JES

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Issue 19 Summer 2020

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

why& how?
PRIMARY SCIENCE TEACHING TRUST

Contents

Issue 19 Summer 2020

Contributions

Response to the Coronavirus Pandemic

Main Articles

Regular Features

Editors:
Amanda McCrory
Suzanne Gatt

Executive Editor:
Jane Hanrott
janehanrott@ase.org.uk

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why & how? PRIMARY SCIENCE TEACHING TRUST

Editorial

Suzanne Gatt

The first cases of Coronavirus (COVID-19) were reported in Wuhan, China in December 2019, and it then spread at growing speed to different countries, reaching a global pandemic in March 2020. These events have made life in the past few months strange for us all, as the world fights a pandemic, which, despite being forewarned that it could occur, no one across the world had believed could ever really happen.

As COVID-19 has spread all over the world and infected people indiscriminately, we have all found ourselves listening to daily briefings from both politicians and scientists. Overnight, the role of scientists in the public community changed dramatically. Politicians started asking science research experts to provide evidence upon which to base their decisions about whether, and to what degree, to close down economic and social activities. Citizens felt insecure as they struggled to understand what this new virus was and how dangerous it could be. They needed scientific advice to learn about how best to protect themselves from COVID-19, and whether an effective vaccine could be developed swiftly. The media dedicated great attention to the pandemic, catapulting many scientists and public health officials into the public sphere, where they ended up on television and social networks on a daily basis (Cinti, 2020). Never before had the human race relied so much on science and scientists to find ways of controlling the pandemic and eventually beating it, and this still remains our hope. Alas, while a lot of hope was vested in science and the work of scientists, the general public were also exposed to the realities of the nature of science. While many, reflecting the positivist view of science, expected scientists to give clear and quick answers to their concerns, they were instead faced with conflicting opinions, and knowledge that kept changing almost on a daily basis as scientists learned more about COVID-19.

Many citizens were not prepared for the uncertainties that normally surround scientific enterprise (Chow, 2020). Not only this, they were also faced with some politicians, with no scientific background, taking advantage of this uncertainty and imposing their personal opinions as 'more informed', using citizens' fears about economic uncertainty to promise economic stability. Never before has the expertise of scientists been under attack as much as in these past few months.

What does all this imply to us science educators? It has to be acknowledged that it is not the scientists who have failed society, even if, at times, some have not communicated as well as they could, in simple language that can be understood by a lay citizen, the problems and difficulties that they face in learning about a new virus within such a very short time frame. It also highlighted how the education system has, to a degree, failed many, as they clearly did not understand that, however rigorous science may be, it always operates within a fair degree of uncertainty. They did not understand that science can still provide a good level of understanding based on a fair amount of evidence, compared to politicians, who tend to base their opinions and decisions more on hunches and are more prone to economic pressures.

Scientists need to learn how to communicate and explain the processes of science in a way that is understandable to the public, but is still scientifically robust (Provenzi & Barello, 2020) – this is why public engagement initiatives such as those led and funded by the Royal Society are so important. Science communication should also become less one-sided, where scientists provide information and citizens receive it passively, to an active two-way engagement in which citizens can share concerns as well as query claims made by scientists. As science citizens, the public can also play a role in supporting scientists, if possible, by providing data that scientists can analyse for the benefit of all.

Science education, more than ever before, needs to focus on helping learners from a young age to understand scientific enterprise and the uncertainty within which it operates. This can be achieved through simple scientific enquiries that children can carry out themselves. Simple investigations can easily highlight how science never gives clear-cut answers but nonetheless provides good insights into how the world works. For example, in a simple investigation where a dozen snails are given different food to test their preferences, one will never get a clear-cut result with all snails choosing the same food. It also creates the opportunity to discuss what further investigations would make our knowledge about snails' food preferences more robust. Young children can understand that, if the investigation is done with more snails and subsequently tests involving more food options, the knowledge gained via outcomes and analysis of the data will be deeper and based on more robust evidence.

It is thus our role as teachers to engage children from a young age in discussions and reflections about how sure we can be with our, and also scientists', scientific conclusions. Such reflections can prepare children better to deal with current events in the world, where science can provide answers, but where complete certainty is not an option – building resilience and a deeper understanding of the nature and processes of science.

During these past few months, teachers have also faced the challenge of teaching students remotely, as schools closed but learning needed to continue. Teaching science, being a hands-on subject, presented additional challenges to that of covering content as in other subject areas. How can one replicate virtually the excitement and effective pedagogy that children experience when carrying out investigation in a group, taking turns, discussing observations and sharing their opinion? Many children all over the world have missed a good part of this scholastic year. We will only know later on what impact this has had on children's education overall, and particularly in science.

This edition of *JES* was prepared in the midst of the pandemic, and includes contributions submitted mainly before the crisis. It does, however, include a paper by my colleague, Amanda McCrory, on examples of good practice in science regarding how teachers have managed to teach science against all odds. Her paper ***What a Coronacoaster!*** provides insights from interviews with EYFS and primary teachers about how they have been coping with the situation during April and May, and how they navigated their way around existing limitations to deliver science curricular activities to the best of their abilities.

The article by **Harrison *et al*** focuses on how primary children can investigate atmospheric pollution using Defra's Air Quality Archive. It provides examples of existing data and how teachers can use these data for science investigations. While written prior to the pandemic, it provides some inspiration on which science activities primary teachers can provide remotely.

MacAogain focuses on barriers to creativity in primary science lessons. He reports on results from a small-scale study with primary school teachers from rural Irish schools about their experiences with creativity and teaching science. It highlights the tension between creativity and teaching for assessment, and the perceived constraints by the curriculum that is to be covered.

The paper by **Rupali *et al*** tackles enquiry-based science on the topic of food chains and webs, and how worksheets promote classroom engagement and discussion among students and their ideas about the environment in the context of Indian classrooms.

We finally present two **book reviews,** and a related article by **Amy Broemmel and Kristin Rearden,** which is topical, considering how scientists' work in science and engineering can be brought to life through picture books, engaging children in the nature of science. On the other hand, the review of the book by Kirsty Bertenshaw highlights many examples of tried and tested simple experiments that can be organised in class. Since many use simple everyday materials, they also have potential for use in remote learning, as children can try things out themselves at home. The book by Sue Dale Tunnicliffe examines how children develop as emerging biologists, with a focus on play and effective talk illuminating this well.

It is hoped that this issue will be interesting reading for educators, who can reflect on their practice, as well as on how important it has become to help children to understand scientific enterprise, which, despite its uncertainty, can still be considered as the most trusted source of information during these times.

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Suzanne Gatt is Co-Editor of the *Journal of Emergent Science.*

Note:

ASE would like to thank Suzanne Gatt and Amanda McCrory for whom this is their last issue as Co-Editors of *JES*. For the past few years, they have worked tirelessly to ensure that the high quality of articles for those involved in teaching the 0-11 age range has been maintained. We are very grateful to Suzanne and Amanda and wish them well for the future.

‘What a Coronacoaster!’

