both groups. These findings indicate that learning science experientially may be fundamental in engaging young people with science and helping to maintain their enthusiasm for the subject. More than 70% of pupils were open to the idea of further involvement in science after completing school. Moreover, the data indicated that, in schools with higher PCP Headteacher impact ratings, the pupils were significantly less likely than their peers in schools with a lower Headteacher impact rating to see their attitudes and beliefs about science follow the general 'negative shift' over the evaluation period. This suggests that the SSERC CLPL may, in addition to supporting pupil enjoyment of science activities and confidence in conducting science tasks, also encourage the preservation of positive pupil attitudes towards science.

The future

This paper summarises PCP at the end of March 2018, when the programme had reached all 32 Local Authorities across Scotland. From April 2018, SSERC has been working with new clusters from across 13 LAs on Phase 2 of PCP. With ongoing support from PSTT, we have been able to put in place a 2-year programme, which will allow for greater opportunity for further experiential professional learning.

The Scottish Government recently set out in its 'STEM Strategy' (Scottish Government, 2017) several challenges, including the need to ensure that:

- All learners experience relevant and engaging STEM learning, in both formal and informal learning settings, which equip them with skills and capability to be scientifically, technologically and mathematically literate citizens, fully involved in our society as it becomes increasingly reliant on science and technology, and informed and empowered to take decisions about their lives and society as a whole.
- There is equality of access, opportunity and outcomes in STEM learning and STEM experiences for everyone, regardless of gender, background or circumstance or geography.
- There is increased practitioner confidence in STEM learning in the early years, primary years and in community, learning and development settings and increased practitioner engagement in STEM professional learning opportunities.
- Through the development and delivery of a new and significantly enhanced professional learning package in relation to STEM, all early learning practitioners, primary and secondary teachers, technicians and community learning and development practitioners will have the opportunity to build their capacity to deliver effective STEM learning.

It is our belief that PCP and its associated workstreams are making a significant contribution to the Government's aspirations. However, meeting these aspirations as laid out in the Government's recent STEM Strategy will require additional significant investment. There are some 2000+ primary schools across Scotland and, in the period to the end of March 2019, the PCP has worked with 676 of them. The strengthened partnership between SSERC and PSTT will continue to deliver high quality CLPL opportunities, but the finite resource pool that is currently available will inevitably mean that the benefits of the PCP will not be felt by *all* primary schools in Scotland for several years to come.

Acknowledgements

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[1]The term Continuing Professional Development (CPD) has, in large part, been replaced by Career-Long Professional Learning (CLPL) and we will, unless quoting the work of others, use CLPL throughout.

[2]In this manuscript we use the term experiential to describe activities in which participants gain first-hand experience of, and confidence in, hands on, practical science and technology; participants also reflect on how such activities might be used in classroom settings.

The SSERC Primary Cluster Programme in Science and Technology – Reflections from a classroom practitioner

● Nicola Connor ● Euan Mitchell ● Emma Bissett

Abstract

The Primary Cluster Programme in Science and Technology (PCP), a programme of professional learning for primary school practitioners, continues to have a significant impact on the quality of learning and teaching in schools involved. A major feature of PCP is the creation of a group of mentors who share their expertise amongst their colleagues in primary schools in their clusters. Here, we explore the journey of one mentor through the programme and reflect on changes in her own classroom as well as those of her colleagues.

Keywords: Professional learning, primary science and technology, teacher mentor, programme impact

Background

Since April 2012, the Scottish Schools Education Research Centre (SSERC) has, with the support of a number of agencies (including the Scottish Government, STEM Learning, the Primary Science Teaching Trust (PSTT) and the Edina Trust) been responsible for the delivery of the Primary Cluster Programme in Science and Technology (PCP). Through PCP, SSERC seeks to work with teachers from across a set of primary schools to provide a group of teacher mentors.

Briefly, the first part of PCP provides opportunities for Career-Long Professional Learning (CLPL) at two levels:

- mentors initially participate in immersive, experiential, residential CLPL of 3 days' duration to help raise their levels of confidence and expertise in science and technology. In addition to workshop sessions, mentors are provided with resources (physical and electronic). Ongoing advice and guidance from SSERC personnel is offered; and
- the mentors are tasked with developing a programme of experiential professional learning for all primary teachers in the cluster. The professional learning programme is delivered either by the mentors or by external providers whose contributions have been approved by the team at SSERC.

Some nine months later, mentors participate in a second, immersive residential event, which falls during the implementation of the tailored cluster professional learning programme. At this second residential, mentor cluster groups highlight, *inter alia*, the progress and impact of their work with teachers and pupils. During the following academic year, clusters are eligible to receive support through the PSTT Sustain and Extend Programme (SEP), available through a financial contribution from the Trust. Further detail on the structure of PCP is available in the first article in this issue (see Crawford *et al*, 2020). Since its inception, PCP has been subject to external evaluation and a wealth of data is available on its impact on mentors, teachers and pupils (Lowden *et al*, 2019). In this article, we focus on the impact on teacher mentors and describe how PCP has been a powerful vehicle for change in learning and teaching in one cluster in West Lothian.

In the context of impact on mentors and their own personal development, we will reproduce some of the data relating to the impact of CLPL from SSERC on the roles of mentors (data taken from Lowden *et al*, 2019). Following both CLPL events, participants were asked about the extent to which they expected to take, or had taken, on a greater role in science and technology developments in their school, cluster, Local Authority (LA), and/or nationally. Table 1 demonstrates that, after a relatively short period of time, the overwhelming majority of mentors had taken on development roles in both their own school and in their cluster. There was also evidence that some mentors had embarked on science development roles within their LA and, in a small number of cases, had taken on a role at a national level.

Table 1. Impact of SSERC PCP: how well did the CLPL facilitate the mentors' role?

I will / I have taken on a more significant role in science and technology developments	& Very or quite likely from 1st residential event	& Has happened by 2nd residential event
In my school (N=428 / 370)	98	93
In my cluster (N=431 / 373)	98	90
At local authority level (N=430 / 363)	47	21
At national level (N=427 / 364)	15	9

(Numbers in dark blue = after residential 2). (Data from Lowden *et al*, 2019.)

The observations of mentors are supported by those of senior managers, who indicate substantial impact from the Programme on school and cluster developments in science and technology roles.

For example, almost all senior management responses (90%) indicated that *their staff had taken on a more significant role in science and technology developments*, and a large majority (79%) also reported that *their school had taken on a greater role in science and technology developments within their cluster*. There was less evidence of impact at the LA or national level as a result of the Programme; this is hardly surprising, since the Programme is designed primarily to foster developments at a school and cluster level (see Table 2).

We believe that the experiences of one of the authors (NC) are mirrored by those of significant numbers of mentors across Scotland. There is ample evidence that the PCP is ensuring improved learning and teaching for pupils across the primary sector at a time when government policy and strategy call out for such changes (Donaldson, 2010; Scottish Government, 2017). In the next section, we will explore the impact that participation in the PCP has had on one of the authors (NC).

What is it like to be a mentor?

Nicola Connor is a SSERC mentor and class teacher at Peel Primary School in the Inveralmond Community High School Cluster in West Lothian (for further information about Nicola, see SSERC, 2019). Prior to her involvement in PCP, Nicola had little by way of a scientific background, but a keen interest in the subject area. In 2016/17, Nicola was one of 6 teachers to represent the Inveralmond Cluster at PCP.

Table 2. Changing role of the school in science and technology developments.

Action	% has happened
Staff have taken on a more significant role in science and technology developments in the school (N=215)	90
The school has taken on a greater role in science and technology developments within our cluster (N=210)	79
The school has taken on a greater role in science and technology developments at local authority level (N=196)	25
The school has taken on a greater role in science and technology developments at national level (N=194)	7

(Data from Lowden *et al*, 2019.)

Soon after the residential at SSERC, Nicola and her fellow mentors met to discuss what the CLPL programme would look like for the Inveralmond Cluster. It was agreed that, to know what the teachers wanted and needed, they would have to assess teacher confidence on their delivery of science within the classroom. Teachers were invited to complete a questionnaire to identify those areas of the curriculum that they found challenging in terms of delivery. Based on the data provided, Nicola and the mentors were able to design a bespoke CLPL programme that met the teachers' needs, utilising the expertise of both mentors and external providers.

All mentor-led sessions were fully attended and very well received. One of the factors that was crucial to the success of the mentor-led programme of professional learning was the excellent support from the cluster schools' senior leadership teams in assuring that attendance was compulsory. Following the implementation of the CLPL programme, Nicola and her fellow mentors carried out a follow-up survey and the data gathered indicated that staff found an increase in their levels of confidence in their delivery of science. This in turn has also enabled the associated cluster primaries to further enhance the links with the associated secondary school.

Knowing that teachers require appropriate equipment to run engaging science lessons, Nicola and her fellow mentors decided to create several shared cluster resource boxes. These boxes would be stored centrally and accessed by the cluster primary schools. Some of the resource boxes were purchased with additional support via a grant from the Edina Trust. This additional funding stream allowed access to enhanced teaching aids, guidance and worksheets provided and written by the mentors. During the two years since they became available, the resource boxes have been incredibly well used and remain popular. This model has been highlighted as an example of excellent practice.

Inveralmond Community High School had previously worked closely together on moderation of literacy and numeracy; however, through PCP, the Cluster has worked much more closely together on science and the mentor group is still very active two years on, despite the challenges of staff turnover. Nicola continues to attend other SSERC professional learning events and, in 2018, won a UK-wide ENTHUSE STEM award for her Excellence in STEM Teaching[1].

Nicola is now the lead science co-ordinator for West Lothian Council as they progress through the PSTT SEP. She feels that this leadership role has provided her with an excellent opportunity to unite the PCP clusters and has given the mentors a larger platform from which to share expertise, experiences and contacts across the LA. In her role, she has been able to recruit new mentors who are incredibly keen to share the robust SSERC CLPL that they have undertaken to continue the delivery of science CLPL across the LA. The LA, following the success of PCP, has now set up a STEM Strategy Group to create a STEM agenda/rationale/aims for the authority, in which Nicola and a number of mentors are included.

The impact that the programme has had on the pupils across the cluster has been amazing. Pupils' perceptions and misconceptions of scientists and science in general have been addressed. There is now a consistent whole-school approach to science; the school proudly shares its work through social media and the school blogs. Nicola states that the pupils in her school love science and that they are more motivated to learn. Everyone, regardless of age or stage, gets a new experience in science and now the school seeks to use expertise from outside the school, bringing in partner providers and parents with a science background to talk to the pupils more frequently.

Through her journey in PCP and PSTT SEP, Nicola herself has grown in confidence and, in addition to winning the 2018 ENTHUSE Award for Excellence in STEM Teaching, she has been involved in several exciting science opportunities. She has talked live via video conferencing to teachers in Victoria, Australia; she was included in an article for an EU report about science teaching in different countries; and, most recently, she talked about her experiences in PCP as part of a joint reflective seminar, *Scotland's National Primary Cluster Programme in Science and Technology: Impact on Learning and Teaching*, with SSERC at the 2019 PSEC conference.

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Co-teaching as a viable model for raising teacher confidence in the delivery of primary science within a small rural school in Northern Ireland

● **Kathy Schofield**

Abstract

This article explores the experiences of classroom teachers, a science subject leader and a Principal taking part in a project on co-teaching practice. The study discusses the findings from a small-scale action research project involving a Primary Science Teaching Trust (PSTT) Fellow (the researcher) co-teaching with each member of staff in a rural school in Northern Ireland. The Principal supported the science subject leader to introduce the co-teaching model as a method for bringing about change in teaching practice, to enhance teaching and learning in science. The staff worked collaboratively with the researcher to enhance the delivery of practical science enquiry. Following the co-teaching sessions, the teachers were encouraged to work with the children to carry out an investigation each half term, and share this with the rest of the school by contributing to a whole school display wall demonstrating good practice. The approach was successful in this setting, with the unreserved support from the Principal; however, in a different context with a greater number of people, a different mixture of personalities and support structures, the outcome could be different.

Context

The Primary Science Teaching Trust (PSTT) awards primary teachers for the delivery of good practice in science, with award winners becoming Fellows of the PSTT's virtual College (Shallcross *et al*, 2015). Northern Ireland has seen many award winners and these Fellows have been instrumental in many innovations (e.g. the *Titanic* resource, McDaid, 2016), shaping the future of professional development for primary teachers in this region.

Nevertheless, within many locations in Northern Ireland, there are schools, particularly those in rural areas, where teachers lack confidence in the delivery of science. This is evident in the number of schools requesting PSTT support for the delivery of practical primary science. There is a need for these teachers to have high quality professional learning opportunities, principally in the delivery of hands-on investigations.

As a PSTT Fellow and Area Mentor for Northern Ireland, I was approached by a small rural school to support them in raising the profile of science enquiry across the school. Being aware of how little professional development rural schools receive, a model of co-teaching (e.g. Kohler-Evans, 2006) was suggested so that teachers had the opportunity to trial new approaches to teaching and learning. The aim was to support teachers in their own setting by utilising the resources they have and working with them to enhance the curriculum that they are currently delivering. This research aims to explore co-teaching as an approach to support teachers in the delivery of science in a school that has had little or no access to Continued Professional Development (CPD).

Implementing the research

Why co-teach?

Working collaboratively is the foundation of co-teaching, which involves two or more teachers who plan, teach and evaluate their teaching together to provide a rewarding and informative practical experience of science for the children, whilst also benefitting from the experience themselves by learning from each other. When teachers begin working together, and share the full responsibility for planning, teaching and reflecting on lessons, there is *'automatically a greater range of action possibilities'*, and collective activity enables each individual to develop, since *'any individual can now enact teaching practices not available in individual teaching'* (Roth & Tobin, 2005, p.x).

Co-teaching has been part of inclusive practices for nearly 30 years (Bauwens, Houcade & Friend, 1989). There is growing evidence of its effectiveness, with co-teaching implementations associated with significantly improved student outcomes (Benningfield, 2012). Although much has been written about the importance of co-teachers having a strong professional relationship (Kohler-Evans, 2006), and co-teaching often being referred to as a 'professional marriage' (Friend, 2014), this emphasis must be weighed against the purpose of co-teaching to ensure improved student outcomes. In this research, the emphasis initially is on building a relationship with teachers in a short time span, whilst being mindful that the shared experience will impact upon children's learning in the long term.

Planning the co-teaching lessons

The instructional potential of co-teaching makes it imperative that those involved collaborate effectively in designing and delivering instruction and interventions that will best meet the unique needs of the teachers and pupils. There are a large number of factors to be taken into consideration on how to structure and deliver the shared experience, including practical factors pertaining to resources, classroom layout, and the amount of time available for each lesson. In this study, 3 co-teaching approaches from Cook and Friend (2017, p.165) were considered at the pre-planning stage:

- *One Teach, One Observe.* One of the advantages in co-teaching is that more detailed observation of children engaged in the learning process can occur. With this approach, co-teachers can decide in advance what types of specific observational information to gather during instruction and can agree on a system for gathering the data. Afterwards, the teachers analyse the information together. The teachers should take turns teaching and gathering data, rather than assuming that only one person should be the observer.
- *Teaming.* In teaming, both teachers share delivery of the same instruction to a whole class. Some teachers refer to this as having 'one brain in two bodies' or 'tag team teaching'. Most co-teachers consider this approach the most complex but satisfying way to co-teach, but it is the approach that is most dependent on teachers' styles.
- *One Teach, One Assist.* In this approach, one person would keep primary responsibility for teaching while the other professional circulated through the room providing unobtrusive assistance to children as needed. This should be the least often employed co-teaching approach (Friend, 2014), since it does not use the skills of both teachers or support the concept of co-teaching being a shared experience in its purest sense.

Project background

The school in this study is a rural school with 220 children; there are 7 classes, 7 members of staff and the science subject leader, who is also Vice Principal. From the outset, the project had the full support of the Principal who, on my first visit to the school, immediately convened a staff meeting so that all staff would hear about the project personally, reinforcing a positive approach with their own personal enthusiasm for the research.

The project ran for a full academic year, spanning either side of the summer break. It should be noted that, in the Northern Ireland curriculum, 'science and technology' comes under the umbrella of the 'World around Us', which also includes history and geography. As a result of these subjects being amalgamated, and the curriculum being topic-led, science in some schools has 'dropped off the radar'. Compounding this problem is the demise of subject advisers in education boards and the small availability of science-specific CPD, resulting in limited support for primary teachers.

Before the planning meetings, each teacher completed a questionnaire requiring them to share their most recent qualification, length of career, phases taught, training, level of confidence in the delivery of practical science and in each area of the science curriculum. This information gave an understanding of their background within teaching and how they felt about teaching practical science. Lack of professional development opportunities were borne out by the responses concerning training: none of the respondents had received any formal training in science in the previous 10 years, whilst 75% had received training of 1-3 days in literacy within the 10-year timescale but, interestingly, only 12.5% in maths during the same period.

The co-teaching experience

Interactions with the Key Stage 1 (ages 5-7) teachers at the planning phase focused more on planning for progression rather than choice of co-teaching models, with *Team Teaching* selected due to the significant amount of time co-planning. Despite the deficiencies in discussing the co-teaching model at length, the initial experiences were rewarding, with future targets identified for both the teachers involved and the researcher. Co-teaching generated the opportunity for reflective teachers to recognise the need to spend more time on practical science and to increase the use of scientific vocabulary. Questioning children's understanding throughout the investigations without negating the experience also became apparent during the sessions. Although the researcher had only been at the school a short time, the experience of collaborating with teachers during the co-teaching sessions was a useful tool for reflecting upon teaching approaches. Researching co-teaching approaches highlighted the importance of interpersonal communication to enhance the effectiveness of communication between professionals (Adler, Rosenfeld & Proctor, 2015). Working with another colleague creates an awareness and reflection of one's own strengths and weaknesses. This aspect of co-teaching was demanding but valuable, recognising the need to adapt your approach to each teacher to get the best out of the situation. The skill of building positive working relationships was crucial to providing the children with a constructive environment for learning.