Navigating primary science education in primary schools during the ongoing COVID-19 pandemic: EYFS and primary school teacher perspectives on the affective and pedagogical impacts of the pandemic

- Amanda McCrory

Abstract

The literature in science education highlights the important role of children learning conceptual science via enquiry, through age-appropriate pedagogies, to engage them in active, collaborative learning opportunities. Given the recent closure of schools and the global pandemic of COVID-19, how have primary schools been providing science education for the children they serve? The perspectives of ten EYFS and primary school teachers from schools in North and East London, England were investigated. The purpose was to gain in-the-moment insights regarding the teaching and learning of science in primary schools during the ongoing COVID-19 pandemic, an understanding of the questions some primary-aged children have asked about the virus, and teachers' perceptions about the affective impacts of the pandemic on them.

Data were collected via semi-structured online interviews between April and May 2020, during the enforced lockdown in England. Analysis of the interview transcripts utilised the five phases of thematic analysis approach and grounded theory. Seven distinct themes emerged from this: (1) Active learning and scientific enquiry; (2) Challenges for teachers and for children's learning; (3) Assessment; (4) The status of science and expertise; (5) Viruses and staying safe; (6) Anxiety and sense of value as a teacher. Outcomes suggest that teachers have been planning for children's science education using activities to promote science understanding via active learning – where possible – as well as an ever-growing database of online resources; however, issues regarding the equity of children's access to these resources, as well as concerns regarding what children are actually learning due to challenges in assessment, are clear. In addition, the perceived elevation of the status of science in schools as well as an emphasis on science expertise have been highlighted as a positive outcome.

Children's questions centre around conceptual understanding of what viruses are, as well as concerns regarding keeping safe and family members dying; however, for some, robust school practices relating to hygiene and forums that promote children's agency to ask questions helpfully address these. Lastly, the uncertainties that have arisen from the effects of the pandemic – aptly referred to as a ' Coronacoaster' of emotions by one participant – highlight how the contradictory guidance given by the British Government, and the media as a whole, has impacted negatively on teachers' levels of anxiety and sense of value as a teacher in society.

Keywords: COVID-19 pandemic, primary science education, teacher perspectives, socio-scientific issues, pedagogy, mental health, wellbeing

Introduction

The COVID-19 pandemic has brought unprecedented challenges, profoundly affecting the lives of millions of people globally (WHO, 2020). The rapidly changing nature of this pandemic and of the scientific advice available is a challenge for governments and science specialists to negotiate, let alone the public. This pandemic has been and is increasingly affecting either directly (by contracting the virus) or indirectly (by dealing with the social, emotional and economic impact of the virus) all teachers and their students, in all settings globally.

Science is neither separate from society nor indeed from politics: children do not exist in a vacuum. The prevalence and impact of media in all its forms, on every aspect of modern life, cannot be underestimated and thus children are constantly being subjected to issues in society that may concern them and, indeed, challenge their thinking (Woolley, 2010). Furthermore, children are exposed to many scientific issues and situations via their families, school and wider community, which might galvanise or indeed frighten them, with some educators arguing strongly that schools and teachers have a duty of care to address issues that have a negative effect on children. Arguably, there are many children who wish to take an active part in solving these issues (McCrory & Worthington, 2018).

This has never been more evident than with the recent meteoric rise of young climate activist Greta Thunberg and the very positive impact she has made, not only on the sphere of politics but also on the lives of thousands of young people (Asmelash, 2019), clearly demonstrated via the 2019 climate strike protests held around the world. Yet, one of the main reasons that children give for not choosing science as a career option is lack of interest, enjoyment and perceived non-relevance to their lives, as well as not having a clear understanding of the value that science can have in a future career (Palmer *et al*, 2017); *ergo*, there seems a paradox at play here, which should not escape science educators and those responsible for curriculum design.

To research the effect of COVID-19 on the science education that primary schools provide, as well as the health and wellbeing of teachers and students during this pandemic, is to take seriously a broad conceptualisation of the aims of education, one that includes attempting to ensure that students flourish (Reiss & White, 2014). Schools are also establishments in which subjects are taught to give students access to 'powerful knowledge', which otherwise they would be far less likely to be able to access (Young, 2018; Guile *et al*, 2017). Related to this, researchers and others have called for subjects to re-examine the bases of their curricula, including their aims, content and pedagogy and to consider each subject's contribution to epistemic literacy.

This move has been especially strong in the sciences (Harlen *et al*, 2010). The COVID-19 pandemic therefore brings sharply into focus many of the principal aims of science education.

Science pedagogy in primary schools and socio-scientific issues

The COVID-19 pandemic is an unparalleled situation that has clear implications for science education, one of the main aims of which is to foster *all* students' appreciation of the epistemology of science (Lin & Chan, 2017). The context offers students the opportunity to become scientifically literate and to understand the nature of science; to enable them to participate more effectively in civic and cultural affairs, as well as to make personal decisions and informed judgements regarding social issues using knowledge and understanding of scientific concepts and processes (Archer *et al*, 2015).

An education to promote epistemic literacy does not begin in secondary schools, far from it – children interpret and start to make sense of the world around them from the day they are born, establishing the foundations of their scientific knowledge and understanding of the world in their home and communities prior to formal schooling (Tunnicliffe, 2020). The National Curriculum for Science in England and Wales (2013) recognises this; it is no coincidence that science in the Early Years Foundation Stage (EYFS) Statutory Framework (2014) focuses on young children 'understanding the world' via learning about people and communities, the world and technology.

Children's natural curiosity about the world around them is then built upon in Key Stages 1 and 2 (ages 5-7 and 7-11), marrying the formal requirements of the National Curriculum for Science (2013) with children's everyday experiences and interests, using direct experiences as well as a myriad of pedagogical approaches such as storybooks to develop conceptual understanding (Russell & McGuigan, 2016). Therefore, high quality science education in English primary schools has the potential to '*provide the foundations for understanding the world through the specific disciplines of biology, chemistry and physics… ensuring that pupils understand that science has changed our lives with pupils being encouraged to* *recognise the power of rational explanation and develop a sense of excitement and curiosity about natural phenomena'* (DfE, 2015: 1). Given the situation in which we all find ourselves with the pandemic and the stark effect that it is having on our lives, this statement from the Department for Education could not be more pertinent.

The COVID-19 pandemic is a socio-scientific issue of monumental proportion affecting all schoolchildren regardless of age and key stage. Socio-scientific issues are complex, socially relevant real-world problems, which are informed by science, but also include ethical and other dimensions (Sadler *et al*, 2016). Debates regarding the teaching of science via socio-scientific issues in primary schools have centred around concerns regarding the conceptual understanding of science needed by children to negotiate socio-scientific issues, as well as their place in the primary curriculum; the authenticity of socio-scientific issues being discussed and their age-appropriateness; and the pedagogical and science subject knowledge of primary teachers who teach these issues (Levinson, 2006; Evargarou *et al*, 2011; Sadler *et al*, 2019).

More recent research has focused on addressing these concerns by taking an additive rather than deficit model to primary science teaching. Strong recommendations have emerged for how primary schools can take a socio-scientific approach to teaching primary science and the positive impact that this can have on children's understanding of science concepts (McCrory, 2017), their scientific literacy, the development of their science capabilities for citizenship (Bull, 2015) and impact on their engagement in science (Hodson, 2013; Zeidler, 2014), by giving children an opportunity to address issues in science that affect and interest them (McCrory, 2017). Giving children the opportunity to generate their own lines of enquiry from their own questions promotes ***a sense of agency*** as well as encouraging a ***diversity of opinions,*** as children identify the interests and concerns of stakeholders in any given socio-scientific issue, thus uncovering the myriad of positions and opinions regarding the best solution for all involved. This in itself, argue Gormley *et al* (2019), offers children a chance to use and examine the quality of 'evidence and data' as well as the possible existence of bias to critique the arguments presented, therefore providing children with opportunities to develop an understanding of the complexities of the issue at hand, as well as promoting an understanding of the nature of science.