Co-teaching in Key Stage 2 provided two different experiences: the *One Teach, One Observe* approach, and *Teaming* with elements of parallel teaching. Both these sessions were pre-planned with the teachers, as these members of staff had mixed ability classes, including some children with special educational needs, and they wanted to be fully briefed on how the sessions would run. Both teachers were receptive to experiencing practical investigations involving active hands-on experiences for the children related to their current topics.

The *Teaming* session involved the modelling of the digestive system, which was a new experience for the teacher. The digestion lesson leads the children in groups of three through a set of instructions to show the changes that occur as food travels through the body and is finally excreted (Figure 1). They begin by mashing Weetabix and banana with a knife and fork to replicate their teeth. Then, they use a food bag to represent their stomachs and, finally, move the mashed moist food through tights to represent the small and large intestines. At each stage, they add the appropriate liquid to help break down the food: e.g. saliva, stomach acid, bile and pancreatic juice. This modelling of the procedure supports the children to understand the process of digestion and gives the opportunity to introduce the scientific vocabulary in context.

Figure 1. Modelling digestion: From the stomach to the small intestine.

During the practical activities the teacher and the researcher alternated pausing the lesson to recap children's understanding and reinforce scientific vocabulary. There was no pre-fixed agenda for this to happen; it evolved due to the interaction between the two teachers as reflective practitioners. This was deemed to be a rewarding experience for both teachers. Following the session, the class teacher was surprised to hear that a previously quiet child had taken the lead in his/her trio. This feedback highlighted the positive impact of co-teaching by having a second teacher in the room, which allowed for more observation and interaction with pupils. The teacher was also impressed with the way that the whole class had responded to the practical approach to teaching digestion and felt it would significantly support their learning. Both teachers enjoyed the co-teaching experience and recognised the positive outcomes of a mutual focus, with the children benefitting from two teachers collaborating to support their learning.

The *One Teach, One Observe* approach was requested by the second teacher involved in this study, so that they could gain an understanding of the researcher's approach to scientific enquiry. In response to the initial questionnaire and discussions prior to the session, this teacher acknowledged enjoying science and was confident teaching the subject. There was a reluctance to be involved in the planning of the session, despite reassurances that it could be taught collaboratively. The *One Teach, One Observe* model was agreed so that the observer could determine how a class that needed a lot of support would respond to practical science enquiry involving an open-ended investigation.

As part of the topic of 'Rescue at Sea', the session was placed in the context of the famous Victorian, Grace Darling, who assisted in the rescue of survivors from the shipwrecked *Forfarshire* in 1838. The lesson took place in the school hall, with the children put into groups of 4 and asked to replicate a distress 'flare' from the *Forfarshire* crew. The children were given a photograph of other children launching a Stomp rocket and asked to produce their own, before considering which group had created the best design. They were offered a selection of equipment for their own design. Initially, the children were hesitant and unsure, as they were not used to working in this way.

Reassuring the children that they could take any equipment they thought appropriate, and convincing them that they were scientists testing prototypes, gave them the confidence to go ahead and test their designs. Their first attempts were unsuccessful and the teacher-observer wanted to intervene, but the researcher advised to wait for one group to succeed and the others would then

Figure 2. Stomp rockets: testing.

follow their lead. This happened (Figure 2) and the children then devised a way of measuring the distance travelled by the rockets. At this point, the teacher became as excited as the children and stated how pleased they were with the outcome. As with other lessons, the children were paused in their investigations to discuss and evaluate their work, using scientific vocabulary and, again, the teacher stated how pleased they were with their answers.

The Principal later noted that the teacher was amazed at what the children had achieved and how much the teacher had enjoyed observing them working in that way. The opportunity for a teacher to observe children working independently can be one of the key factors in influencing teachers to consider change in their own practice.

Teacher reflections on the co-teaching experience

I returned to the school after a period of three months to interview the staff and discuss the developments in science since my previous visits. In the interim, I had remained in touch with the subject leader to offer support with planning and progression as and when needed. The responses from the teachers were as follows:

'I was surprised that I didn't feel threatened by your presence in the classroom. I actually enjoyed the collaborative experience and would like to do more co-teaching. It gave me confidence in my own ability to teach science.'

'At first I thought raising the profile of practical science would mean a lot of extra work, it does require more preparation but it is worth it as I now see the engagement and enjoyment the children get from the experience.'

'The science subject leader has brought us all together and supported us to deliver more science enquiry lessons, which the children really enjoy. Their enthusiasm inspires me to make the effort to gather the resources to deliver practical lessons.'

Discussions with children confirmed that they had been taking an active part in practical science enquiry sessions. There was evidence of problem-solving and children taking the lead in scientific enquiry, both at school and at home. There were up-to-date displays showing science progression across the whole school and evidence of scientific vocabulary in most classrooms. P7 (aged 10-11) children shared their STEM project on Wind Turbine design within a school assembly prior to presenting their findings at the Young Innovators event in Belfast. At a subsequent meeting, the Principal confirmed that science was now firmly established on the school development plan and that the school had decided to apply for the Primary Science Quality Mark (www.psqm.org.uk).

Thoughts on the co-teaching model were shared in an interview with the Principal:
'The current in-service model consisting of those teachers who are interested in a particular area of the curriculum attending training and reporting back to others has its drawbacks: cost and time to implement change, particularly in a small school. Whilst in-house co-teaching has the desired impact because you bring every member of the team with you in relation to new aspects of learning. For this to have any element of success, it is essential that senior managers know and understand their staff well if they want their school to experience co-teaching.'

Reflection

This experience highlighted the importance of interpersonal skills, in particular the need to clearly communicate the concept of co-teaching as a model for sharing, not a one-sided experience for the class teacher to be influenced by the researcher. There needs to be awareness that, when working alongside teachers in school, the researcher is not perceived as the expert. The whole concept of co-teaching is that each participant benefits from the experience, not just the classroom teacher. The exercise of co-teaching helps all those involved to reflect upon their own practice. What was surprising was how easy and enjoyable the experience of co-teaching became, with teachers I had not met before, which gave rise to the opportunity to reflect upon personal teaching skills. Reflective teaching means looking at what you do in the classroom, thinking about why you do it, and thinking about whether it works – a process of self-observation and self-evaluation. The experience raised an awareness of questioning techniques and the methods used for classroom management. On reflection, if this model were to be repeated in a different setting, more time should be spent pre-planning with the teachers and confirming that they fully understood the concept of co-teaching as a shared experience. There is no doubt that this would not have been as fulfilling an experience without the support of the Principal – their input throughout the duration of the project was a positive constant.

However, despite the apparent success, it also demonstrated there are no easy answers to implementing change within a school. With these teachers in their own familiar setting, the co-teaching did go some way towards providing in-service training that brought about a change in practice. The level of implemetation is down to the individual teacher. Fullan (1991, p.114) observes: *'Changing structures is easier to bring about than changes in values, beliefs, behaviour and other normative and cultural changes'.*

Change was successful in this case study due to the support given to the science subject leader. The Principal enabled him to grow in confidence and to lead the staff to significantly raise the profile of science across the school. The Principal confirmed that the science lead had grown in confidence and had been the driver for change within the school. Establishing the co-teaching helped him to understand the teachers' needs and doubts through observations and discussions, which enabled him to recognise that he could influence the teaching and learning in science throughout the school.

Co-teaching as a model of CPD involves meeting individuals, getting a clear picture of where they are in relation to their ability to adapt their own learning and teaching style to enable them to reflect and improve their practice. It is labour-intensive, but can lead to 'changing people', both researcher and teacher. In a larger school, the Lesson Study approach would be worth considering, with previous studies showing how, in this model, schools can provide their own CPD. Lesson Study involves groups of teachers collaboratively planning, teaching, observing and analysing learning and teaching in 'research lessons'. Over a cycle of research lessons, they may innovate or refine a pedagogical approach, which will be shared with others (Dudley, 2011).

This project began by asking: is co-teaching a viable model for Continued Professional Development? For this setting, the answer is 'yes': the experience was positive from both from the researcher's perspective and that of the school. There was a change within the school in its approach to delivering practical science. This study gave the opportunity for the researcher to reflect upon her approach as a mentor supporting teachers in a variety of settings and with differing needs. Fortuitously, in this case study the experience of co-teaching was immensely beneficial and the researcher would welcome the opportunity to repeat the practice.

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

● Lynne Bianchi ● Amy Bonsall

Abstract

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

Keywords: Scientific questions, children's scientific questioning

Introduction

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

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

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

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

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

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

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

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

Methodology

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

Table 1. Key search phrases.

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

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

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

At the time, these were to:

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

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

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

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

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

Figure 1. Process of principle paper identification.

Stage 1. Initial broad literature search

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

Stage 2. Joint abstract sifting

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

3. Individual read and rate

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

4. Priorisation and theming

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

5. Co-review with Lead Teachers

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

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

Findings & discussion

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

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

This paper was concerned with examining the following:

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

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

Key point(s):

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

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

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

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

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

Key point:

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

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

This paper was investigating the following two key questions:

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

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

The authors state that:

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

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

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

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

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

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

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

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

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

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

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

Conclusion

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

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

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Towards a pedagogy of 'clown': using archetypes of clown to develop a model of effective primary science teaching

● Deborah Herridge

Abstract

This paper suggests a model of classroom delivery and transformative pedagogy of teaching primary science based on archetypes of 'clown' (Bala, 2010; Gaulier, 2016), 'clown' being an embodiment of dualities of silly and serious, play and work and, in the classroom context, as an agent for transformation through imagination, learning and play.

This study is situated in the context of Initial Teacher Education (ITE) in the UK and focuses on the development of a model of practice devised from studying films of primary science lessons and reflective dialogue from teachers featured in these. There are sixteen teachers featured; eight are from high schools where science has a high curriculum profile and levels of expertise, and their practice is contrasted with eight practitioners working in schools where science has a lower profile.

From an analysis of the films, a model of pedagogy based on the emerging commonalities between all participants has been devised. This paper reports on early, and tentative, findings of the study.

Keywords: Primary science, pedagogy, clown, PCK

Background

What do you think of when I say the word 'clown'? Do you smile and recollect happy childhood experiences of circuses and parties, or do you feel a chill of apprehension at the memory of a particularly gruesome horror film? Do you visualise the cartoonish face of a 'Ronald MacDonald', or the intellectual and physical challenges of a Cirque du Soleil? Either way, I'm sure you will have some mental image of what 'clown' means to you.

We all hold a cultural image of 'clown' (Butler, 2012) and some would go further and argue that we recognise cultural archetypes like that of the jester or clown, in the Jungian sense of re-occurring motifs and themes or patterns that are found in all cultures (Bala, 2010). What about a 'classroom clown'? Now, perhaps, you have another image, one that may strike a note of discord or irritation, or even perhaps admiration of a challenger of authority? And the teacher as clown? What image does that evoke?

This study is part of ongoing doctoral research into outstanding science teaching in primary schools and seeks to develop a transformative pedagogy based on an understanding of historic ideas of 'clown' (Gaulier, 1999, 2007; Wright, 2006; Bala, 2010; Amsden, 2016).

Unleashing your 'inner clown' as a pedagogy is not about being funny, although it can be fun. 'Clown' is used here as an archetype, a recognisable and re-occurring motif, an embodiment of dualities of silly and serious, play and work and, in the classroom context, as an agent for transformation through imagination, learning and play.

The idea of 'serious play', that which is creative, liminal and embraces uncertainty, has been developed recently in many industries as a vehicle for problem-solving and communication in work-related contexts (Schrage, 2000). I seek to deconstruct the more ancient idea of 'clown' as an embodiment of serious play in a classroom context and to identify and exemplify strategies and techniques that can be used to inform effective practice.

This paper reports on work completed to identify models of classroom delivery based on the principles embodied in traditional and modern ideas of 'clown'.

Context

This study is situated in the context of Initial Teacher Education (ITE) in the UK and focuses on the development of a model of practice devised from studying films of primary science lessons and reflective dialogue from teachers featured in these. The study was conducted over a two-year period as part of a larger ongoing study on the idea of 'fun' in primary science teaching and learning, and used a mixed methods approach, where observations of classroom science teaching, digital video records of teaching inside the classroom, semi-structured individual and paired interviews and reflective dialogue from teachers commenting on film of their teaching took place. The data collected were transcribed, compared and contrasted and emerging themes identified. There was a specific focus on not only what the teachers said that their intentions for learners were, but also on what they did. The physicality of teachers and their use of the body became a strong emergent theme and resonated strongly with both the classical and modern ideas of the European practice of 'clown' (Lecoq, 2000).

From an analysis of the films, a model of pedagogy based on the emerging commonalities between all participants has been devised.

Research question

The question central to the research is:

- How do recognised outstanding teachers of science embody the ideas of 'clown' in their practice?

And, subsequent to this:

- Can a model of clown pedagogy support student teachers in understanding what excellent teaching in primary science looks like?

Research design

A realist approach was taken in this study with a pragmatic aim of finding out 'what worked' in the context of primary science teaching (Pawson, 2006, 2013; Oliver, 2012; Edwards *et al*, 2014). Sixteen teachers in eight schools participated in the study, which followed a mixed methods design based around ideas of video-stimulated reflective dialogue (Moyles *et al*, 2003; Powell, 2004; Husu, Toom & Patrikainen, 2006; Muir & Beswick, 2007).

The schools were diverse, ranging from small rural schools to large estate schools, private, state and faith schools. The participating teachers had varying degrees of experience of between three and over twenty-five years, and all but two were female, which reflects the sector as a whole. Teachers were sampled from all year groups, so evidence was gathered of science teaching from Nursery and Reception through to Year 6 (age 11).

The fieldwork took place over two years and in two stages. I felt it important in sampling that recognition of achievements in science teaching came from independent sources and were not determined by my own views on what excellence might look like. In Stage 1, eight teachers were recruited, six of whom had won awards from the Primary Science Teaching Trust (PSTT) for excellent practice in teaching primary science and who were fellows of the Primary Science Teacher College. All eight of the first group of participants were science subject leads in schools that had achieved the highest level of award in the Primary Science Quality Mark (PSQM), which indicated that they were leading science in schools where science has a high profile and a shared understanding of good practice. These teachers formed the 'expert' group. The second phase of the research was exactly the same, with eight teachers involved, but this time they were general classroom practitioners with no specific interest in science. Many had other leadership roles in schools, but not for science, and none had been nominated for science-related awards. These teachers formed the 'general practice' group. It is important to emphasise that the 'general practice' group were all excellent classroom practitioners, but not specialists in science.

Teachers were filmed teaching curriculum lessons for science and these recordings were then played back to them straight after the lesson, or as close in time to the lesson as possible (usually within 48 hours as a maximum), in their classroom surroundings. They were asked to comment on their practice and to give a 'running commentary' on their pedagogical choices. This too was filmed and the researcher guided the responses to focus on these choices, with questions such as *'Can you tell me what you were thinking when you did...?'*, or *'Can you say a bit more about...?'*, etc. Participant responses were transcribed and compared and, at a later date, some participants were re-interviewed individually and in groups to clarify themes.

A form of thematic analysis (Charmaz, 2006; Denzin & Lincoln, 2011) was employed to discern commonalities and differences between the classroom practices of the participants, which led to the creation of a model of pedagogy based on clown archetypes.

Early findings, interpretations and prototype model

In order to understand ideas of how a model of clown pedagogy could lead to improved practice outcomes of trainee teachers in primary science, it is necessary to have some knowledge of the historic clown archetypes. There are three historic types of clown: the 'Whiteface', the 'Auguste' and the 'Tramp'. The archetypes proved to be a useful 'shorthand' to explain different elements of practice. However, in plausibility testing it was found that the teachers did not like the names of the archetypes, particularly feeling that the idea of 'Tramp', although historically accurate, was derogatory. Therefore, I have changed them to 'Learning', 'Fun' and 'Authentic' for the current model.

The Whiteface clown, a descendent of Harlequin and, later, Pierrot (Ward, 2014; Buckmaster, 2019) is clever and sophisticated, his clothes are stylish and refined, he is in a position of power and control – the straight man to the comic Auguste. The Whiteface is the clown with authority; he is in charge and the person who tells the Auguste what to do. Clear in his objectives, he provides the leadership and the challenge. For me, this traditional clown embodies the 'Learning' aspect of the lesson.

Auguste is the fool, the slapstick, physical comedian and the originator of the jokes, the one who has the water thrown in his face at the circus, falls over, wears exaggerated clothing such as huge shoes or baggy trousers, has exaggerated make-up and a red nose. He (and it was always a he, until the mid-19th century) was an actor and a mime, sometimes a mimic using his whole body and facial expressions to make himself absurd (Simon, 2014; Bouissac, 2015). He is often mischievous, naughty and subversive. This clown embodies the 'Fun' aspect of learning.

Finally, there is a more modern embodiment of clown, which is associated with the idea of an 'everyman' or, in America, a 'tramp' character such as Charlie Chaplin (LeBank & Bridel, 2015). More amiable and in many ways more loveable and compassionate than the other forms, the tramp is the clown who tries and fails, and fails again. He is a naïve truth-seeker, embodies all of the authenticity, bewilderment and awkwardness of modern times and is the most naturalistic of the types. This clown's characteristics signify the relatability of the lesson to children's lives and represents 'Authenticity'.

Table 1. Clown characteristics.

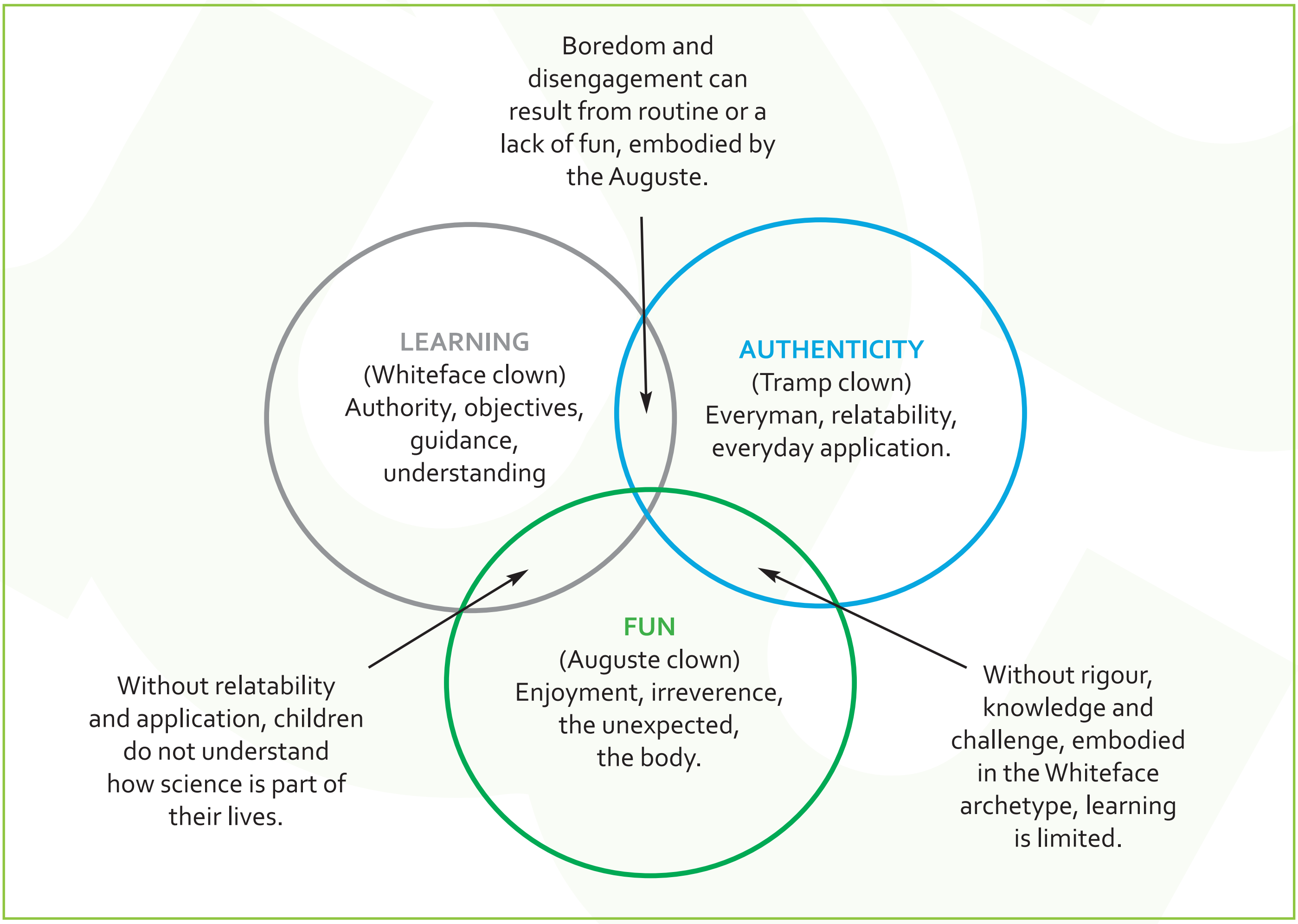
Characteristic	Example from teacher data (letter represents teacher identifier)
Teacher encourages children to move or mimic (Auguste/Fun)	N: Children mimic use of hand lenses and magnifiers and exaggerate the actions of focusing.
Exaggerated use of action/ ethology by teacher (Auguste/Fun)	N: Teacher mimes and exaggerates concept of 'chemical reaction' using body to illustrate 'fizzing' and 'exploding'.
Exaggerated use of voice by teacher (Auguste/Fun)	T: Increase in pitch and repeated exaggerated pronunciation of vocabulary.
Clothing or prop used by teacher or child (Auguste/Fun)	T: Teacher wears oversized white coat and adopts 'professor' persona.
Learning is directly controlled (Whiteface/Learning)	J: Explicit objective written on board and related to curriculum. Success criteria explained. Both recapped at end of lesson.
Learning relatable to children's experiences (Tramp/Relatability)	A: Learning is contextualised in terms of a popular film on release at the time.

The characteristics of 'clown' vary with the type of clown and this became important to recognise as the model developed. I looked at the films of the lessons once more and picked out particular clown behaviours that the teachers displayed. I wanted to identify some commonalities in the teaching of expert teachers and, in using clown characteristics as identifiers, this emerged as a very clear model. Clown characteristics observed are summarised in Table 1, with brief examples from the study.

What became apparent as the study progressed was that the 'expert' group portrayed some very different pedagogical characteristics from the 'general practice' group, most specifically in their physicality. There appeared to be no noticeable differences between experienced or less experienced teachers, and age, gender and locality did not appear to be significant factors either. All of the 'expert' group used their bodies and voices in far more exaggerated ways than did the 'general practice' group; for example, they would hyper-enunciate words, use exaggerated facial expressions, mime and use props and costumes either for themselves or the children to heighten the sense of the dramatic. This was something not observed in the 'general practice' group. There was more attention paid to the affective dimension of the lesson in the 'expert' group also – much more of an emphasis on the children enjoying science and having fun, and the teachers were keen in the reflective interviews to draw attention to that aspect of their practice. For example, one teacher said, *'If you make it more fun for them then you're ahead. You've got a much better chance of them learning something'.*

The 'expert' science teachers showed a clear preference for more active involvement, more novel context and approaches and a more dramatic, theatrical approach to structuring learning in science. The 'general practice' group were not exclusively without these traits, but demonstrated them less often. Practitioners in the 'expert' group all incorporated elements of the three archetypes of clown in their practice. The non-expert teachers did not and concentrated more on the 'Learning' elements and didactic

Figure 1. Pedagogy of clown: A model.



pedagogical approaches, favouring the 'Fun' and the 'Authentic/Relatable' elements less. However, it became clear that it was in the interaction of all the elements in the model that the practice of the 'expert' group was situated and that over-emphasis of any of the three elements, or a lack of any one, could lead to less successful outcomes.

The practice of the 'expert' group suggests that their pedagogy contains aspects of all three archetypes of clown and resides in the central portion of the diagram. The model also highlights some effects of being without the characteristics of one of the triad of archetypes. This was clear in the films, where there were examples of children being too engaged in the fun elements of a science lesson, losing sight of the learning and so not being able to relate any learning that did happen to their own lives, or alternatively, where, although children were compliant and being effectively 'instructed', they found little enjoyment in the lesson. This resonates with the latest findings from Ofsted (2019) on 'Intention and Substance' in primary science, where they found that many schools had engaged only superficially with the objectives of the National Curriculum for Science and that many schools had weaknesses in developing children's scientific knowledge and understanding of scientific concepts.

Concluding thoughts

A useful model to define teacher knowledge stems from Shulman's (1986, 1987) work on pedagogical content knowledge (PCK). He suggests three types of knowledge: knowledge of our subject, the 'content' knowledge; knowledge of instructional methods, our pedagogical knowledge; and the knowledge that Shulman (1986, 1987) suggests is unique to teachers, our pedagogical content knowledge. This is how teachers relate what they know about teaching to what they know about what they teach.

It is my suggestion that we can aid student teachers to develop their pedagogical content knowledge in an imaginative and enjoyable way through unpicking and deconstructing the practice of outstanding teachers in the application of a pedagogical model based around archetypes of clown. This is a work in progress and the study is now in the post-testing plausibility phase. Early results are promising and teachers have recognised the elements of the model as 'making sense'. However, whether it helps students in their practice remains to be tested, but is planned for the coming academic year. The model of the three dimensions of 'clown' deconstructs what is in reality one cohesive act of teaching by each individual involved but, by this explicit deconstruction, it is hoped that beginning teachers can reach a more complete understanding of the individual elements of effective practice in science teaching as demonstrated by the 'expert group' and that this will inspire them to emulate this in their own classrooms.

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Can you tell who's more creative than me?

● Ana Paula Bossler ● Pedro Z. Caldeira

Abstract

The definitions of creativity from de Bono (1982), Munari (2015) and Young (2003) suggest that creativity involves forming new ideas by connecting pre-existing unrelated ideas, in a structured process. This paper argues that individuals with broader knowledge repertoires can be more creative, implying that, when they have to deal with typical school knowledge, educated adults are potentially more creative than children, contrary to the prior assumption that children are more creative. Results from a workshop[1] attended by 17 primary science teachers from the UK are presented and analysed, in which participants were asked to consider how the human body could be 'improved' and to present their ideas in a drawing. The results obtained in this workshop were compared with those achieved by children aged between 5 and 13 years in previous studies from other authors. In terms of creativity, when children or adults are asked to draw 'improved' human bodies, adding or deleting organs or features, less than 20% of the former give answers that include some creativity (de Bono, 1982), in contrast to adults, where close to 70% present some creativity in their drawings. Thus, the results suggest that broader repertoires of typical school knowledge generate more creative responses, causing the authors to argue for the consideration of knowledge expansion to support creativity.

Keywords: Creativity, children's drawings, human body, repertoire of knowledge

[1]The workshop was presented at the Primary Science Education Conference (Edinburgh, June 6th-8th, 2019). The workshop had 18 teachers enrolled and was attended by 17 of them.

Introduction

Definitions of creativity range from very simple definitions (those that refer to creativity as the production of ideas, products or solutions that have value (Stein, 1953)), to those that consider it the highest form of thought (Anderson & Krathwohl, 2001).

This article uses three definitions of creativity:

1. As a repertoire of knowledge and experience (de Bono, 1982), assuming that the larger the repertoire of knowledge of the individual, the greater is their creativity.
2. As a structured method of work that requires effort and dedication (Munari, 2008, 2015) – ideas do not depend only on the inspiration of the moment.
3. As a combination of old and new elements (Young, 2003).

In a world experiencing constant technological change, it is easy to find examples of scientific research that present creativity as an indispensable tool for the survival of individuals in current or future work environments (Kremer, Villamor & Aguinis, 2019): '*the complex problems of today and massive unpredictability of tomorrow require more investment and support for human creativity*' (Pugsley & Acar, 2018, p.1).

The question that arises for educators in the face of this is: 'How to develop primary science pedagogy that promotes creativity?'.

In this article we analyse the results of a workshop that we facilitated for 17 primary teachers in June 2019, where de Bono and Munari's use of children's drawings to measure creativity was replicated to evaluate their findings and consider the implications for educators.

Table 1. Inside the human body: children aged from 5 to 13 years (source: Munari *et al*, 1976).

Organ/System	Frequency	Age
Heart	Very frequent	5 +
Brain	Very frequent	6 +
Cardiovascular	Frequent	8 +
Skeleton	Least frequent	10 +
Digestive	Frequent (in and out tubes)	7 +
Lungs	Frequent (no place defined)	7 +
Bones	Frequent (scattered all over the body)	8 +

Using children's drawings to measure creativity

Inside the human body – child's version:

A team of psychologists at the University of Geneva, in partnership with Italian and Swiss teachers, performed an experiment with 600 Italian (Northern Italy) and Ticino (Switzerland) children, asking them to draw the interior of the human body (Munari, Filippini, Regazzoni & Visseur, 1976; Munari, 2015).

Our analysis of the drawings (Table 1) shows that the brain and heart were the organs that were drawn most frequently by children from the age of 6, that the circulatory system was frequently represented from the age of 8, and that, by the age of 10, the skeleton was still infrequently represented.

The typical child's drawing shows a fragmented and lacunar representation: many parts are missing, and those parts represented are disjointed. As they get older, because of the impact of school learning,

Table 2. Improving the human body: children aged from 7 to 9 years (n=16, source: de Bono, 1982).

Body part	Adding/Subtracting (n)	New part or new feature
Legs	More legs (6)	No
Heart	Two hearts (1)	No
Arms	More arms (6)	No
Eyes	More eyes (6)	No
Head	More head (1)	No
Ears	More ears (3)	No
Fingers	More fingers or different fingers (2)	No
Mouth	More or bigger mouth (6)	No
Appearance	Change quickly (1)	Yes
Nose	More noses or in another place (5)	No
Radar	One radar (1)	Yes
Feet	Feet with spiral springs	Yes

children draw in more detail and include parts that are missing from younger children's representations. However, some systems are still typically represented as black boxes, for example the digestive system, where children know where the food enters, have an idea that it is processed inside the body and comes out as faeces (most frequent child description of how the digestive system works), regardless of the child's age.

Make a more efficient human body:
Maltese psychiatrist Edward de Bono, in his book *Children Solve Problems* (1973), presents a problem posed to children aged 7, 8 and 9 years: how to make the human body more efficient. Our analysis of drawings of the improved human body from the study reveals that children usually almost entirely limit themselves to multiplying existing body parts (see Table 2).

Of 39 parts or characteristics added by children in this study (de Bono, 1982), only three were not a mere duplication or transformation of existing body parts or features, which reveals, according to the creativity criteria used in this article and based on de Bono (1982), Munari *et al* (1976), Munari (2015) and Young (2003), a low level of creativity.

Evaluating de Bono's and Munari's findings in a CPD workshop for primary teachers

We began the workshop with the following question put to 17 participating UK primary teachers: 'In your opinion, who is the most creative, children or adults?'. The answer was unanimous: 'Of course, the children are!'. No definition of creativity had been presented. A group of 72 Brazilian pre-school and primary teachers (June 2018) and a group of 83 Brazilian undergraduate students in the fields of Natural Sciences and Mathematics (July 2017) had given the same answer when questioned. When asked for a rationale, the teachers argued that children have more imagination and greater capacity for fantasy and therefore children are more creative.

We then gave the participants the following instructions:

- 'What do we have underneath the skin? Please draw the inside of the human body.'
- 'Now draw an improved human body, adding or subtracting features that increase its efficiency.'

Participants had five minutes to make their drawings. We repeatedly stressed that the drawings would not be analysed for their aesthetic component.

Our comparison of the first of the participants' drawings to the children's drawings in the Manuri study reveals that the adult ones were more complete and realistic. Many drawings included a complete skeleton and various body systems (respiratory, cardiovascular, digestive...) and organs (brain, heart, lungs, kidneys...).

Table 3. Drawings by the workshop participants: inside the human body (n=17).

Organ/System	Present (n)
Heart	Yes (12)
Brain	Yes (12)
Cardiovascular	Yes (10)
Skeleton	Yes (10)
Digestive	Yes (9)
Lungs	Yes (12)

Note: The relative position of organs/systems was accurate.

After making their sketches, participants were shown Drawing 1 (Figure 1) adapted from Munari (2015) to show drawings typically made by children aged 5 to 13 years.

Although some of the participants' drawings resembled those of children, it was evident (see Table 3) that they included many more organs and systems. One participant (Figure 2) had developed an alternative representation of the human body using a mechanical model (literally the human body as a machine), with gears replacing the brain, a clock instead of the heart and a factory representing the complexity of the functioning of the body systems.

Therefore, the participants showed a broad repertoire of knowledge regarding the organs and systems inside the human body, and one showed his creativity by using a mechanical metaphor to represent the functioning of the human body.

Figure 1. Typical drawing from children aged 5 to 13 years after the instruction 'What do we have underneath the skin? Please draw the inside of the human body' (adapted from Munari, 2015 – brain, spine, heart, veins, lungs and bones, drawing by Ana Paula Bossler).

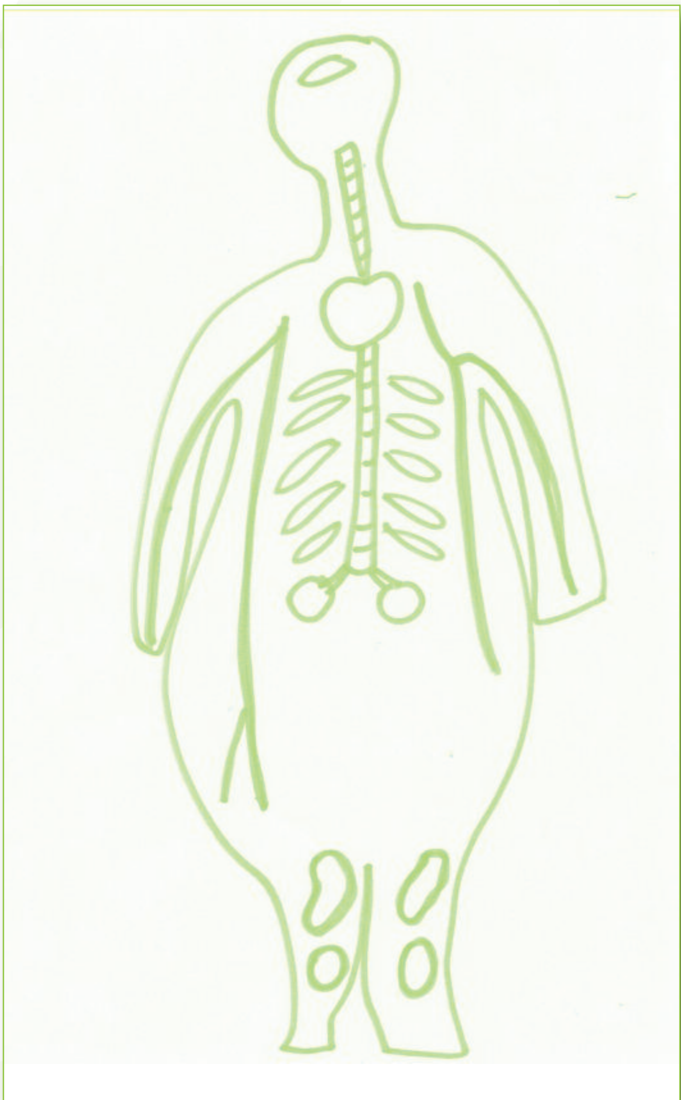
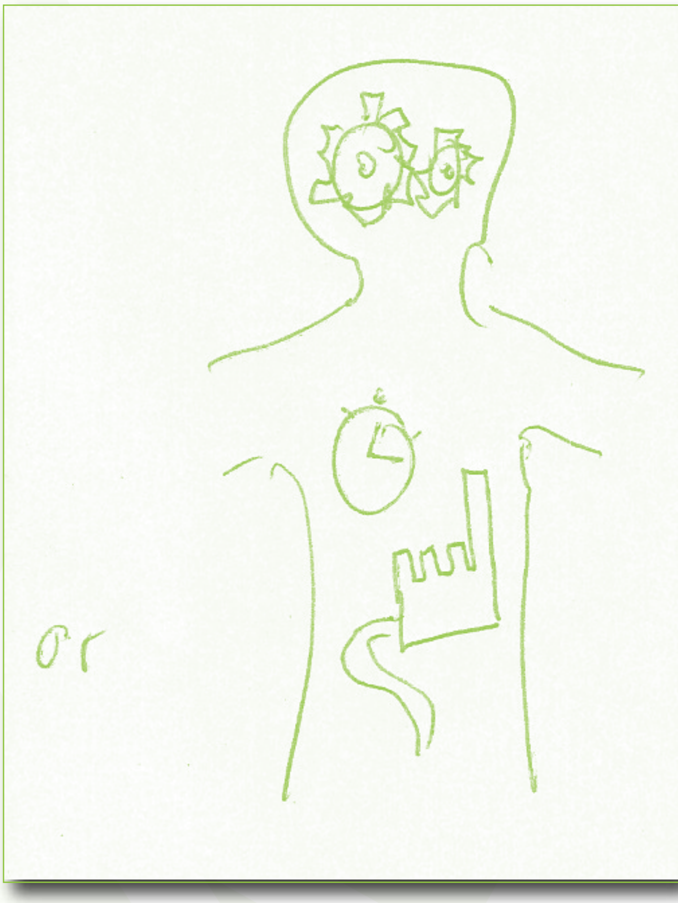


Figure 2. Alternative representation from participant.