In addition, research projects such as the Promoting Attainment of Responsible Research Innovation in Science Education (PARRISE, 2017) demonstrate how Socio-scientific Inquiry-Based Learning (SSIBL) can also emphasise ***social justice,*** as it promotes civic involvement in scientific research and innovation via activities in both primary and secondary schools. Despite the exciting and interesting research focusing on the teaching and learning of socio-scientific issues in primary schools, this remains nonetheless an under-researched area within the field of primary science education (McCrory & Worthington, 2018). The impact of the COVID-19 virus might very well change this, as teachers and curriculum designers respond to the learning needs of *all* children as they grapple with the reality of living a new 'normal' both during and after this pandemic. To deny children the opportunity to raise their questions about society in schools is to remove its role in education – information is important, but being able to understand and then use and apply that information is even more so (Woolley, 2010). When the in-the-moment information is complex, contradictory and even confusing, and the reliability of worldwide reporting on COVID-19 questionable, it is undeniably the role of research and education to support schools and communities to navigate this.

Purpose of research

Schools with their teachers constitute the core public service that makes a difference to the lives of their students. It is teachers who see students every day, form key relationships and, along with their families, know them best. Teachers require an understanding of their students' mental health needs and have a role in intervening when students manifest anxieties or other mental health issues (DoH/DfE, 2017). In 2019, Harding *et al* reported that better teacher wellbeing was associated with better student wellbeing and lower psychological distress. Given the range of emotions raised by COVID-19, and the relentless role that the media have played in focusing on growing concerns regarding the impact of learning loss on a generation of children (Green, 2020), as well as the potential impact of school closures widening the disadvantage gap for children (Children's Commissioner, DfE, 2020), all teachers are being faced with questions from peers, students and students' families regarding the virus, which might very well be compounded by affective impacts of the mental health and wellbeing of teachers and students alike. This context must be antecedent therefore to important questions for all who are concerned with students' education and wellbeing.

Research questions

The purpose of this research therefore was to gain insights into how teachers and science leaders in primary schools have been providing science education for their students both pre- and during the enforced lockdown in England. In addition, this research sought to discover what questions children have had regarding the virus and how teachers have responded to these, to better understand the affective impacts of the pandemic on teacher wellbeing via the following research questions:

1. How do EYFS and primary school teachers report changing, if at all, the content of their teaching and/or their pedagogy to facilitate science education for their students during COVID-19?

2. What do EYFS and primary school teachers say have been the questions that students have asked in relation to COVID-19?

3. What do EYFS and primary school teachers say have been the affective impacts of the COVID-19 pandemic on them?

Research design

The interpretivist paradigm is the theoretical perspective that underpins this research given that *'Social actors negotiate meanings about their world therefore social reality consists of their attempts to interpret it'* (Briggs *et al*, 2012: 35). The interpretations of EYFS and primary teachers actually experiencing the COVID-19 pandemic whilst providing science education for the students whom they teach are considered in order to explore phenomena from their individual perspectives (Gray, 2014). With the belief that social reality is constructed by people's thoughts and actions (Denscombe, 2014), a qualitative approach was therefore taken in this research. As each participant will be experiencing the pandemic differently, a wide range of perspectives was anticipated.

Sample and context

The perspectives of 10 EYFS and primary school teachers from schools in North and East London (7 female and 3 male from across EYFS, Key Stages 1 and 2) were investigated via a grounded theory approach. Two teachers were also school science leads and one teacher worked in a special educational needs setting (nursery to 19-year olds). This approach was taken in order to derive a general abstract theory of a process, action or interaction derived from the views of participants (Creswell, 2018), as well as to explain the phenomenon being studied (Birks & Mills, 2010).

Data collection and ethics

Qualitative research often seeks to obtain deeper insights into practices of specific samples rather than to discover generalisable patterns of larger data sets (Gray, 2014). Purposive sampling was used to select samples of teachers who were most likely to produce data relevant to EYFS and primary science education and who were accessible for interview during the pandemic (Cohen *et al*, 2013).

Accessible information sheets detailing the aims of the research project were e-mailed to a network of schools in North and South London with which the researcher had prior connections. Prior to this, ethical approval was sought and granted by UCL Institute of Education and participants were reassured of this. Potential participants were informed of the voluntary nature of taking part and that they were under no obligation to do so. The research purpose, methods and possible uses, in this case in a journal article, were made clear to the participants. Participants were also assured of anonymity – that neither they, nor their schools, would be identifiable, as all data collected would be anonymised and kept in line with GDPR policy as prescribed by UCL Institute of Education.

Participants were then asked to sign a form giving informed consent and reassured that they could withdraw at any time without fear of reproach (BERA, 2018).

To ensure confidentiality, all participants undertook a 1:1, face-to-face, semi-structured interview via Microsoft Teams, which lasted approximately one hour and was recorded. In addition, the researcher took notes throughout each interview, recording data via coded names for each participant to ensure anonymity (Cohen *et al*, 2014). Semi-structured interviews were chosen based on their flexibility, allowing the researcher to probe new questions spontaneously when a participant gave an unexpected or interesting answer (Gray, 2014). Participants were given the option of switching their camera on or off during the interview, if they felt this would make them more comfortable during the process. Interview questions were sent to participants prior to interviews taking place to ensure ongoing ethical consent (BERA, 2018) and to give participants time to consider if there were any questions that they would like to omit from the interview.

Participants were reminded at the beginning of each interview that they did not need to answer any questions that they felt to be inappropriate – this was especially important given the nature of some of the research questions focusing on the affective impacts of COVID-19. In addition, participants were reassured that they could take breaks from the interview if they needed to; given that all participants were interviewed whilst at home during the lockdown, with many attending to their families and children, recognition of this was important given the unusual social conditions that a lockdown brings, and this option as a course of action served to reassure participants and put them at their ease.

Data analysis

Video recordings and interview responses were transcribed and then coded for themes using inductive thematic analysis, as this was conversant with grounded theory (Braund & Clarke, 2006). Furthermore, the five phases of thematic coding analysis as proposed by Robson (2011) was adopted. Initial coding and categorisation of data is a way of identifying pertinent words and labelling them accordingly (Birks & Mills, 2010). The transcripts from each participant were coded to illuminate significant and repeating words or themes via clusters. The data were then analysed again to enable the researcher to actualise and identify the core themes emerging from the data (Birks & Mills, 2010). Themes that were not consistent with patterns generated from the data were still acknowledged (Creswell, 2018).

Findings and discussion

From the thematic analysis, six main themes emerged in relation to the research questions posited: (1) Active learning and scientific enquiry; (2) Challenges for teachers and for children's learning; (3) Assessment; (4) The status of science and expertise; (5) Viruses and staying safe; and (6) Anxiety and sense of value as a teacher.

Research question 1: How do EYFS and primary school teachers report changing, if at all, the content of their teaching and/or their pedagogy to facilitate science education for their students during COVID-19?

❒ *Theme 1: Active learning and scientific enquiry*

All participants highlighted the importance of active learning opportunities for children when learning about science and that this was an important and embedded part of their pedagogy for science teaching – in particular, children learning science via enquiry to develop their conceptual understanding (Russell & McGuigan, 2016; McCrory, 2017). Early years practitioners specifically talked about their concerns for not wanting children to *'sit in front of computers all day long'* (Participant 2).

Figure 1 (see p.11) demonstrates this: activities are based around children working with an adult and child-initiated activities where possible.

All participants reported that they were planning weekly activities based around scientific concepts from the National Curriculum (2013), via activities such as cooking (baking) and horticulture, and nature walks for children to do when they went out for exercise during the lockdown – using process skills such as *'observation, recording, asking*

Figure 1. Example of EYFS Home School Learning – a week of activities for children to do at home, centred around the EYFS curriculum (author: Participant 2).

Here are some home learning activities:

1. Explain that you will be spending time at home for a while.
The Government has decided that the safest place for everyone to be is at home. So this means that they will not see their teachers or friends at school for a little while but they will still do some school work at home. Try to make a basic routine for them. We have a suggested one but edit and amend to suit your needs.
https://theautismeducator.ie/wp-content/uploads/2020/03/The-Corona-Virus-Fr ee-Printable-.pdf
Ask if they have any questions.

2. Can you make an alien puppet?


3. Discuss what COVID-19 is
Here is a great resource which explains what it is in child friendly language. Stress that currently most people are at low risk of catching the virus, and even if they do most people's symptoms are not serious.
https://www.mindheart.co/descargables
Ask if they have any questions. Reassure them that they are in the safest place.

4. Listen and learn the planet rap. Can you make your own planet song?
https://www.youtube.com/watch?v=mVMTDjKDbws

5. Discuss handwashing
Explain why it is important for everyone to wash their hands and how it keeps us healthy. Here is a catchy handwashing video.
https://www.youtube.com/watch?v=825gGELjB98
Can you make your own hand washing video and upload it to tapestry?

6. Can you make a junk model alien?


7. Discuss having a worry
Watch Miss Butler reading *Ruby's Worry*.
Ask if the children have any worries. Try to rationalise some of their thoughts and feelings reassuring them that currently most people are at low risk of catching the virus, and even if they do most people's symptoms are not serious. Talk about a worry you have had and share it with your child.

8. Pick your two favourite planets and listen to them from Gustav Holst - The Planets
https://www.youtube.com/watch?v=UmOTMkoCCkM
Once you have listened to your two planets once listen to each one again, this time drawing a picture in response to the music. Is the music fast or slow? How does it make you feel? Do they use quiet or loud notes?

9. Play Snakes and Ladders with your family.
If you don't have a printer make your own Snakes and Ladders board. You can use a coin as a counter or make your own one from paper. If you don't have a dice at home use an online dice.
https://www.twinkl.co.uk/resource/t-n-668-snakes-and-ladders-1-20

10. Can you find out about what astronauts wear and make their space suits?

PE - Please do one activity a day and practise your favourite two on the final two days.

Joe Wicks Activity 1 **https://youtu.be/d3LPrhIov-w**	Cosmic Yoga - Space Picnic **https://youtu.be/d85dw-AcAaU**	Go Noodle - Banana Banana Meatball **https://youtu.be/BQ9q4U2P3ig**

questions, measuring, classifying' (Participant 6). Model-making, listening to songs, reading storybooks and then writing scientific reports, as well as watching videoclips online – using the Internet to research *'scientists and their work'* – (Participant 7) were also high on the agenda. Participant 2 stressed that she started to record videos of herself undertaking science experiments to share with the children in her EYFS class at home, because she wanted to ensure that it was *'age appropriate'*, linked to what she knew *'were the interests of the pupils in her class, appropriate to her pupils' learning needs'* (Pollard *et al*, 2014), and she felt that her pupils would be more likely to engage with the video, *'watch, listen and learn'*, if she was in the video herself, as they *'knew her and could relate to her'*.

Online resources such as *Kitchen science* (see Figure 2) were highlighted *'as incredibly helpful'*, as Participant 8 stated: *'This resource has been a lifesaver. It has really clear instructions, including safety information and, most importantly, explains the science and has discussion points so I didn't need to add any more questions for the children to discuss at home. Everyday materials found in the home were the focus for resources. Also, they have links to videos on the Science Museum, which use cartoons and historical objects with explanations to show how they were used'.*

❒ *Theme 2: Challenges for teachers and children's learning*

Participants reported that one of the biggest issues encountered was time constraints and working longer days; this was compounded if participants also had their own children to look after or vulnerable family members to take care of. Although planning generally seemed to be shared across year groups, and participants were, in the main, working from home (only 2 participants reported attending school to teach key workers' children), participants felt that everything took so much longer to put together. Participant 7 noted that *'When writing instructions for activities, it is just taking absolutely ages to write detailed instructions for parents. In my school we e-mail everything directly to parents with all resources, so putting all of the resources together takes time'.*

In addition, trying to ensure that what was being planned met the needs of children, taking into account the *'demographic of the children being taught'* (Participant 3) was also time-consuming. Participant 7 added: *'I work in a special school. I have 7 children who are aged between 4 and 7; they are all pre-verbal and working within the EYFS framework. Their needs are social and emotional and so interaction between me and them is very difficult to get across via technology. There needs to be an exaggeration of how you present yourself; you need to be lively and this has been difficult to maintain.'*

Figure 2. Kitchen science activities – Science Museum London.

Children's access to schoolwork via online platforms was also a concern, especially for those children who are disadvantaged, and there were concerns when planning activities whether children would have '*the basic resources at home to undertake the activity*' (Participant 1), reflecting the claims made by Green (2020) that COVID-19 has potentially widened the disadvantage gap for children. Although resources such as additional laptops and 4G Internet for disadvantaged children were promised by the Government (DfE, April 2020), Year 10 (age 15) and children aged between 0-19 with a social worker were prioritised, with primary schools only very recently being able to access this resource. Participant 9 noted that, to try and combat this, parents in his school were encouraged to pick up a weekly activity pack for their children: '*This has not been ideal but the school undertook a risk assessment in line with government policy on social distancing during the lockdown, which meant that some children were receiving schoolwork at least.*'

❒ *Theme 3: Assessment*

Participants reported that that they were concerned with the element of the 'unknown', meaning that it was difficult to gauge whether or not learning (in any form) was happening at home and what indeed that looked like, even with routines in place such as engaging with and using 'Tapestry' https://tapestry.info/; 'Google Classroom' https://edu.google.com/products/classroom/?modal_active=none#%2Fready-to-go; or 'London Grid for Learning' https://www.lgfl.net/default.aspx.

Participants stated that schools were able to see if pupils/parents were logging on to access resources or upload videos/pictures of their children's home-school activities, but that uptake of this was low, on average around 30%, and responses were varied, *'sometimes just photos with no annotations'* (Participant 5), and that there was no directive from leadership to undertake assessment of what children were doing at home during this period other than when participants spoke to parents/children during weekly check-ins. Therefore, participants expressed concerns about what will happen when students return to school in September, given the inequities at play regarding children's access to school planning and the prioritisation of maths, English and phonics.