The analysis of participants' second drawings shows the inclusion of new parts and features that go far beyond the mere multiplication of body parts drawn by children in de Bono's study. Out of 12 participants who gave us their drawings for the study, five added flight-permitting parts (either by adding helicopter propellers or wings), four added gills (which allow breathing in water), and three others included X-ray vision and a further three a mind-reading mechanism (some drawings included more than one of these characteristics).

New part/feature	Present (n)
Wings or helicopter propellers	5
Gills	4
X-ray vision	3
Mind-reading mechanism	3

Table 4. Sketches by the workshop participants: a more efficient human body (n=12).

New body parts such as wings or gills, or new features such as X-ray vision or a mind-reading mechanism, are indicators of creativity: combining two or more different pieces of unrelated knowledge in a new idea (Young, 2003).

Which drawings showed most creativity?

The workshop in Edinburgh confirmed our assumption that, when adults are asked about who is most creative, children or adults, the answer is invariably the same: children! Independent of the age, background or even national or cultural background of the participants in our *ad hoc* observations, the answer is always unanimous.

However, if Young's (2003) creativity indicator, taking two unrelated ideas to generate a completely new one, is applied to the evidence from the workshop, it suggests that children tend to be less creative than educated adults. We argue that this is because creativity depends not only on the ability to combine ideas, but also on the individual's repertoire of ideas (knowledge and experiences). Therefore, the argument we propose is: the wider the repertoire of knowledge and experiences, the more creative is the individual.

The Munari study shows that, when children are still at the beginning stages of learning anatomy, between ages 5 and 13, they cannot list some of the body parts, nor position parts relative to one another. The adult workshop participants had already had time to consolidate their learning on the theme. Thus, it is not surprising that their drawings are much more complete, with the parts generally well positioned relative to one another. Moreover, one of these adults even managed to make a metaphorical representation of the functioning of the human body as if it were a machine: that is, the drawing brought together two ideas and created something new, something different, something creative.

However, the difference in creativity between children and adults becomes more apparent when comparing the second set of drawings from the workshop participants with those of children (de Bono, 1982). Fewer than 20% of children in that study drew creative solutions to make the human body more efficient, while, in our workshop, 70% of participants devised creative solutions to the same problem.

Discussion

The findings from our workshop indicate that children are less creative than adults when using typical school knowledge, due to the differences in their respective repertoire of knowledge and experience (Young, 2003). When comparing two groups as disparate in knowledge and experience as children between the ages of 5 and 13, and primary teachers of science, with the latter group having much broader and deeper knowledge and understanding of what is inside the human body than the first, it seems clear that adults are far more creative than children (Young, 2003), even though researchers have argued that children have a more vivid and active imagination (Munari, 2015). Thus, it seems that an important determinant of creativity is the repertoire of knowledge and experience: the wider the repertoire, the more unrelated ideas can be used to create new ones. Adults tend to be much more creative than children, as they have a much more extensive repertoire or repository of knowledge and life experiences, due to the amount of learning, knowledge and experience accumulated throughout their lives. And this is evident when comparing educated adults (the participants in the workshop), and schoolchildren (those studied by de Bono, 1982).

Conclusion

There are roughly two ways of assessing an individual's creativity. The first is self-referenced (through questionnaires in which, for example, individuals indicate how much they consider themselves creative in different situations). The second is hetero-referenced, that is, how others consider us creative. In comparative terms, the second is more robust than the first, since self-assessment of traits in humans – intelligence, creativity, kindness and so on – is extremely flawed.

This difference between self- and hetero-assessments of creativity was used in this article in choosing the theoretical frameworks for creativity, favouring authors with solid definitions of creativity and who have developed work in professions where being creative is central to professional success, namely: someone from advertising (Young, 2003), someone from the field of industrial design (Munari, 2015) and, finally, someone whose focus over the last 50 years of his career was to support the development of creativity (de Bono, 1982).

For these three authors, creativity is determined by the accumulated amount of knowledge (Young, 2003), the ability to combine unrelated pieces of knowledge into new ideas (Young, 2003), and using structured processes that can be analysed and replicated (de Bono, 1982; Munari, 2015; Young, 2003). Thus, to identify an idea as creative, it is enough to verify that it results from two pre-existing ideas presented in an innovative format.

Using these criteria, this study found that:

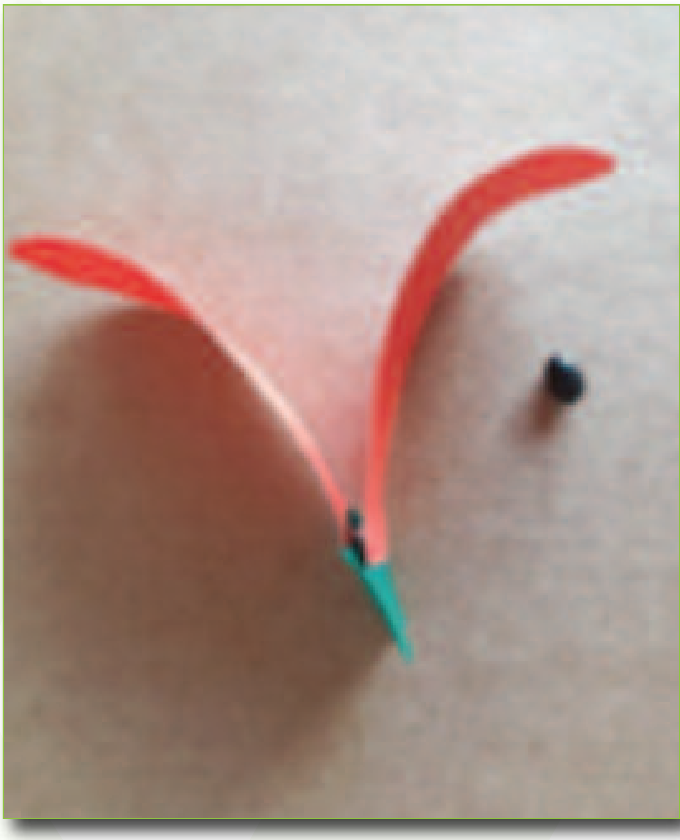
- Educated adults have a broader and more correct repertoire of knowledge relating to the human body, both with regard to body parts and systems and their relative positions, when compared to child repertoire on the same subject (Munari *et al*, 1976).
- Adults generate more ideas that are considered creative in a typical school activity when compared to children (Munari, 2015; Young, 2003).
- Broader repertoires of knowledge regarding a specific theme tend to generate more creative responses from individuals.

Since students are more creative regarding science content in school compared to out of school (Runco *et al*, 2017), the school can and should leverage science-related learning to provide students with opportunities to be not only more creative with regard to scientific knowledge, but also to all other types of knowledge related to it (e.g. arts, maths or drama).

What teachers can do to promote their pupils' creativity: expanding children's repertoire of knowledge

The creativity definitions of de Bono (1982), Munari (2015) and Young (2003), suggest that creativity involves forming new ideas by connecting pre-existing unrelated ideas, in a structured process. Thus, expanding the children's repertoire of knowledge can support creative explorations. For example, in the workshop, we presented a practical example of what teachers can do to increase their pupils' creativity related to the teaching of seed dispersal in biology (flying seeds, Figure 3). Before building their own seed wings for the beans, the children explored natural flying seeds, thus allying conceptual learning and a play-based teaching strategy *'as it involves the children in a meaningful and stimulating activity in which they participate on their own terms'* (Björklund, 2014, p.391). The children's seed wing designs are enhanced by the experience of launching a range of seeds and watching them fall. By building, reviewing and rebuilding the flying seeds, children increase their repertoire of knowledge about both seed dispersal and systematic investigation.

Figure 3. Flying seed.



Petrich *et al* (2013) listed four tentative indicators of learning when learners are involved in active learning processes such as observing seed flights: engagement, intentionality, innovation and solidarity. These kinds of behaviours can be observed when children 'play' with flying seeds in the kindergarten. These behaviours were also observed in the workshop when primary science teachers 'played' with flying seeds: when they built them, when they launched them, and when they thought collectively about the impact that a similar activity could have on their classrooms.

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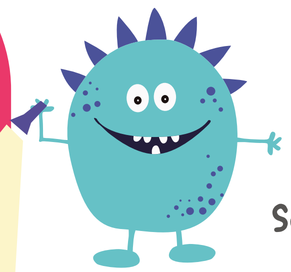

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Developing understanding of science skills in Northern Ireland through co-teaching between pre- and in-service teachers

● Sarah Earle ● John McCullagh

Abstract

The Teacher Assessment in Primary Science for Northern Ireland (TAPS-NI) project (2017-19) worked collaboratively with pre- and in-service teachers to consider progression and assessment of science skills within the context of the World Around Us strand of the National Curriculum. Co-teaching, where two teachers work together on phases of co-planning, co-practice and co-evaluation, was employed to find out if such an approach could be fruitful in terms of both practice and curriculum development. Project data included participant questionnaires and semi-structured interviews. All participants reported increased understanding of science skills and their progression, and all contributed to the development of activity plans that contained a focused skill within the context of a whole investigation. The outcomes of the project indicate that co-teaching can be an effective form of pedagogy at both pre- and in-service phases of teacher education, supporting reflection and agency.

Keywords: Primary science, assessment, co-teaching, science skills

Introduction

The Teacher Assessment in Primary Science (TAPS) project is based at Bath Spa University and is funded by the Primary Science Teaching Trust (PSTT). TAPS has been working collaboratively with teachers across the UK since 2013 to develop support for valid, reliable and manageable assessment (Davies *et al*, 2017; Earle *et al*, 2017). One of the key findings from the TAPS project is that, in order for assessment to support teaching and learning, there needs to be a shared understanding regarding both the purposes of assessment and progression in the subject being assessed. This provides a challenge for professional learning, which needs to consider both teacher assessment literacy and teacher understanding of the subject content. In order for a summative assessment of primary science to be valid, it should sample as wide a range of the construct as possible, which includes a consideration of science enquiry skills.

The process of enquiry broadly relates to: *'identifying investigable questions, designing investigations, obtaining evidence, interpreting evidence in terms of the question addressed in the inquiry, and communicating the investigation process'* (Harlen, 1999, p.129). This is not enquiry in isolation, but combines the development of both ideas and enquiry skills. Despite this general consensus in regard to the nature of scientific enquiry, there is no definitive list of science enquiry skills or enquiry types; they are *'not well-defined constructs'* (Millar, 2010, p.127). This poses potential difficulties when it comes to assessment, since there is a lack of agreement regarding the scope and criteria. An 'ill-defined construct' is problematic in assessment terms; it is difficult to set assessment criteria for achievement of something that cannot be precisely described. In addition, the diversity of skills within the subject means that the *'assessment capabilities required by science teachers are wide ranging and complex'* (Edwards, 2013, p.212). A shared understanding of science enquiry skills is important for both the validity and reliability of assessments, since validity concerns whether it assesses what it is supposed to, and reliability concerns whether others would agree.

An area of debate, particularly pertinent to research on assessment, is whether it is possible, or indeed advisable, to separate science into component parts, teaching atomistically rather than holistically. Some educators separate 'knowledge', which is seen as factual information, and 'understanding', which is linked more with explanation, criticising that the drilling of facts does not lead to connected in-depth understanding (Davis, 1998). This is not to say that facts are not important, but that making links between the facts via thinking and experience is needed to develop learning for understanding (Harlen, 2018, p.33). The teaching and assessment of enquiry skills takes place in a context, so any enquiry will draw upon science conceptual content, for example, when making predictions or drawing conclusions. It is questioned whether it is possible to teach transferable skills in isolation (Standish, 2007) and that skills are *'strongly content dependent'* (Millar, 2010). Ollerenshaw and Ritchie (1993) argue for a holistic view of primary science, suggesting that practitioners should be *'wary of fragmenting children's learning in science into arbitrary compartmentalised skills'* (p.150). Harlen (2006) suggests that any description of separate skills is a *'convenience rather than an attempt to describe reality…We look at the components so as to help children develop skill in all aspects of enquiry'* (p.96). McMahon and Davies (2003) suggest that a 'focused teaching' model could *'bridge the gap between atomism and holism'* (p.37), with specific teaching for component skills, which are then applied in the context of a real investigation, as proposed by the TAPS Focused Assessment approach.

TAPS for Northern Ireland (TAPS-NI) began in 2017, based in the Ballyclare PSTT cluster together with local Primary Science Quality Mark (PSQM) schools. The group found that the Northern Ireland Curriculum (CCEA, 2007), which placed science within the World Around Us alongside history, geography and technology, lacked detail about science content. The curriculum provided schools with the freedom to personalise their teaching and make cross-curricular links, but this made assessment for learning or summarising difficult because there was no shared criterion-referenced scale upon which to make judgements or plan next steps. Early in the TAPS-NI project, the Council for the Curriculum, Examinations & Assessment (CCEA) published a progression document (CCEA, 2018) which outlined suggested lines of progression for scientific and technological knowledge and skills. This document provided a starting point for the TAPS-NI group to develop a shared understanding of attainment expectations in science, but the development of focused activities and exemplification was needed to relate this to classroom practice. In order to widen the working group and draw on Stranmillis University College's expertise in co-teaching, pre-service teachers were invited to join the TAPS-NI project.

Co-teaching

Co-teaching is where two or more teachers work together to meet the needs of a class of pupils and, at the same time, develop and extend their own practice. The co-teaching pairs can comprise two pre-service teachers, two in-service teachers or, as in the case of the TAPS-NI project, a pre-service and an in-service teacher. It has been shown to be a highly effective form of pedagogy within initial teacher education (Murphy *et al*, 2014) as a model for continuing professional development (CPD) and as a strategy for enhancing pupils' attainment and their enjoyment of primary science (Murphy & Beggs, 2005). During co-teaching, both parties share responsibility for planning, teaching and evaluating. The close physical and intellectual collaboration resulting from two professionals sharing ideas, classroom practices and post-lesson analyses provides a learning experience that can transform the future practice of both parties. While co-teaching involves the sharing of expertise – in this case the science specialist knowledge of the pre-service teachers and the situated pedagogical knowledge of the in-service teachers – the project sought to benefit from the synergy to tackle the challenging area of skills progression. It was hoped that employing co-teaching within the TAPS-NI project would both enhance the practice of the pre- and in-service teachers and give rise to new TAPS-NI activities and supporting resources for future use by other teachers in Northern Ireland.

Research methods

TAPS employs a Design-Based Research approach whereby researchers and teachers collaborate in iterative cycles of development, alternating development days and trialling of approaches in school, to develop theoretical and practical products (Anderson & Shattuck, 2012; Davies *et al*, 2017). The TAPS-NI project extended the research team to include pre-service teachers. This novel use of the co-teaching model led to the following research questions (RQs):

RQ1. What affordances can a co-teaching model provide for pre- and in-service teachers during a curriculum development project?

RQ2. What is the impact on pre- and in-service teachers participating in the TAPS-NI project and how might this inform the pedagogy of teacher education?

Six pre-service teachers, in their third year of an undergraduate degree, were geographically matched with six in-service teachers. The project spanned a full school year, with the planning and co-teaching taking place from September to December and the revising and drafting of new resources carried out from January to June. It took place in three phases. In the first, planning, phase, a series of seminars allowed the co-teachers to come together to develop their understanding of science skills and to explore the challenges and opportunities that co-teaching might present as they tried out the TAPS-NI activities. The pre-service teachers visited the co-teachers' schools, observed lessons and planned alongside their partner teacher.
The next phase, co-practice, involved co-teaching and evaluating a series of four weekly science lessons, beginning with pre-existing TAPS activities, then devising new ones. The final evaluation phase involved all participants coming together to share their classroom experiences and allowed for an audit of skill assessments.

All were fully briefed on the scope of the project and were asked for permission at each data collection point, in line with informed consent procedures (BERA, 2018). The following research data were gathered and anonymised:

- Each teacher and trainee completed questionnaires regarding their experience of the project;
- Semi-structured interviews were carried out with 4 teachers and 5 trainees;
- Co-teaching lesson plans and evaluations; and
- Field notes and observations made by researchers throughout all phases of the project.

An interpretive stance was taken as we sought to capture any consensus across the reported experience of participants from a range of practice settings, thus enhancing the authenticity and transferability of our findings. The interviews were transcribed and, as with the questionnaires, thematically analysed for recurrent themes and perspectives.

Outcomes and findings

RQ1. What affordances can a co-teaching model provide for pre- and in-service teachers during a curriculum development project?

All participants reported, via questionnaire or interview, that co-teaching developed their appreciation and understanding of the place of science skills within the Northern Ireland Curriculum, together with enhancing their confidence and ability to promote progression of skills within their science lessons.

Co-teaching was considered to have been instrumental in developing each aspect of practice:

- **Co-planning:**
  - More ideas from the fresh perspective of the other practitioner.
  - The opportunity to critique and identify weaknesses in plans as they emerge during joint planning.
  - Having to plan and choreograph individual roles allowed each partner to reflect more deeply on the role of the teacher throughout a lesson and how it evolves.
  - Pre-service teachers benefitted greatly from their partner's insight into the individual needs of pupils and abilities of groups and could modify their plans.
  - In-service teachers valued the enthusiasm and creativity of the in-service teachers.

- **Co-practice:**
  - The additional teacher allowed each teacher to work more closely with particular groups of pupils and to therefore make more accurate assessments of both the effectiveness of the activities and the pupils' acquisition of skills.
  - The opportunity to add in or qualify something their partner said or omitted to clarify.

- Raising questions for each other or engaging in scripted dialogue to promote the narrative of the lesson and scaffold pupil thinking.
- The opportunity to 'observe from within' a lesson and, whilst teaching, smoothly modify or change their approach based on hearing or seeing their partner's progress.
- Pre-service teachers felt being closer to 'the action' made it easier to acquire the physical attributes of classroom management and assimilate them into their own future practice.

- **Co-evaluation:**
  - The post-lesson discussion based on a shared experience was probably the most frequently cited merit of co-teaching.
  - The extra set of eyes and ears when evaluating.
  - The experience of another professional to challenge or confirm their personal opinions.
  - The moral support when things didn't go well!
  - A focus on successes and exploration of effective practice can be overlooked when evaluating independently.

Of course, it should be acknowledged that, in an interview with a tutor who leads on co-teaching, the participants may be more likely to focus on the positive aspects of the project. In addition, in both the anonymous questionnaires and in one of the interviews, participants reported the need for more time together, particularly for collaborative planning and evaluation. Even within co-teaching, the demands on practitioners' time can be a challenge.

RQ2. What is the impact on pre- and in-service teachers participating in the TAPS-NI project and how might this inform the pedagogy of teacher education?

Questionnaires completed at the end of a co-teaching section (November 2018) included the following comments from the pre-service teachers, which have been selected to represent the range of ideas in this exploratory study:

'I found myself realising the importance of assessment throughout science lessons and strategies to do so...Thinking about assessment in general – got me better at it' (Pre-4).

'We usually just do this [assess] based on the concept...I learnt how to question children more effectively in order to assess their understanding... The project helped us to focus on science skills' (Pre-1).

'Limiting the planning of the lesson to focus on one science skill, e.g. observation, made it easier to plan for and made a feasible and achievable outcome' (Pre-2).

The comments from pre-service teachers indicate thinking around both assessment and science skills. It could be that 'realising the importance of assessment' (Pre-4) represents more a raising of awareness rather than development of understanding, but the building of teacher assessment literacy is a career-long endeavour, not something that can be mastered quickly (DeLuca & Johnson, 2017). The TAPS Focused Assessment approach, where one skill is chosen for the focus of the lesson, within the context of a whole investigation, is present in the pre-service teacher comments above, with manageability noted as an advantage of the approach (Pre-2).

At the end of the second year of TAPS-NI (May 2019), the in-service teachers were asked about the impact of the project on their schools:

'More willingness to do science and more science evident across the school. Move away from fear of "need to know"' (T4).

'Promoted science. When teachers have tried a lesson they are asking for more that are available. > Increase in diversity of science' (T1).

'Greater awareness of science skills...Better understanding of progression in skills from FS to KS2 (and what this looks like in reality)' (T5).

'Pupils know and understand skills...Use of scientific language and knowledge. Buzz about science... parent feedback: "children love science"' (T3).

For the in-service teachers, promoting science across the school and developing understanding of science skills were at the forefront. There was little mention of assessment, indicating that, for this sample of in-service teachers in Northern Ireland, teacher assessment literacy is not a priority for development. Interestingly, the in-service teachers' preference for the term 'progression of skills' rather than 'assessment' also might reflect a more summative than formative conceptualisation of assessment.

Discussion

Previously at Stranmillis, the success of primary science co-teaching had been in programmes between pre-service science specialists and in-service non-science specialist teachers, meaning that the pre-service teacher had a clear contribution to the partnership. In this project, both parties had expertise in primary science and so it was not at all clear whether the partnerships would be equally effective, hence this initial study. Our findings that both pre- and in-service teachers described the co-teaching experience as very fruitful suggest that the benefits of co-teaching extend to pairings where both partners have comparable levels of competence in the focus area. This is consistent with our studies of co-teaching between pairs of pre-service teachers and point to a conceptualisation of co-teaching as the joint exploration and creation of new practice (McCullagh & Doherty, 2018). Since pre- and in-service teachers were collaborating on a challenging curriculum project, there was a shared goal: to develop activities and examples that could be used to support teaching and assessment of science skills.

The outcomes of the project indicate that co-teaching is an effective form of pedagogy at both pre- and in-service phases of teacher education. For the pre-service teachers, the experience was very different from their block placement, where the schools' strong curricular focus on numeracy and literacy restricted the time for teaching science. Where there is an opportunity to teach science, it can often consist of a one-off lesson and rarely enables pre-service teachers to follow through a series of lessons with a complete cycle of reflection for science (Jones, 2008). The fact that, during co-teaching, the pre-service teachers are not being assessed on their classroom teaching allows them to be more ambitious and frees them up to adopt a more enquiry-based stance in their approach. It accommodates a collaborative approach to action research in line with Carter's (2015) call for student teachers to develop their own teaching *'in an environment where they are able to trial techniques and strategies and evaluate the outcomes'* (p.21). Co-teaching presents reflection as manageable, valuable and powerful. We have noticed that students who have experienced co-teaching usually attain higher grades during their subsequent school placements.

For the in-service teachers, co-teaching addresses many of the weaknesses traditionally associated with a course-led model for professional development (Craft, 2000). In contrast, CPD that is based within the classroom provides the teacher with greater agency for change and allows for the influence of the school itself and the day-to-day activities of teachers and pupils. The merits of co-teaching in our study are in line with those identified by Kerr (2010):

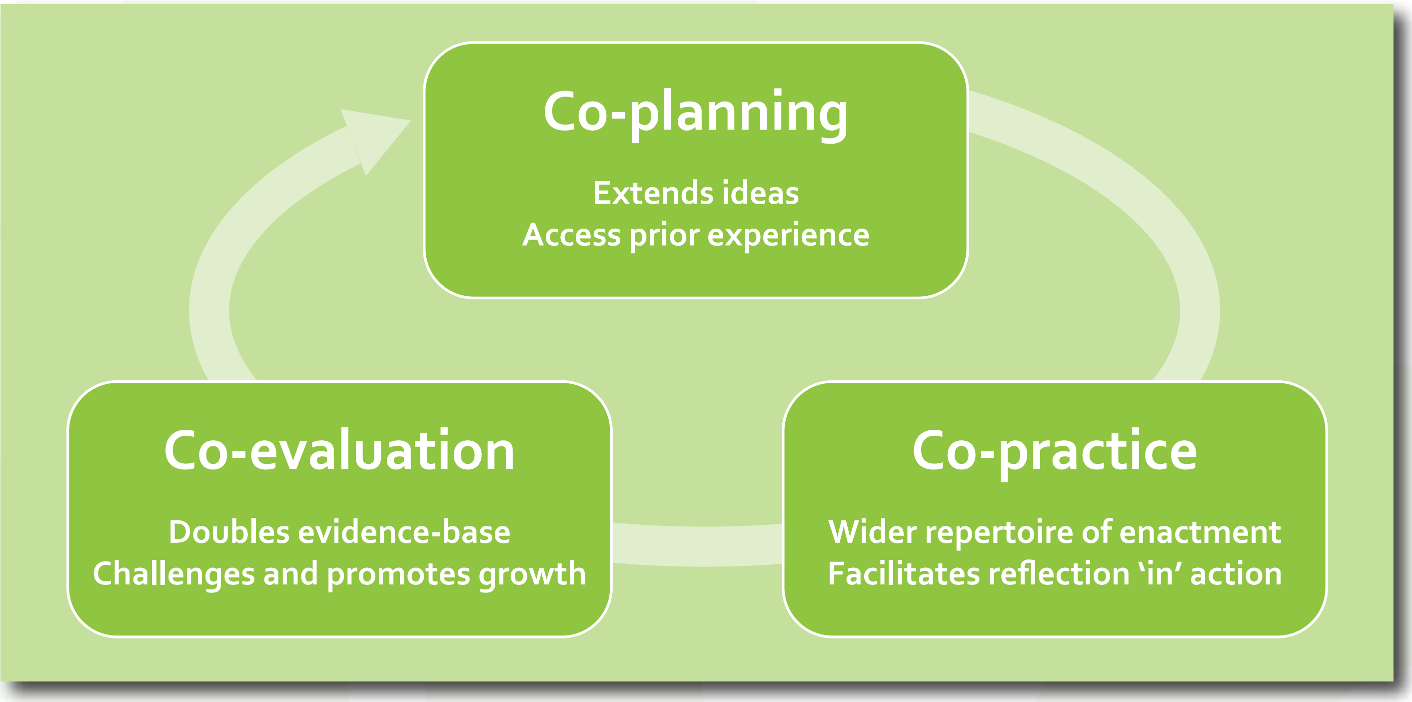
- Active participation;
- Collaboration;
- Addressing specific needs; and
- Sustainability.

By facilitating dialogue and collaboration, the transformative impact of co-teaching need not end with the individual teacher, but could help nurture communities of practice.

Figure 1 provides a summary of our identified affordances of co-teaching, highlighting the benefits of practitioners working together to transform their individual and collective practice, and are consistent with Vygotskyan-based theoretical frameworks (Murphy, 2016).

Our findings also show that co-teaching is productive for curriculum development. When both parties are equal partners, co-teaching can lead to the creation of new practice. This provides a very different learning dynamic to the traditional school-based placement where the student is considered to be the 'novice' and expected to conform and replicate the current practices of the 'expert' host teacher. The Northern Ireland Department of Education's publication *Learning Leaders: A Strategy For Teacher Professional Development* calls for a focus on *'next'* as well as *'current'* practice (2016, p.8).

Figure 1. The affordances of each aspect of co-teaching.



Co-teaching allowed for the refinement and the creation of new classroom guidance and activities for assessment and progression (TAPS-NI, 2019). For example, the TAPS-NI skills flower (Figure 2) was created to display in classrooms to support discussion and coverage of the seven skills.

Figure 2. The TAPS-NI skills flower showing the seven science skills specified within the Northern Ireland Primary Curriculum.

Professional development in science education can be enhanced by more meaningful and productive partnerships between schools and ITE institutions. In light of this study, we propose that co-teaching can play a significant role across the continuum of teacher education and in the area of curriculum development.

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‘I have been doing some science at home’: children’s relationship with science

● Zoe Crompton

Abstract

In a study spanning two years, I generated data with eight children in their first years at school, from ages 5 to 7. The purpose of my research is to gain, from a sociocultural perspective, a greater understanding of science interests as part of children’s fluid and constantly forming identities. The study explores the social situatedness of children’s relationship with science, and examines the symbolic meaning of their interests, the cultural signs and tools they use to story themselves, and how they are storied by others. The findings indicate that children’s science interests are deeply embedded in family practices.

Keywords: Interest, identity, sociocultural, Mosaic approach

Introduction

Interest in science begins at an early age, but can wane as children get older, particularly at the transition from primary to secondary education. Many studies have written about a general decline in pupils’ attitudes towards science from age 11 onwards and the concern that fewer young people choose to study science subjects post-16 (Potvin & Hasni, 2014).

This generalisation masks a detail that some students, who had been recorded as having a low interest in science and technology overall, were nevertheless very interested in a specific aspect of science (Yang, 2010).

Some of the current initiatives seeking to address the perceived decline in children’s interest in school science do so from a premise that the problem can be *fixed*. For example, an Ofsted survey of science provision in 180 schools chastises teachers for focusing improvement plans on achievement in science and advocates strategies to ‘*make science interesting*’, engage pupils and ‘*maintain curiosity*’ (Ofsted, 2013, p.26).

Rather than starting with the design of new and exciting science activities, my study takes a different approach, looking at how children story themselves, and are storied by others, as being interested in science (by ‘story’, I refer to the way we construct our identities (Holland *et al*, 1998)). This is why I employed a participatory research method, the Mosaic approach (Clark & Moss, 2011) to gather data from a wide range of sources.

The nature of science is multidisciplinary and philosophically complex (Chalmers, 2014), yet school science presents a rather simplified view of science as the study of scientific concepts and processes (DfE, 2013). Much of the research about children’s interest in science focuses on children’s engagement with science as a school subject (Mantzicopoulos *et al*, 2009), and children’s aspirations to study science-based higher education courses, or pursue a STEM (Science, Technology, Engineering and Mathematics) career (Macdonald, 2014). However, often the activities in which children engage, such as tinkering or constructing, are not found in traditional school science lessons (Luce & Hsi, 2015).

Science is socially and culturally embedded, so that learning science in school is restricted by curriculum prescription. When asked what science is, many young children cannot explain what the term means and would not recognise the kinds of activities they carry out as science activities (Crompton, 2013). Of course, not knowing what science is does not prevent children from engaging in numerous activities that could be categorised as science, as they observe, experience and learn about phenomena.

Research design

During the course of two years, I generated data with eight children, through monthly visits to two schools (four children in each school), using participatory methods. The methodology that I used is based on Clark and Moss's (2011) Mosaic approach, which is a framework for listening to children's perspectives of their lives, and uses creative polyvocal data generation techniques that do not rely on written words or verbal accounts. I generated data with child participants through observation, interview, photographs and drawings, and with their parents and teachers using questionnaires and semi-structured interviews.

Children were social actors in the research and made active choices about how to express their interests, as well as reflecting on data collected during previous visits. The Mosaic approach has been used in many studies (Schiller & Einarsdóttir, 2009) and is regarded as an authentic and flexible methodology (Greenfield, 2011). I focused on children's social practice in order to understand the ways in which children story themselves as someone interested in science and how they are storied by others. Therefore, my research questions explore children's interest in science as part of their developing identities:

- *How do children express their interest in science between the ages of 5 and 7?*
- *What is the relationship between young children's identities and their expression of interest in science?*

This article addresses these research questions by discussing the data generated by and about two children in the study, Robert and Hakim (all names are pseudonyms).

Robert: 'You can make whatever you want'

In March of Year 1, when I asked Robert what he would like to photograph using an iPad, he photographed three different types of construction materials in the classroom (Figure 1). I started our conversation by asking him about his choice of subjects to photograph; his responses illustrate how he sees himself as a child who likes to make things.

Figure 1. Robert's photographs in March of Year 1.

Zoe: So what was your favourite thing to photograph?
Robert: The castle.
Zoe: And why the castle?
Robert: Because you can build any castle you want out of it.
Zoe: And what about Lego, what can you build out of Lego?
Robert: You can build spaceships, you can build… [distracted by activity in the classroom] and in the K'Nex you can make whatever you want in the K'Nex.
Zoe: In the K'Nex, yes that's right. So what else have you made apart from a spaceship? What are you making at home?
Robert: I've made a Lego Movie garbage cruncher and a Lego Movie ice cream squirter and gun. The guns are lollies and the squirting thing can transform into the ice cream thing as well as the squirting.

(Interview with Robert in March of Year 1)

Robert describes the properties of the Lego Movie models he has made at home and explains that he likes the castle and K'Nex because 'you can make whatever you want'. He describes himself enthusiastically as a child who knows the endless possibilities for building by repeating the phrase 'you can'.

The following extract is from an interview occurring 9 months later:

In this exchange, Robert provides a detailed description of what he thinks science is, positioning himself as something of a scientist in his response, 'I have been doing some science at home' when I asked about what a scientist would be doing. His account of making 'Bob's Best' – using his own name – associating his extraterrestrial inedible sauce with science, demonstrates a sense of ownership and that he sees himself as an experimenter.

Interviewer: So what about science, do you like science?
Robert: Yes, a bit.
Interviewer: So what do you think science is?
Robert: Well, I'll say it was moving stuff like pushing and pulling, they are the big two groups, then there are smaller groups like winding and spinning.
Interviewer: Yes, so that's what you've been learning about at the moment, about forces, but more generally what's science? What would a scientist be doing?
Robert: Well…I have been doing some science at home. I've been trying to make a Bob's Best that no one's been able to eat.
Interviewer: Bob's Best?
Robert: Bob is my nickname.
Interviewer: I see. So, no one else…?
Robert: Can eat it, cos it's made out of salt, pepper, cinnamon and nutmeg.
Interviewer: You're making food that nobody else can eat?
Robert: Yes, it's a kind of sauce that you put on that's supposed to be from Mars.
Interviewer: Wow, very good. So, do you want to find out any more about science?
Robert: Well, the next stage of science is to mix some liquids together.
Interviewer: What liquids are you going to mix?
Robert: Soap and my own shampoo and my Dad's bubble bath and my little sister's bubble bath and my potion will make it all bubbly, so you can't see underwater, except for with goggles.

(Interview with Robert in December of Year 2)

Hakim: 'I don't play with nothing. I've got a big grown-up bike'

During a visit in the month of April in Reception class (4-5 years), I watched Hakim intently painting several pictures of houses. His finished pictures were laid out, one above the other, on the drying rack and there were several on display around the classroom. Most of his paintings were of houses and the photographs that he chose to take during my visit were of his pictures (Figure 2).

Figure 2. Hakim's photographs in the month of April in Reception class (4-5 years).

Hakim expressed his interest in painting through his choice of photographs and in his two references to liking painting in this interview. Hakim told me that he liked learning about 'fishes', and both fish and dogs appeared multiple times in our future conversations. In addition, in several of his comments he positioned himself as grown up. He said that he did not play with his toys; had a 'big grown-up bike'; and that he was planning to 'sell his fish tank and get a dog'.

In a school record book about Hakim, his mother provided her views on his strengths and interests when he started school (opposite).

It is notable that his mother begins her description of Hakim with a strong statement that attributes an essential characteristic to her son – 'Hakim is

Zoe: So, tell me what kind of things do you enjoy doing at school?

Hakim: Painting and running in the playground.

Zoe: Anything else?

Hakim: Going on the bikes and climbing.

Zoe: What is it you like about being outside?

Hakim: Because it's my favourite.

Zoe: What do you like doing at home?

Hakim: More painting.

Zoe: You paint at home, yes, and what toys do you like playing with?

Hakim: I don't play with nothing. I've got a big grown-up bike.

Zoe: And what do you like learning about?

Hakim: Fishes.

Zoe: Go on, tell me about fishes.

Hakim: To dive. I went to an aquarium last time and then I got some fishes.