❒ *Theme 4: The status of science and expertise*

25% of participants noted that, for the first three to four weeks of lockdown, maths and English activities were prioritised, followed by other areas of the curriculum, reflecting ongoing concerns regarding the status of science in primary schools. This perception was reinforced by Participant 6, whose school has been using the Government recommended Oak Academy resource https://www.thenational.academy/ and who was frustrated that science was stated as a non-core subject, reinforcing the perception that science in primary schools had lost its status (Wellcome, 2014).

Science leads also reflected that there was a positive outcome for them in relation to the monitoring of science in school. They could respond in real time, daily, to queries about science from staff and they could easily see online what was being planned for pupils. There seemed to be a more collaborative approach to the planning of science, and online CPD opportunities for staff regarding the teaching and learning of science, as well as scientific knowledge, was made available and, on the whole, welcomed, with staff encouraged to engage. In this case, Headteachers were supportive of staff finding time each week to undertake CPD activities that would impact on their practice; however, as Participant 7 noted: *'Yes, we are given time each week for CPD but we are expected to keep a log and evidence what we have been doing, which in itself is not supportive. The micromanaging seems to me to be counter-productive and not necessary, especially at the moment – we have enough to cope with'.*

Being an 'expert in science' was also highlighted as incredibly important by 60% of participants, reflecting research by the Wellcome Trust (2014). As Participant 6 noted: *'My background in medical biochemistry and love of reading science research papers came into play. Everyone came to me to ask my advice and I was easily able to explain to the children, pre-lockdown, what a virus is and how it spreads, by drawing diagrams on my whiteboard.'* Participant 2 noted that, although she had no background in studying science at a higher level, *'I have GCSE combined science'*; it was her love for science and engagement with the news and reports from research such as that from the World Health Organisation that meant she could take the lead at school and discuss the situation of the pandemic as it developed. This, she noted, gave her a sense of validation and value in the school community, but also was really important because, at the time, her school did not have a science lead. This reflects the arguments made by McCrory and Worthington (2018) that being a successful teacher of science in primary schools does not necessarily mean that teachers need to have science degrees, although this is advantageous as we can see from the comments made by Participant 6: a passion to learn and engagement with science, to relate it to the real world and our lives, and to keep up-to-date with science subject knowledge as well as pedagogical content knowledge for teaching science effectively, are what matter.

Research question 2: What do EYFS and primary school teachers say have been the questions that students have asked in relation to COVID-19?

❒ *Theme 5: Viruses and keeping safe*

Thinking back to just before the lockdown started and when children were in school, participants reflected on the questions that the children were asking. It would seem that, on the whole, children were full of questions about the virus, demonstrating 'epistemic curiosity' (Chin & Osborne, 2010): from 'what it is, where it came from, how it spreads, how it grows, whether it is alive or dead, can anyone catch it'; to questions that demonstrate inconsistencies between pupils' knowledge and new knowledge, which engender 'cognitive dissonance' and, at times, concern for family members: 'Mum and dad are old so will they catch the virus and die?; Will the virus just get bigger and bigger and roll down the road after us?' (Festinger, 1957). It is clear that questions raised by pupils activate their prior knowledge, focus their learning efforts, and help them to elaborate on their scientific knowledge, but also demonstrate how they are trying to assimilate all that they are hearing about the virus.

Participant 6 added that, as a science lead, she led training with staff who needed support to understand the biology of viruses but also how to appropriately teach about them to primary-aged children. She also reflected that '*Taking a socio-scientific approach to teaching children about viruses and this pandemic would have been really effective and would fit in with the curriculum. But this approach is not embedded in my school; it is something we could look at when the children return to school*.'

It is also clear that children's anxieties and concerns about death and dying were at the forefront of their questions, with participants noting that children were given plenty of opportunities via circle time, reading stories and question time in lessons to ask questions. Woolley (2010) advises that, although these types of questions might make teachers feel awkward, it is important to address them honestly and acknowledge that we don't have all the answers; if this indeed is the case, giving reassurance informed by the facts is key, as is listening. It is important to acknowledge the children's emotions and help them to feel safe and secure. Participant 6 noted: '*As a teacher we have a duty of care to our children to discuss issues even if they make us feel uncomfortable*'. This sentiment was reflected by all participants.

Participants also noted that children were concerned with how to stay safe and not catch the virus. Participant 2 stated that '*Embedded hygiene practices really helped here. I have focused on hand washing in class, using tissues to wipe and blow noses and put straight into the bin so washing hands for longer was just an extension really of what the children are used to.*'

Participants also used activities such as 'Glitter germs' (https://www.parenthub.com.au/kids/glitter-germs/) or 'Pepper water' (https://www.youtube.com/watch?v=uvG6uBq-dVo), which both demonstrate how important it is to wash hands thoroughly, as well as showing how creative primary teachers of science are (Cutting & Kelly, 2014).

All participants reported that they were grateful to be able to access free online resources and books for children to read at home that discussed the science of COVID-19 in child-friendly ways, and which had positive and diverse representations of scientists (Figure 3) and addressed children's worries (Figure 4) (see p. 15).

Figure 3. *Coronavirus – A Book for Children* by Elisabeth Jenner, Kate Wilson and Nia Roberts. https://nosycrowcoronavirus.s3-eu-west-1.amazonaws.com/CoronavirusABookForChildren.pdf?fbclid=IwARoj-1xR1CapoWj5gGocVgMNAk3Ma3f7Suim3AYcggCa2shvHyYYIS7Qbc

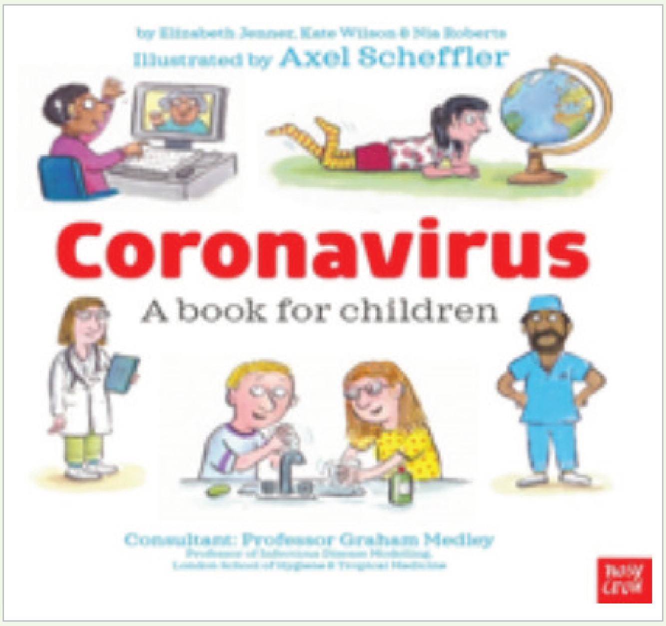
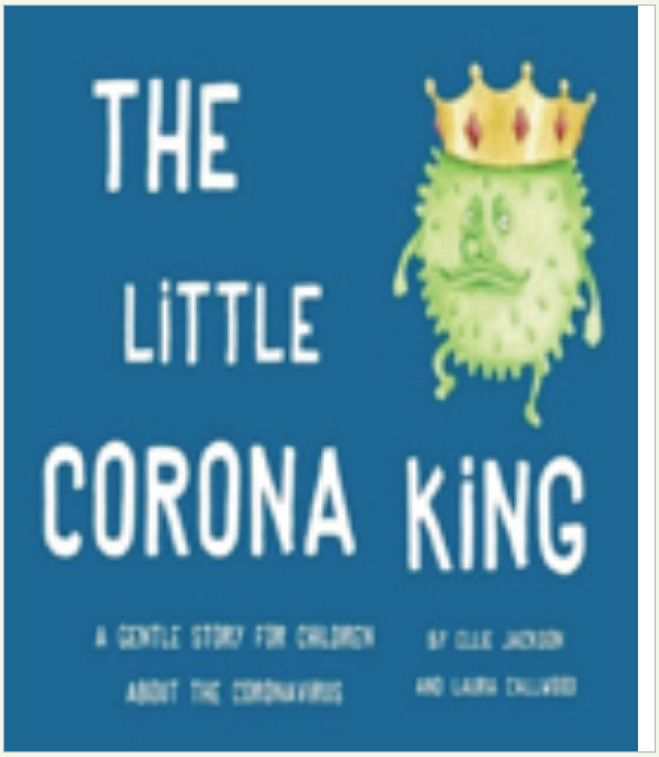