Zoe: And how many fishes have you got at home?

Hakim: I've got more than a hundred fishes. I've got a big fish tank and I've got some food for them and I'm going to buy a dog.

Zoe: You're going to have a dog as well as fish?

Hakim: I'm going to sell my fish tank and get a dog.

(Interview with Hakim, Visit 2, in the month of April in Reception class (4-5 years)

Child's strengths: Hakim is artistic, always ready to get the craft materials out at home (drawing, painting, sticking). He is very helpful, always ready to join in and help me with anything I am doing.

Child's interests: Hakim is very interested in construction and building things. His dad is a joiner. Hakim takes great interest in watching and helping his dad and grandad. Rather than playing with his toys, he takes great interest in gardening, mowing the lawn, washing the car, cooking and baking. Hakim recently has been interested in experimenting – with ice, different materials, seeing which is stronger.

(Entry in school record book by Hakim's mother, in January of Reception) artistic'. Elsewhere, she repeats the words 'great interest' to emphasise her points about Hakim's general nature, underlining her comments about what her son likes to do at home by using words like 'very', 'always' and 'anything'. Hakim's mother stresses that he does not play with his toys, storying him as a child who prefers 'helping his dad or grandad' around the house and garden. According to Sfard and Prusak (2005, p.16), identity can be defined as 'narratives about individuals that are *reifying*, *endorsable* and *significant*'. Here, his mother's language reifies Hakim as a particular type of child. This identifying narrative is endorsed by Hakim; in other words, it is a story that he tells about himself that reflects his mother's storying of him, particularly his self-positioning in terms of his membership of his family. Entries in my research diary included observations of Hakim building a house out of Lego and helping the adults to tidy up, which echo his mother's description of the activities he did at home.

An entry by his teacher in Hakim's school record book provides further clues about Hakim's motivation for building houses (opposite).

The teacher's photograph (Figure 3) captured the moment when Hakim had finished building his house and was perched inside it. The school record book entry reflected Hakim's storying of himself as 'grown up', recording his use of words that are related to his father's profession as a joiner: 'workshop', 'tools', 'drill' and 'plaster'. The house is the subject of his paintings and construction. We can see that Hakim stories himself as someone interested in construction, especially building houses, and that this identity is situated in the context of his family's shared activities, particularly his father's work.

Discussion

The case studies of Robert and Hakim's practice illustrate contrasting funds of knowledge (González *et al*, 2006). The concept of funds of knowledge is a useful way to foreground the importance of context, in order to view interests as situated in children's participation in everyday experiences, family activities and cultural practices (Hedges & Cooper, 2016). Children draw on funds of knowledge located in their family and community, and their actions can be perceived as symbolic of deeper interests (Chesworth, 2016).

Hakim was using the wooden blocks in the outside area and was sat down. I asked him what he was making and he told me, 'It's a house. This is my workshop. My tools are here. It's not finished, I need to drill some holes and plaster the walls'. A little while later, he called me over and said 'It is finished. I have drilled the wall and done the plaster'.

(Entry in school record book by Hakim's teacher, in January of Reception)

Figure 3. Photograph in school record book of Hakim, in January of Reception.

My first observation is about the presence of implicit cultural and family values in the way in which parents storied their children's interests. When I asked what their children would do given an hour of spare time, Hakim's mother described him helping to mend things with his father, whereas Robert's mother wrote that he would play with his toys. It would seem that the mothers are drawing on particular funds of knowledge when describing their children's practice. Robert's mother refers to children's toys, whereas Hakim's mother refers to participation in domestic activity and helping the adults. The case studies also reveal different discourses about the cultural construction of childhood (Wood, 2013), whether it is a time to play with age-appropriate toys (in the case of Robert) or contribute to adult endeavours (in the case of Hakim).

Another interesting contrast is in how Robert and Hakim's practice of building things and expressions of interest in construction materials, such as Lego, might at first appearance seem to be similar practice. However, for Robert, the process of building structures is as important as the product, and the appeal of construction materials is that 'you can make whatever you want'. In contrast, Hakim's purpose when using construction materials was often to build houses and emulate his father's profession, which he role plays by saying, 'It's a house. This is my workshop. My tools are here'.

Implications for primary teachers and science educators

Some science initiatives that aim to promote children's engagement in science take a *cause and effect* approach, which assumes that exposing children to science activities will trigger and sustain their interest in science (Jack & Lin, 2014). However, something in the environment cannot *demand* children's attention. Rather, being interested is an expression of children's identity, situated in a context. Science is more than a curriculum subject and we need to provide space for children's meaningful enquiries. Hence, I argue that we cannot *make* children interested in science; instead, we need to understand development of interest in science as embedded in children's practice and symbolic of deeper interests.

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Raising STEM career aspirations through the primary years

● Fran Long

Abstract
Within an already crowded curriculum, can primary teachers raise the STEM career aspirations of their pupils? A national shortage of engineers persists (Engineering UK, 2017) and a body of evidence highlights the need to inspire young people to consider future STEM careers by the age of 10 (Archer et al, 2013). This research study measured the impact on pupils of monthly contact with real scientists and engineers from a diverse range of careers, through a STEM assembly programme. STEM career aspirations, perceptions of the roles of engineers, and Engineering Habits of Mind (EHoM) exhibited by pupils were all measured through multiple research methodologies and were markedly higher in the trial group than in the control group. Science and engineering career aspirations overall in the trial were much greater than those reported nationally, especially amongst the girls. In this paper, we discover how this initiative could be replicated in your school.

Keywords: STEM, careers, engineering, science capital, research

Introduction

Limited prior research had specifically measured the usefulness of engineer visits in the primary years for enhancing STEM career aspirations. The author worked as a primary science specialist teacher in the South East of England, in a county rich in science and engineering heritage, research and industry, and saw an opportunity to utilise this, with the aim of enthusing the next generation of engineers.

Previously, a large-scale study, published in 2018, of 20,000 primary-aged children (ages 7-11), 13,070 of whom were from the UK, gauged pupil STEM career aspirations, reporting that boys were over four times more likely to want to become an engineer than girls (Chambers *et al*, 2018). It stated that *'Early intervention can be a very cost-effective targeted way of raising children's aspirations and broadening their horizons'* (Chambers *et al*, 2018, p.vi). There is a significant opportunity, as the ASPIRES report (2013) claims, that STEM career aspirations in primary-aged pupils act as an accurate indicator for future careers.

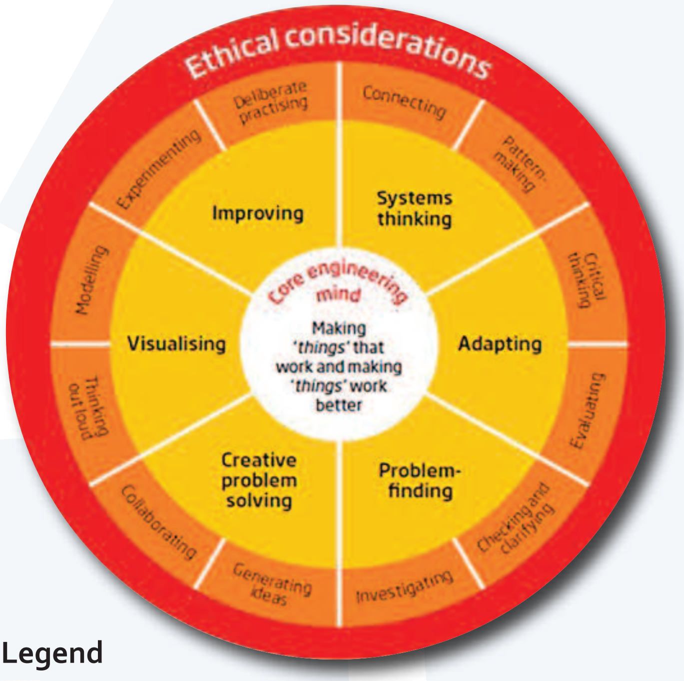
Engineering Habits of Mind (EHoM)

Lucas *et al* (2014) demonstrated distinct mindsets linked to engineering, showing that engineers are typically creative problem-finders and problem-solvers who are resilient and curious. A high proportion of engineers have a family/community member who is a scientist, engineer or practical type (for example, when the author interviewed 35 engineers in the workplace, this was true for 80%). Such links build 'science capital', with research confirming that families with medium to high science capital exert positive influence over pupils' STEM career aspirations (Archer *et al*, 2013). Providing opportunities for children to tinker and experiment with knowledgeable adults is key (Bianchi & Chippindall, 2018).

For pupils where there is a deficiency of engineering role models in families, can we compensate in school? *'Our current education system... does not sufficiently develop these habits of mind of young people to encourage them to pursue further study towards engineering careers'* (Atkinson, cited in Lucas *et al*, 2014). Can we, as teachers, be part of the solution?

Whether pupils pursue a STEM career in the future, or not, these habits of mind are beneficial to all walks of life and nurturing them in the younger years could be significant.

Figure 1. Engineering Habits of Mind (EHoM) (Hanson *et al*, 2018).



Legend

- Six Engineering habits of mind
- Twelve sub-habits

The curriculum

Whilst engineering is rarely visible in primary schools (Lucas *et al*, 2014), the National Curriculum (NC) design and technology (DT) content is highly supportive of developing EHoM as well as '*... develop[ing] a critical understanding of ...[the] impact [of DT] on daily life and the wider world*' (DfE, 2013, p.180). A report by the Institute of Mechanical Engineers (2016b) states that '*...pupils should be taught about engineering and the manufactured world alongside the natural world*' from the age of six. With non-core subjects frequently squeezed off the primary timetable, available time remains a challenge (Lucas *et al*, 2014; Leonardi *et al*, 2017; Macleod, 2017). However, the author believes that creative teachers can effectively use the current NC to provide ample opportunity to nurture EHoM, raise 'science capital' and open children's eyes to the numerous and varied career options that studying STEM subjects present beyond the traditionally recognised roles of doctor or scientist (Archer *et al*, 2013).

Methodology

Context and sample size

A monthly whole-school STEM Assembly series was designed and run for 16 months in an average-sized primary school in a market town in England.

The impact on 59 upper Key Stage Two pupils (age 9-11) was evaluated as part of a Masters' level study with the organisation Primary Engineer and accredited by Strathclyde University.

The effect that this initiative had on attitudes and aspirations was monitored through multiple research methods (questionnaires, a focus group and pupil reflections), to canvass the opinion of all stakeholders (pupils, parents and staff). The study was designed to evaluate the impact of a STEM Assembly initiative that had already begun, so baseline pre-intervention data were not available. Therefore, a control group (26 Year 5/6, ages 10-11, pupils) from a local primary school of similar size and demographic, which did not run this programme, was used to make comparison. The gender split of the research groups was broadly even.

STEM Assembly practicalities

Recruitment of engaging engineers and scientists for the monthly STEM Assemblies came largely through the parent community, with additional speakers gained through Twitter and the STEM Ambassador network. Presenters were asked to foster curiosity amongst pupils by sharing about a day in their working lives, demonstrating how STEM subjects are used in the workplace, explaining what inspired their career choices, expressing their greatest job satisfaction, as well as the largest challenges faced.

An interactive talk of 20-30 minutes, with question time after (which the author led interview-style), was the model implemented. Contributors were asked to keep text on slides to a minimum, include photos and videos, bring kit to demonstrate work and give real world contexts. Curriculum-linked workshops for specific year groups followed, where applicable, with experts in these fields. For example, there was a session on aerodynamics and forces for Year 5/6 and an in-depth exploration of the skeletal system for Year 3/4 (ages 8-9) led by experts.

Range of role models

Contributors (male and female), from varied careers included a Formula 1 race engineer, who explained that there are 10,000 parts on an F1 car and 500 measurements that have to be taken, which requires patience, perseverance and resilience. Others included the Bloodhound Education team, an orthopaedic surgeon, design engineer, biomedical scientist, civil engineers, volcanologist, cardiologist, medical engineer, Olympic bicycle engineer and space engineer, who all enthused pupils by giving fascinating insight into their jobs.

Findings and discussion

Knowledge of STEM

98% of pupils at the trial school reported having heard the term STEM, compared to 19% in the control. On its own, knowledge of the acronym STEM may have a limited impact, but this finding does highlight the opportunity to raise awareness in primary schools.

Favourite subject at school

More pupils (49%) in the trial school listed science as a favourite compared to 4% (equating to 1 pupil) in the control school.

STEM career aspirations

Attitudes towards science as a future career were very low for pupils in the control group, at 3% of boys and 7% of girls. Scientific careers are considered by a significant number of pupils in the research school (28% of boys and 40% of girls).

The ASPIRES report (Archer *et al*, 2013) stated that 15% of young people (aged 10-14) aspire to become scientists. The trial school had a much larger proportion than the national average.

Whilst broadly similar numbers of boys would consider becoming engineers (48% versus 50%), 33% of girls in the research school were open to looking at a career as an engineer compared to none in the control school.

A comparison of the most popular potential careers (Table 1) reveals an interesting picture, with 'sportsperson' being the top choice locally and nationally (Chambers *et al*, 2018), but being matched with numbers of pupils in the study school who wanted to consider a career in engineering. Scientist takes third place in the research school compared to 7th nationally and 11th in the control school.

Figure 2. Favourite subject.

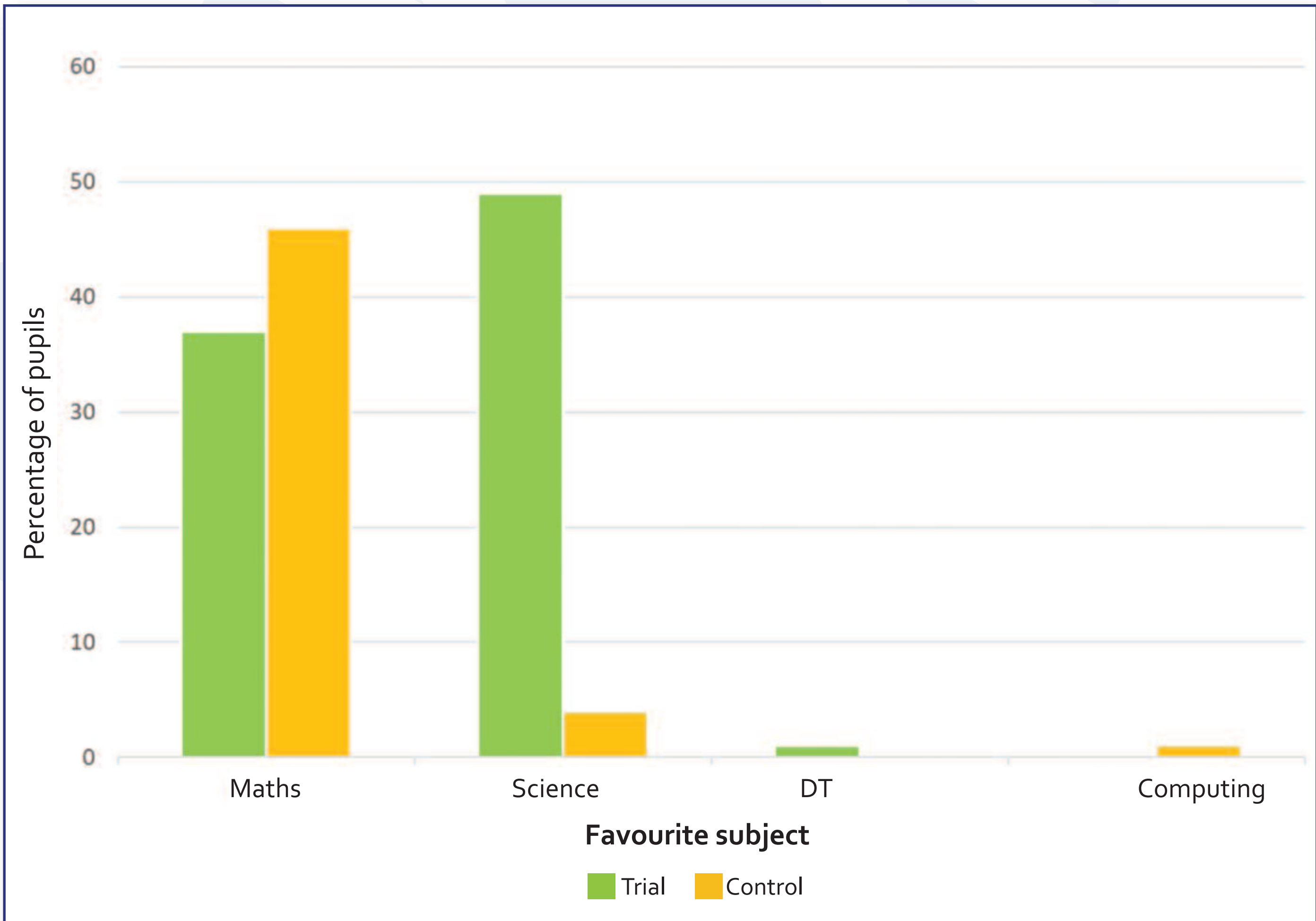


Table 1. Jobs that pupils aspire to do.

	Trial (n=59)		**Control** (n=26)		**Large scale study** (n=13,070)	
RANK	JOB CATEGORY	%	JOB CATEGORY	%	JOB CATEGORY	%
1.	Sportsperson / **Engineer**	41%	Sportsperson / Teacher / Artist / Dancer	31%	Sportsperson	21.3%
2.	-		-		Teacher	10.9%
3.	**Scientist** / Artist	34%	-		Vet	6.9%
4.	-		-		Social Media and gaming	5.7%
5.	Architect / actor/ police	29%	Architect	27%	Police / doctor	5.2%
6.	-		Author / chef / **engineer** / mathematician / vet	23%	-	
7.	-		-		**Scientist**	4.2%
8.	Author / film maker / mathematician / dancer	25%	-		Artist	3.9%
9	-		-		Musician	3.8%
10	-		-		Military	3.3%
11	-		**Scientist /** Police	19%	**Engineer**	2.5%

Figure 3. STEM career aspirations after intervention (trial) or no intervention (control). Pupils selected all jobs that they would consider.