Figure 4. *The Little Corona King* by Ellie Jackson and Laura Collwood. https://littlecoronaking.com/



Research question 3: What do EYFS and primary school teachers say have been the affective impacts of the COVID-19 pandemic on them?

❒ *Theme 6: Anxiety and sense of value as a teacher*

90% of the sample reported varying degrees of anxiety in response to the 'unknown' nature of the virus and, for those who revealed that they had existing mental health conditions (40% of the sample), they reported that social distancing and lockdown exacerbated their conditions. Long working hours, difficulties in sleeping, ruminating and overthinking, have resulted in *'hypervigilance'* – feeling in a state of increased alertness – for some, and a lack of access to NHS services added to this, although there was recognition that the service that some GPs were offering via telephone or video call consultations (Health Service NHS X: https://www.nhsx.nhs.uk/) was supportive and a positive response to the needs of people during the pandemic.

A small percentage of the sample (20%) noted that they lived alone. This created, for one participant, a sense of *'isolation'* and *'a feeling of being disconnected from colleagues and the world'* but, for the other, *'having time to myself, peace and quiet to work without the rush of travelling to work – or fear that I will catch the virus on the tube, has been a comfort'*. All participants did note that they felt their Senior Leadership Team had been very supportive of their mental health and wellbeing; checking in weekly with them as well as providing links to online support and local authority services. Participant 2 added: *' My school already provides a weekly therapy session for all staff, as they recognise that there has been a rise in mental health needs of teachers; but during this time, the school therapist has kept in even closer contact with all staff, which has been reassuring.'*

This reflects the outcomes of research by Jerrim and Allen (2020), which focused on the wellbeing and rise in mental health needs of teachers and found that 1/20 teachers in England are reporting a long-lasting mental health problem. They noted that, although there was an increase in mental health issues being reported and treated amongst teachers, they argue that this could be because teachers are more willing to talk about and seek help for such issues. However, they also note that – similar to the commitment that has been made to track teachers' workloads – more needs to be done to monitor and improve the mental health and wellbeing of the teaching profession.

In addition, participants felt that Government guidance for schools has been *'contradictory and unhelpful'* and that there *'was a middle-class assumption that schools had more resources than they actually did'* (Participant 9). Negative media surrounding the role of teachers has also been a frustration: Participant 5 noted that *'In a system where I already feel that my professionalism has been de-valued, reading articles and listening to reports that vilify me and my colleagues has been really hard to take'*. This echoes recent research by the *TES* (Lough, 2020), which found that teachers and staff in schools feel that they have not been listened to by the Government during this time.

Limitations of the research

Limitations of this study could be attributed to the sample size, but this research makes no claims to 'generalise' findings to the teaching population (Gray, 2014), taking instead a qualitative approach to illuminate the *in-situ* experiences of ten EYFS and primary teachers during the COVID-19 pandemic. It is also important to recognise that not all the themes discussed necessarily reflect all the participants' views, which could account for another possible limitation. Thematic data analysis was undertaken strictly using the approach as advocated by Robson (2011), in light of the literature and research questions, and this rigorous process served to negate, as much as possible, researcher bias (Braund & Clarke, 2006).

Conclusion

In conclusion, during this very challenging time, it is evident from this research that planning for the ongoing science education of primary-aged children has not only been merely possible, but has utilised – where possible – sound pedagogical strategies akin to effective primary science provision. It is also clear what some of the benefits of using quality online materials, about science in general and the COVID-19 virus in particular, can bring to primary-aged children learning science. It is heartening to see that the status of science, school science and its connectedness to our lives has been highlighted positively. Children are interested in real-life socio-scientific issues, and further research examining effective pedagogical approaches to teach pertinent authentic issues in science, in an age-appropriate way across the primary age-range, is needed – if nothing else, the COVID-19 pandemic has highlighted how important this is.

In addition, issues with assessment and accessibility to learning opportunities for *all* children are a real concern, as is the additional pressures that teachers have been under, and continue to experience, during this pandemic, which has had an impact on their mental health and wellbeing, although support from senior leadership in schools regarding this has been and is very welcome. Most notably, given that there has been a longstanding issue with recruitment and retention in teaching, the frustrations and anger expressed by some here at being vilified by the media and Government, and how this impacts further on what is seen as the de-professionalisation of teaching, are important to highlight; further research is needed to gauge deeper insights into what the current issues are and how these can be addressed. Given also that parents have just spent the last four months at home with their children as *de-facto* teachers, further research would also be fruitful to gain their insights into the value that teachers have given during the COVID-19 pandemic and, more generally, bring to their children's science and wider education.

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Amanda McCrory is Co-Editor of the *Journal of Emergent Science.*

A theoretical reflection on the contributions that scientific enquiry and school leadership make towards a whole school culture of good wellbeing

Susan Marks

Abstract

Research recognises the need and benefit for schools to promote a culture of good wellbeing (Department of Health & Department of Education: a Green Paper, 2017), particularly in the light of stretched resources supporting young people's mental health (Young Minds, 2017). Specific programmes in schools benefit pupils, promoting social emotional development (Howard et al, 2017), with a whole-school approach to mental health and a culture of good wellbeing impacting positively on pupil progress, with long-term benefits (Public Health, 2015). Appropriate leadership strategies support the establishment of a culture of good wellbeing (Teasley, 2017). Pupils' development of the skills of enquiry, taught via science education (National Curriculum, 2013), enables them to 'take appropriate actions that affect their own wellbeing' (Harlen, 2010). A scientific enquiry skills-based approach promotes pupils' engagement and curiosity (McCrory, 2017) across the whole curriculum (National Curriculum, 2013), facilitating development of a whole school culture of good wellbeing.

Keywords: Good wellbeing, leadership, science education, enquiry skills, whole-school approach

'Children's and young people's emotional health is increasingly being recognised as important, not only in its own right, but because emotions play a significant role in learning' (Blake *et al,* 2007).

Over the years that have passed since this was written, concerns regarding young people's mental health and wellbeing have continued to grow (Department of Health and Department of Education: a Green Paper, 2017). Both within daily school interactions and through national media reporting (Guardian, 2018), it is evident that young people are finding the challenges and stresses of their daily lives troubling (Young Minds: Wise-Up Report, 2017). According to a survey carried out by NAHT in May and June 2018, schools have found that, due to the continuing cuts in funding, *'it's now harder to resource the support required to meet the needs of pupils with SEND than two years ago'* (Hall, 2018). A report by the National Health Service on the Mental Health of Children and Young People in England (2017) noted that emotional disorders had become more common in 5-15 year-olds, with a rise from 4.7% in 1999 to 5.8% in 2017. It goes on to state that, among children with mental health disorders, around one in five reported waiting over six months for contact with a mental health specialist, with the *Young Minds Impact* report (2017) noting a wait of nearly ten months until the start of treatment. This report goes on to point out that, of the portion of NHS budget spent on mental health, only 8% of it is spent on children. This published data suggest that the problem outweighs the resources available at present. Merrell and Guelder (2010) recognise this woeful lack of adequate resources available to effect appropriate intervention, and suggest that Social Emotional Learning (SEL), a focused programme of activities and learning opportunities designed to help develop the understanding, recognition, expression and regulation of pupils' emotions, provides an alternative approach for delivering preventative classroom-based mental health services that will reach all students.

The Scottish Government Policy Guidance (2018) also recognised that a positive whole-school culture and ethos or climate was a key feature in the promotion of wellbeing and mental health across the school community. This is strengthened by the incorporation of three key aspects: safety, engagement and environment, which promote and sustain positive relationships in their communities.

The guidance (Scottish Government Policy Guidance, 2018) also demonstrated that, where schools were achieving higher outcomes than expected from the catchment area, positive relationships and pupils were involved meaningfully within their schools. A study carried out in Australia, (Dix *et al*, 2012) noted strong links to support this idea, commenting that schools that implemented positive mental health initiatives improved pupils' *'socio-emotional competencies and, in turn, academic performance'*. An engaging environment that offers active participation plays a protective role in relation to physical, social and emotional health, and enables young people to thrive academically (Glazzard, 2018). Science education via scientific enquiry (McCrory, 2018) leads the way with the provision of this type of learning environment, encouraging curiosity, active participation, reasoning and problem-solving.

The following words from one of the principals interviewed during a further study clearly bring the message home: *'We found that happy kids and contented kids, and kids who know how to interact better with one another, are much better learners'* (Slee *et al*, 2009). This illustrates that positive engagement and interaction via science enquiry can provide successful learning. In addition, the Public Health England report (2014) argues that positive links are made between the inspection framework's key judgements and pupil health and wellbeing, and attainment. The briefing highlights the value of schools promoting health and wellbeing as an interwoven aspect of a school effectiveness strategy. It goes on to champion a whole-school approach (Glazzard, 2018) going beyond the learning and teaching to one that includes all aspects of school life: the culture, ethos and environment, and a broad curriculum to include development of attitudes and skills about health, wellbeing and partnership with families and the community.

Education is about far more than the acquisition of subject-based knowledge (White, 2011), and a curriculum that promotes human flourishing supports the provision of a whole-school approach, which includes the development of attitudes and skills that promote fulfilling lives (Reiss, 2018). The aims-based approach to the teaching of science argues that *'school education should equip every student to lead a life that is personally flourishing and to help others to do so, too'* (Reiss & White, 2014).

Developing a science curriculum founded on an enquiry-based approach (McCrory, 2018), guided by the principles and big ideas of science education (Harlen, 2010), provides the opportunity to develop skills and attitudes that foster informed decision-making and subsequent actions that affect personal wellbeing as well as that of society and the environment. This whole-school approach is advocated as a means to enhance the health and educational outcomes of the pupils and is supported in the NCB's (Stirling & Emery, National Children's Bureau, 2016) *Resources for Leaders*, which indicates that schools using this ethos and approach have improved individual and school performances. Morris (2015) supports this thinking and considers that a school that is truly committed to caring for those in its community must by default be committed to the development of excellence. They would care about outcomes for all and therefore aim for the best.

Recent studies have indicated that performance can be further enhanced with the implementation of positive mental health initiatives (Dix *et al*, 2012). The SEAL (Social Emotional Aspects of Learning) programme was an example of such an initiative, which offered schools a programme to assist with the development of a positive culture promoting good mental health. It was introduced to primary schools in 2005 by the Department for Education and Skills, and provided a comprehensive, whole-school approach to the social emotional skills that were understood to support effective learning, positive behaviour, regular attendance and emotional wellbeing. The SEAL programme was designed to be delivered in three 'waves of intervention'.

The first wave was designed to help create a climate and ethos within the school in which social and emotional skills could be effectively promoted. The programme utilised the five domains proposed in Goleman's (1995) model of emotional intelligence. These are: Self-awareness, Self-regulation (managing feelings), Motivation, Empathy and Social Skills. This first wave was evaluated as part of the Behaviour and Attendance Pilot (Hallam *et al*, 2006), and they found that it *'had a major impact on children's wellbeing, confidence, social and communication skills, relationships, including bullying, playtime behaviour, pro-social behaviour and attitudes towards schools'* (Hallam *et al*, 2006).

The second wave involved small group interventions for children who are thought to require additional support to further develop their emotional and social skills. The purpose of these interventions was to facilitate their personal development, explore key issues in depth, practice new skills in a secure environment, develop ways of relating to others and promote reflection.

The final wave of SEAL involved 1:1 intervention with those who had not benefited from waves one and two, providing targeted support. Some of these children may include those at risk of or currently experiencing mental health issues.

A more recent initiative offering a similar three-phase programme is Thrive, which began by supporting around 60,000 children across the UK in 2013. *'Thrive is a systematic approach to the early intervention of emotional development need in children and young people so that differentiated provision can be put in place quickly by the adults working most closely with the child or young person'* (Thrive, 2015). This initiative is based on an integrative approach to emotional and social development underpinned by four areas: the neuroscience of emotional development, attachment theory, the importance of Arts and creativity in emotional development, and child development models. The Thrive work is grounded in some of the current scientific developments in neuroscience (Hughes *et al*, 2012), which have yielded significant insights into the working of the brain and nervous systems and their development.

It has been known for many years how important attachment is for the building of a healthy stress regulatory system (Bowlby, 1982) and that play and creativity are vital for healthy emotional development in children (Sunderland, 2007). Thrive uses a developmental framework to clarify the connections between emotional and social development, behaviour and learning (Illsley *et al*, 1998). Alongside this, Thrive online assessment and action planning tools help to develop secure stress management systems and improved foundations for emotional resilience (Sunderland, 2003).

Although the SEAL and Thrive programmes provide a clearly structured approach for emotional and social development in schools, a pilot study of the SEAL programme in the UK (Hallam *et al*, 2006) found that it was most likely to be implemented successfully when the school leadership was committed to it, where staff valued its principles, and where there was sufficient time for preparation and training. Where the programmes met with resistance, reluctance or scepticism, the success of such programmes was impeded.

So it would seem that the implementation of a specific mental health programme in school offers recognisable, beneficial outcomes, but that to implement it successfully, a positive culture in which it can flourish has to be created. It falls to the school leaders, primarily the Headteacher, to promote the value of a 'Growth Mindset' (Dweck, 2012) approach within the community of the school to support the development of a culture of enquiry-based learning using science as a vehicle.