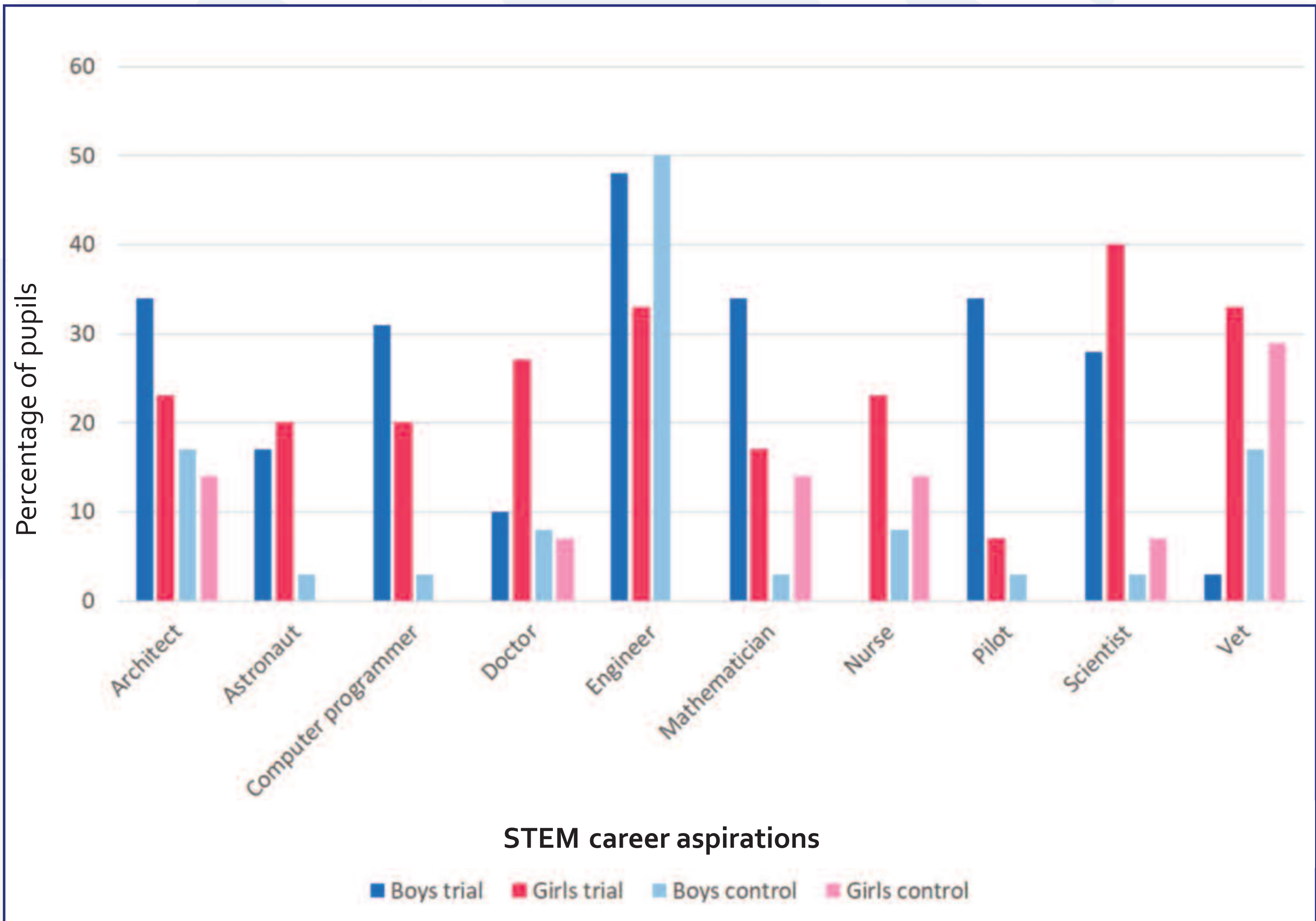
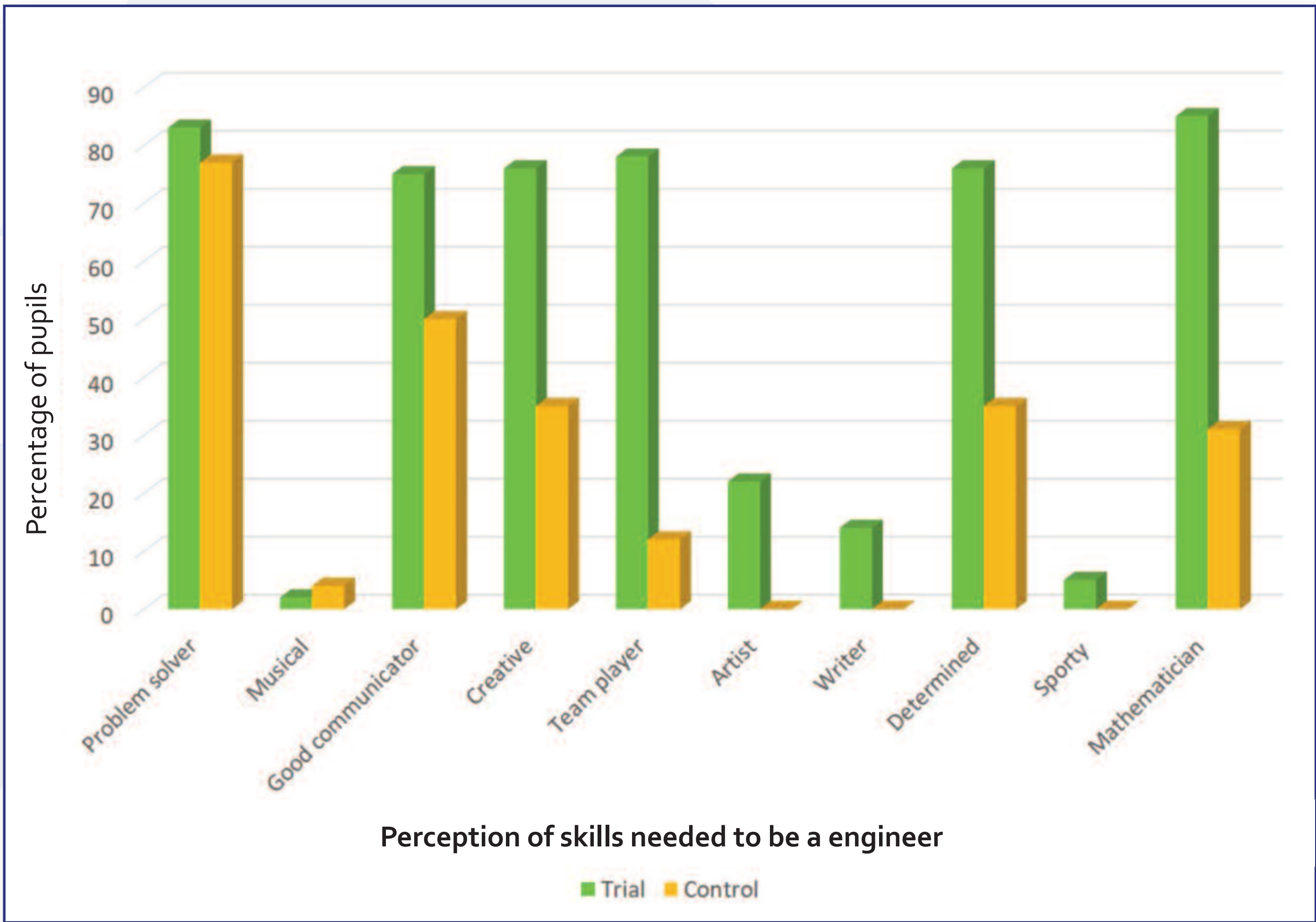


Figure 4. Perception of skills needed to be an engineer.



Perceptions of skills needed to be an engineer

Whilst problem-solving was widely acknowledged as important by both groups, the skills of good communication, creativity, team-playing and determination, which are all key to the role of an engineer, were undervalued by the control school. Only 31% of the control school indicated that maths skills were important for an engineer, compared to 85% in the study school.

What does an engineer do?

Only 57% of the girls in the control group attempted to define what an engineer did and, of those, 88% mentioned the word 'fix'. Whilst many girls in the research school also used the word 'fix', their comments were more detailed and often referred to the diversity of roles that an engineer might have.

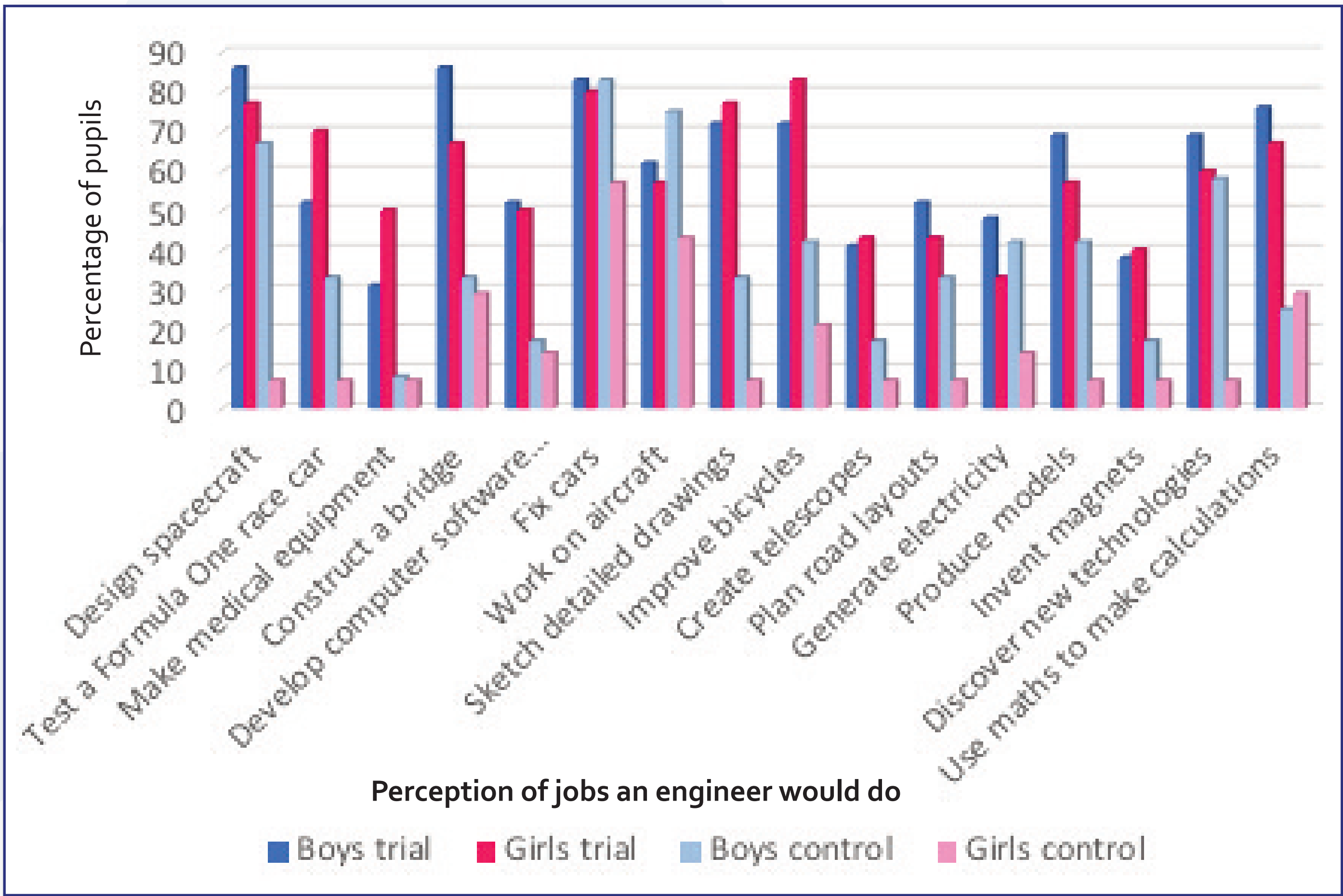
Understanding types of engineering

Greater numbers of pupils (boys and girls) in the research school had an awareness of the diversity of engineering roles. Multiple experiences of meeting different types of engineer were experiences highly valued by the research school pupils.

EHoM (self-reported)

The extent to which pupils in the trial school exhibited EHoM after 16 months of quality contact with scientists and engineers was observed first-hand, with a noticeable increase in creative problem-solving and resilience. In order to gain qualitative data, the EHoM self-report questionnaire, taken from the *Thinking Like an Engineer* (Lucas, 2014) research study, was used, as it had been tried and tested on a large scale. Boys scored similarly for both schools. Most notably, the trial school girls were more likely to enjoy making new things, to acknowledge that they come up with good ideas and use models to demonstrate them, to value group work and have a greater tendency to practise, even when problems are challenging, than their counterparts.

Figure 5. Perceptions of jobs that an engineer would do.



STEM Assembly feedback

100% of focus group pupils reported that it was the right decision to invite engineers to their school. *'The STEM assemblies are inspiring because it shows what you could do when you become older and how you can become that person.'* All expressed their preference to meet an engineer in person rather than see them on TV because *'...you get more about their personal lives by actually meeting them'* and *'...it's just for you'*. They felt more likely to consider a career as an engineer having met one in real life, because *'...they sort of like give you inspiration...tell you something like their life stories and...the challenges'*. Pupils recognised that skills required to be an engineer included *'...being patient because it's not going to work all the time'*.

Determination and perseverance were modelled consistently by visiting engineers. The researcher observed how pupils became more resilient when undertaking associated practical challenges in class linked to the use of the engineer design cycle (Figure 6).

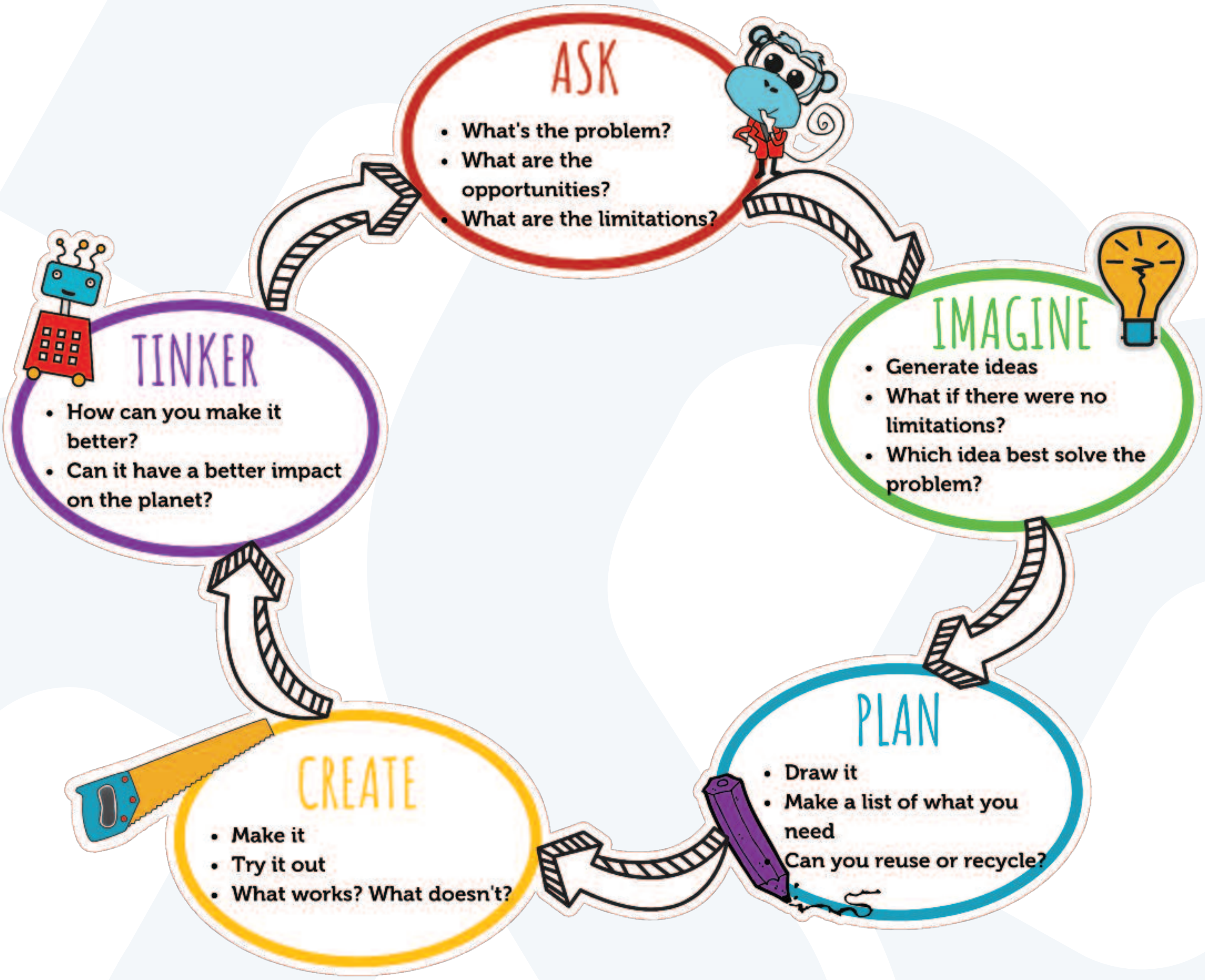
'It helped me to feel like it would be quicker and you actually knew what you were going to do next instead of making it up as you go...it makes it more likely to work.'

Summary of findings

The findings showed that, as a result of the initiative:

- engineering was the top career choice in the trial group along with sportsperson;
- trial girls were more likely to consider engineering and science as a career (compared to the control school and large-scale study);
- trial pupils had a far greater understanding of the role of the engineer and the skills needed;
- trial pupils demonstrated an appreciation for the diversity and scope of engineering careers;
- trial pupils got to experience how engineering related to their everyday lives with real world contexts; and
- science and engineering career aspirations in the trial group overall were much greater than those reported nationally (Chambers *et al*, 2018).

Figure 6. Engineer Design Cycle, The Curiosity Box (2019).



These findings raise the question of how to ensure that pupils regularly meet a range of engineering role models first-hand to see the importance of engineering to our society, view it as a credible, accessible career choice, learn how engineers think (what we now know as EHoM), and see its relevance as well as real world applications (Queen Elizabeth Prize for Engineering, 2017; Lucas *et al*, 2014). It is widely acknowledged by many authors that '*looking forward, engineering has the potential to tackle the global issues facing our planet*' (Engineering UK, 2017).

Impact on practice

This study has shown that, as part of a programme of enrichment activities, monthly STEM Assemblies can positively impact the career aspirations of pupils, most significantly amongst the girls.

As a model, this could be replicated in other schools. Issues to overcome would be gaining support from school leadership and teaching staff alike in order to maximise the impact. Logistics, such as the best time and frequency for the assemblies, would need careful consideration. It takes time and a good network to source high quality engineering presenters from a diverse range of engineering careers, which could be a challenge for some teachers (Lucas *et al*, 2014). Whilst engineers are willing experts, they need specific guidance about how to convey their knowledge to a younger audience. The author acted as a bridge between organisations, academic institutions and pupils to create content that was highly engaging, relevant and, where possible, linked to the curriculum.

With the new Ofsted framework (2019) stating that all pupils are to be given the '*knowledge and* *cultural capital they need to succeed in life'*, opening their eyes to the array of STEM jobs and real-world applications for what they are learning is key. STEM Assemblies and development of EHoM also build *'...knowledge and skills for future learning and employment'.*

Engineering can successfully be embedded in practical activities in the classroom, whether that be in science, DT, history or PSHCE lessons, for example, and through a range of National Curriculum topics such as forces (aerodynamics on a F1 car, making boats and studying floating and sinking, gliders or aeroplanes, bridge-building), space (rockets, space buggies) and climate change (electric vehicles, solar power, recycling). Highlighting to pupils how engineering is part of our everyday lives is vitally important as *'...looking forward, engineering has the potential to tackle the global issues facing our planet'* (Engineering UK, 2017).

Conclusion

In this particular school setting, under the organisation of an enthusiastic promoter of STEM, pupils did benefit from monthly contact with a dynamic range of engineers (and scientists). They were enlightened about the scope and range of engineering careers, made links between what they were learning in class and the real world, gained confidence in persevering with tasks to achieve a desired outcome, and were excited about science and engineering. Asking experts their questions first-hand made a real impression on pupils (as reported by the focus group).

The role and impact of primary educators in fostering and nurturing STEM career aspirations in young children is clearly demonstrated in this research, and is especially significant given that *'the sparks lit at this age could last a lifetime'* (Institute of Mechanical Engineers, 2016a, p.51).

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Gases in the Air: A science demonstration assembly for primary schools

● Tim Harrison ● Jonathan Furze ● Dudley E. Shallcross

Abstract
This article considers the place of science demonstrations for science communicators and teachers who wish to create effective primary science assemblies. Feedback from schools over a 3-year period is used to demonstrate the impacts on pupils and teachers of science assemblies (chemistry lecture demonstrations), given by appropriately trained science communicators, on pupils' (UK Years 1-6, ages 5-11) understanding of the Earth's atmosphere and climate.

The appreciation by teachers of using challenging concepts, correct terminology and in redressing teachers' own science misconceptions is highlighted. The enthusiasm shown by the pupils for live science demonstrations (not to be confused with chemical magic shows) is evidenced.

Keywords: Science communication, science demonstrations, school assemblies, raising aspirations

Introduction

The evidence for climate change is overwhelming (IPCC, 2019) and underpins the United Nation's Sustainable Development Goals (UN, 2019). Children are aware of a wide range of environmental issues, including air pollution and climate change and their importance and urgency. As part of the Bristol ChemLabS Outreach Programme from the School of Chemistry at the University of Bristol, the primary school talk *Gases in the Air* has been given (usually) to children and teachers in around 3000 (mainly UK) primary schools since 2008 (Tuah *et al*, 2010; Harrison & Shallcross, 2011a; Sunassee *et al*, 2012; Shallcross *et al*, 2013; Harrison & Shallcross, 2016a, 2016b).

The talk considers the gases in the air (Figure 1) and introduces the ideas of air quality and climate change. In this paper, we briefly describe the content of the talk and then use feedback from schools to highlight why it has been so effective (evidenced by awards, the number of schools that have engaged, feedback and other examples).

University (chemistry) Outreach programmes often use classic experiments, such as liquid nitrogen (often in the production of ice cream) and the production of a foam during the decomposition of hydrogen peroxide, often referred to as the 'Elephant's Toothpaste Experiment' (Harrison &

Figure 1. A typical experiment (balloon into liquid nitrogen) from chemistry demonstration talks by Bristol ChemLabS' Outreach programme.

Shallcross, 2016a; Pratt & Yeziereski, 2017, 2018a, 2018b, 2019), during outreach events to schools (see Figure 1). In a series of recent papers, Pratt and Yeziereski (2017, 2018a, 2018b, 2019) surveyed university students who were part of outreach programmes across the US and, whilst they believed that school student recipients were having fun, learning new ideas and connecting with scientists, the researchers discovered several science misconceptions amongst the university student chemist presenters and, as a result, some of their answers to questions were incorrect. In addition, their understanding of appropriate language, assumed prior knowledge, and appropriate use of analogy was shown to be problematic, whilst it was clear that primary school outreach posed additional communication problems to those considered at secondary school level.

Content of the assemblies: *Gases in the Air*

The talk uses a range of lively chemistry and physics demonstration experiments to discuss the different gases in the air. A range of liquid nitrogen experiments (Tuah *et al*, 2010; Harrison & Shallcross, 2016a) is used to discuss changes of state, reversible and irreversible change and observational skills, as well as to discuss the major gas in the atmosphere, nitrogen (N_2). Oxygen (O_2) is discussed using the Elephant's Toothpaste Experiment, i.e. the decomposition of hydrogen peroxide (Tuah *et al*, 2010), which also illustrates the role of a catalyst (Figure 2). The role of oxygen in respiration (not breathing) and in combustion is discussed, as is the production of oxygen from photosynthesis by plants (and not just trees). For carbon dioxide (CO_2), another major gas, solid CO_2 (dry ice) is used in a range of experiments that illustrate sublimation, the acidity of carbonated water (water with dissolved CO_2 in it, such as the oceans) and the process of neutralisation. The illustration of properties of the low-density gases hydrogen and helium, through their explosive and non-explosive nature, is memorable (a 'chemistry magic show'). The talk is in the tradition of storytelling (e.g. Dahlstrom, 2014), whereby it weaves a story around the demonstrations rather than just going through experiment after experiment. The longer version of the talk (given to secondary schools and the general public) is called 'A Pollutant's Tale' and demonstrates the strong emphasis on narrative. The audience are encouraged to participate where appropriate, are asked questions and are invited to make predictions throughout in keeping with the model found to be most effective for talks with demonstration experiments (DeKorver *et al*, 2014).

All outreach talks and, particularly, *Gases in the Air*, were devised by a highly experienced secondary school science teacher, who was the first School Teacher Fellow (Shallcross & Harrison, 2007a, 2007b; Shallcross *et al*, 2014) in the UK, working with a research academic expert here in atmospheric chemistry. Such a combination ensures that appropriate science language and concepts are used for the target audience, experiments used can be mapped to curricula and, because a teacher leads this activity, there is good overlap with other teachers whose schools are visited. Pre-visit materials and conversations can prepare the teachers for the visit and they can prepare their children. Like many programmes, Bristol ChemLabS works with postgraduate students (Harrison *et al*, 2011b) who are trained to deliver a wide range of talks. The issue of misconceptions for any deliverer is minimised, as a senior member of the team will work with and accompany a junior member until the former is confident that the talk is being delivered to the high standards set. Analysis of typical feedback allows the impact of the talk to be monitored.

Feedback from schools

Immediately post-assembly, the organising teacher is asked verbally for feedback on 'the impacts of the assembly on their pupils and/or teachers'.

Figure 2. The Elephant's Toothpaste Experiment.

This is followed up with an e-mail sent within 48 hours posing the same question. The consistent question and lack of formalised questionnaire allows for free response-style feedback. Some correspondents simply reply by e-mail; others add tweets and articles in school newsletters. Responses are typically sent within 2 weeks. Occasionally, pupil letters, used by some as a follow-up, are sent by post. These are not considered here. The feedback obtained over the 3 years of the project was then collated by dominant theme. Typically, feedback is positive, emphasising the excitement generated through the storytelling approach, the raising of aspirations, the longevity of the impact and the impact on children and teachers. Themes from feedback that provide insights into aspects of the talk are considered in more detail below, illustrated by representative examples from school feedback.

Explaining the science behind the experiments

It is not enough to carry out exciting experiments; the science behind them must be explained at the appropriate level and this requires expertise and effort to make it happen. The talk/science assembly/lecture demonstration has benefitted from much feedback and advice over the years, has been given in schools across the world and translates well. The issue of the presenter propagating misconceptions is addressed by using a highly experienced school chemistry teacher to deliver the talks, or to train/teach those delivering the assemblies so that misconceptions are not propagated:

'*Thank you very, very much for the most excellent show last week. I have never ever seen anyone do a whizz and bang type of science show* ***before, where they properly explain to the children in language that they can understand and use, exactly what is happening****. Amazing. Shows it is possible, and people like [named commercial groups] should hang their heads in shame. The children really, really loved it and learned masses* ***(and it was excellent CPD for the staff too)*** *and we will all remember it for a long time*' (Science Co-ordinator).

Some examples of misconceptions addressed in this assembly include:

- When asked what colour the nitrogen gas in the air is, pupils often answer in terms of transparency ('clear', 'see-through'), i.e. light passing through the air, rather than answering in terms of lack of colour – 'colourless'.
- Boiling and freezing: in everyday parlance, these terms are used to describe the weather. In science, they have precise meanings. 'Boiling' describes a liquid becoming a gas. Liquid nitrogen boils at a temperature 220°C below room temperature. A solid such as a metal coin is frozen, i.e. solid. Putting rubber tubing into liquid nitrogen cools down an already frozen (solid) material and changes its stretchy properties.
- The breakdown of the structure of expanded polystyrene with acetone is not a melting process, as no heat is used.
- Photosynthesis (oxygen production) is not just carried out by trees, but by all plants, including weeds, grass and seaweed.
- Fuels do not release energy. The combustion (burning) of fuels with oxygen releases energy (heat, light and sound), i.e. reactions release energy.

Knowledge, feedback and answering of questions

Asking and answering questions offers a chance for children to articulate and develop their knowledge. Skill in answering questions is important as the feedback below states, with the way in which the questions are answered (language, tone, etc.) being critical for the audience.

'He handled the questions from the children really well – the answers to some of the more obscure questions were interesting and well thought out. I particularly liked the way he picked up on the words the children were using. If they weren't scientific, he would let them know (giving them examples of words they could try instead)' (Accompanying teacher).

All the audience are engaged with challenging material

The audience of the assemblies is not solely comprised of children; teachers, teaching assistants and, occasionally, caretakers, school governors, administrators and carers/parents may also be in attendance. It is important that those in contact with the children post-assembly understand the content and, where necessary, adjust their own previous knowledge, to answer the inevitable pupil questions.

'I know that there are now children who have had their imaginations ignited as a result of the visit. The presentation was full of facts, figures and fun and

managed to keep Year R to Year 6 captivated – a real skill! X spoke about "CPD by diffusion" and I know that some of the teachers and other adults in the room were equally captivated by the possibilities presented' (Science Co-ordinator).

'Your impressive assembly was the highlight of our school's science week. All of the staff that attended have since commented on the additional subject knowledge that they gained from the session…It is an important part of all our jobs as science leads to instil in our children a love for science' (Science Co-ordinator).

Participants enjoy being challenged by the material presented and supported in their exploration of it. One of the constant issues raised about teaching science at primary school is teacher confidence (e.g. Murphy *et al*, 2007) and it is important that talks of this kind support staff's continuing professional development (CPD).

Raising aspirations and science as a potential career

It is often imagined that discussing science careers, or careers in general, with primary-aged children is neither possible nor effective. However, this is possible, is effective here and is welcomed by all school participants. Indeed, pupils leaving the assembly have often raised aspirations and want to tell the presenters that they now want to be scientists!

'…The show was definitely inspiring for the children: they can see science as something very exciting and hopefully very achievable. I loved the way you talked about the various careers that can stem from taking science as an academic subject as this gives it a purpose and places it in the real world' (Organising teacher).

*'…Many of the **children** have now **decided** that they are going to be **scientists**! ([Named pupil] says that he now knows which university he's going to go to!)'* (Organising teacher).

Talks of this kind make follow-up hard

There are support materials available but, as feedback below shows, school classes can reflect on the material covered themselves. The combination of fundamental science concepts in support of ideas about air pollution allows both teachers and children to explore further. Whether they are used, or how they are used, to expand the National Curriculum is determined by the teachers. The use of these materials has not been monitored. *'The visit was inspirational to the children. There has been a lot of talk since the assembly about gases in the air and all the classes did a follow-up session afterwards. Some classes wrote letters about what they discovered, others made posters and others made poems. All the teachers who attended the assembly have given their praise to the way it was presented to the children. It was very engaging and brought to life 'gases' in a fun and interactive way'* (Organising teacher).

Fun and learning

Humour is one way of delivering materials to students: that is, assuming that the humour is appropriate. Instructional Humor Processing Theory (IHPT) hypothesises that humour related to content correlates positively with student learning, at least in higher education. It has been found that inappropriate humour has the opposite effect (Wanzer *et al*, 2010). From the teacher's perspective, this also applies to primary school children. The use of appropriate humour includes grabbing the attention of students, managing possible disruptive behaviour, creating a positive attitude to the topic, and reducing the anxieties that some have with potentially difficult topics (Ziv, 1988).

'The science show that X did was fantastic!!! Throughout the talk he made all aspects of what he was doing really interesting for all the children. The humour was perfectly pitched for them and that grabbed them and then, on top of that, there were bangs and explosions that made it even better' (Teacher).

'The whole school was buzzing for the rest of the day…It was pitched perfectly to the audience and challenged the children's science investigative skills as well as their knowledge. I particularly liked how you related it to things the children were familiar with so that they could relate to it all.

You always know when something has gone down well in schools when you overhear conversations in the dining hall about what sort of scientist/engineer the children want to be when they grow up!' (PSTT Fellow).

Change in science profile at a school

The poor status of science in some primary schools is often commented upon by organisers while the assemblies are being set up. It is pleasing that feedback indicates that such large-scale assemblies have given science teaching a boost in many of the primaries visited.

'*…The "gases in the air" demonstration has helped to boost the profile of science in our school and made all of the children excited and enthusiastic about science and its possibilities. Thank you, X!*' (Science Co-ordinator).

'*The children enjoyed the range of demonstrations carried out. Subsequently, we have gained a great deal of momentum in our science lessons, both in scientific thinking and in realising as staff and pupils how important it is to really hone down on using accurate scientific language to describe what we observe and hypothesise. Many thanks*' (Headteacher).

It is often said that talks with science demonstrations are easily forgotten and have little long-term impact. Our experience suggests quite the opposite: schools are using the talk to change the way that they teach science and using it as an inspirational launch pad for science in their school.

Summary

There can be much scepticism about science demonstrations for primary school pupils, with criticisms including 'helicoptering in' as being ineffective, follow-up being difficult for schools, poor use of appropriate science language and being perceived as a 'magic show' where exciting experiments are simply shown without correct explanation at an appropriate level for the audience. Through using appropriately trained science communicators and teachers, where vocabulary, the correct science theory and analogies, the relationship to everyday examples and, of course, health and safety considerations are addressed, these criticisms are overcome and pupils, teachers and other staff and stakeholders obtain a valuable learning experience that they will remember for some time. Our experience shows that it impacts on long-term learning, aspirations and confidence.

Acknowledgements

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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.

The Editorial Board

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.

Contributing to the journal

Please send all submissions to:
janehanrott@ase.org.uk in electronic form.

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.

Contributions can be of two main types; full length papers of up to 5,000 words in length and shorter reports of work in progress or completed research of up to 2,500 words. In addition, the journal will review book and resources on early years science.

Guidelines on written style

Contributions should be written in a clear, straightforward style, accessible to professionals and avoiding acronyms and technical jargon wherever possible and with no footnotes.
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.
- Tables, figures and artwork should be included in the text but should be clearly captioned/ labelled/ numbered.
- Illustrations should be clear, high definition jpeg in format.
- 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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Journal article

Reiss, M. & Tunnicliffe, S.D. (2002) 'An International Study of Young People's Drawings of What is Inside Themselves', *Journal of Biological Education*, **36**, (2), 58–64

Reviewing process

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.

Books for review

These should be addressed and sent to Jane Hanrott (JES), ASE, College Lane, Hatfield, Herts., AL10 9AA.

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PLAN is a set of resources produced to enable teachers to have a clearer understanding of National Curriculum (England) expectations for meeting the standard in science. See www.ase.org.uk/plan for more details.

The *PLAN* is evolving

We know from *Understanding the 'state of the nation' report of UK primary science education*, published by Wellcome in January, that only 22% of teachers surveyed 'strongly agreed' that they were confident in undertaking summative assessment and only 21% 'strongly agreed' that they were confident in undertaking formative assessment. We also know from *Intention and substance: further findings on primary school science from phase 3 of Ofsted's curriculum research*, that science assessment is absent or not well embedded in curriculum design in more schools than for English and maths.

PLAN was developed to support teachers with precisely this challenge. To date, the planning matrices are helping teachers ensure that their plans cover all the required knowledge, and the examples of secure work are enabling teachers to confidently judge the knowledge of their pupils.

But we haven't stopped there. We have almost completed the publication of the comparative examples that enable teachers to develop their moderation skills, building their confidence in individual assessment as well as greater consistency across year groups.

We are now turning our attention to supporting the assessment of 'working scientifically' skills. In the near future, we aim to publish new versions of the planning matrices that will include explanations of what the relevant working scientifically statements for each phase mean and, over the next year, we intend to publish examples of what this might look like in practice. If you are interested in working with us to gather these examples, we'd love to hear from you. You can contact us via www.primary-science.co.uk

We are currently trying to capture evidence of how the **PLAN** resources are being used and their impact. We will be creating an online survey for this purpose and would be very grateful if you would share your views with us to inform our plans for the future. Look out on www.ase.org.uk for news of the survey in future months.

***PLAN* resources – only available to ASE primary teacher/school members!**