Ofsted recognises that the most effective science teachers develop curiosity as a priority, with the 'working scientifically' requirements of the National Curriculum supporting a culture of enquiry. This in turn encourages a relational view of learning, promotes links between science and other areas of learning, including PSHE, and encourages a love of lifelong learning (McCrory, 2017), thus supporting the promotion of a culture of good wellbeing throughout the whole school. *'It can be argued that the only thing of real importance that leaders do is create and manage culture…'* (Schein, 2008). Successful cultures have leaders who know how important schools are to children and want to make them the best places that they can be.

Cultures that have a clear focus on pupil learning and that foster high expectation for all students in turn focus the work of staff members and generate a motivation to learn. Where there is a strong educational mission coupled with a sense of community, social trust amongst staff with established customs, values and a shared commitment to school improvement, schools move forward successfully in all aspects (Deal & Peterson, 2016). Deal and Peterson also comment on the resultant '*group sense of efficacy*' (a belief that they could become better) that such schools can develop (2016). Their work promotes an overriding sense that developing a professional culture is at the heart of any successful school.

Professional learning communities have been recognised as having the following features: a collective sense of purpose, teacher influence in decision rituals, concerted effort linking instruction to purpose, shared dedication to unremitting perfection and a sense of shared responsibility for student learning (Deal & Peterson, 2016). Research in this area also firmly links the central role of cultural elements to school success (Newmann *et al*, 1996; Moll *et al*, 1992).

Leading a professional learning community requires an open-minded leadership approach and cannot simply be achieved using an 'old frame' of leadership '*characterised by a charismatic individual in a high status position, directing many others*' (Swaffield & MacBeath, 2009). The 'new frame' suggests a more productive alternative where the leadership is viewed '*as activity, both individual and shared, influencing and serving others, taking initiative and making decisions for the greater good, whilst modelling learning and being sensitive to context'.* Research about more distributive forms of leadership and the part these play in the successful development of schools suggests that this approach has merit (Bennett *et al,* 2003; Harris, 2004).

This approach can be a challenge to senior leadership, as it shifts from the traditional view of those with titles, positions and experience bringing about change, to teacher-led change. Frost (2017) suggests that this process requires a high level of trust in teachers and support staff, humility on the part of the senior leaders and alignment of leaders and staff to ensure that the power wielded by the leaders is used to support the work in the school.

Two key factors play a significant role in the success of this type of leadership: agency and moral purpose: '*Having a sense of self, encompassing particular values and cultural identity, and being able to pursue self-determined purposes and goals through self-conscious strategic action'* (Frost, 2006) or, indeed, the ability to make a difference. Leadership for learning is based on moral principles, is positively benevolent and is based on values that support learning and guide our leadership.

The recent research emphasises that there is a recognised need for schools to provide opportunities to promote, support and guide our pupils towards a culture of good wellbeing via the whole curriculum, where science education can lead the way; that pupils benefit significantly where there are specific programmes in school to address social emotional development and support good mental health, such as Thrive and SEAL; and that the appropriate choice of leadership strategies and whole school approaches to promote a curriculum of enquiry and cultural development, introduce and develop whole school programmes, and ultimately implement change, are key to successful outcomes and the delivery of a culture for good wellbeing.

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Susan Marks, Fellow of the Primary Science Teaching Trust College.
E-mail: marks1family@aol.com

A new resource designed to allow primary children to investigate atmospheric pollution using Defra's Air Quality Archive

- Tim G. Harrison • Alison J. Trew • Anwar H. Khan
- Rayne Holland • Dudley E. Shallcross

Abstract

Air quality is an area of worldwide concern. Scientific research in this area can provide incredible stimulus to primary school children, their teachers, parents, carers and other stakeholders, and empower them and their families to make informed choices about modes of transport and reducing their exposure to pollutants. The UK Air Quality Data Archive of current and historic air pollution measurements from across the country is enormous, containing over 400,000,000 datapoints.

This paper explains how older primary children can engage with these data and even learn about the air pollution in their local area through data mining. A freely available resource has been created in collaboration between atmospheric scientists and teachers to allow this to happen and to explain the science behind it.

Keywords: Atmospheric pollutants, citizen science, air quality, data mining, numeracy

Introduction

Climate change and surface air quality are two of the most pressing global concerns as we move through the 21^{st} century. The impact of air quality on human health is well documented, as is the disproportionate impact on the health of the very young and very old (e.g. Ruchirawat *et al*, 2007). A free resource, created by academics and teachers, will allow primary-aged children, teachers, carers and parents to interrogate the air quality archives, from which they may carry out their own research using freely available data.

The Air Quality Archive

The UK's Air Quality Archive, one of the most extensive in the world, is run by the Department for Environment, Food and Rural Affairs (Defra), a UK government department (https://uk-air.defra.gov.uk/). It contains some 400,000,000 datapoints. A project that utilises this amazing UK resource and allows primary school children, their teachers, parents and other stakeholders to learn about and carry out investigations into air pollutants is a great starting point for a citizen science project.

These data are readily accessible from the website portal and contain measurements on primary pollutants such as:

- nitrogen oxides (NO, NO_2);
- carbon monoxide (CO);
- sulfur dioxide (SO_2); and
- particulates $PM_{2.5}$ (airborne particles with a diameter less than 2.5 µm) and PM_{10} (airborne particles with a diameter less than 10 µm).

The measurements are from calibrated instruments and have much supporting information in terms of how the measurements are made, where the measurements are made (e.g. by the kerbside, in an urban background location) and the instruments used to make the measurements. These data are extensive in terms of geographical coverage, with most UK schools having some network measurements in their vicinity. The children can either interrogate their nearby data or compare them with data from other parts of the UK, perhaps from a clean air site.

The mathematical and IT requirements needed to analyse data are straightforward. At a simple level, these data can be viewed in graphical form, generated by the Air Quality Archive website or from the exemplars provided. If children, or their carers, have spreadsheet experience, more analysis can be done.

The resource

The web-hosted supporting resource (https://pstt.org.uk/resources/curriculum-materials/citizen-science-air-pollution) is freely available from the Primary Science Teaching Trust (PSTT) (Shallcross *et al*, 2015).

The website starts with an overview that introduces the project and includes suggestions of the types of investigation that can be carried out.

The 'Resource' area has a background information section for teachers on specific atmospheric pollutants and how they are measured. To support teachers in introducing atmospheric pollutants to primary-aged children, we have provided activity cards and a classroom presentation describing the source of these pollutants, with graphs showing concentrations of each pollutant measured in a city in the UK, and questions to stimulate discussion in the classroom (with answers). There is also a series of worksheets (graphs and data with question prompts) for primary-aged children to investigate yearly, monthly and weekly trends in air pollution from sites around the UK, and to allow comparison of air pollutants between an urban and a rural site. Children may then want to investigate the levels of pollutants nearer to where they live: there is a guide on how to use the data archive and pre-prepared data sets for primary teachers to use with their classes. The pre-prepared data sets (Excel spreadsheets) include data from the capitals of the four home countries and from a 'clean air' (countryside) site. Each site has yearly data extracted for every two years from 2010 to 2018 inclusive (i.e. 2010, 2012, 2014, 2016 and 2018). There is also an exemplar data set with suggestions of how these data can be manipulated and then graphed/charted. One workcard set allows each child in their class a fortnight's worth of data on one pollutant and a common blank graph grid so that they can each plot results and put them altogether to make a plot of annual data. Other workcards have pre-graphed data on daily, monthly and annual selected pollutants, with questions about patterns and site comparisons.

The resource has a section that provides profiles of climate scientists associated with the Atmospheric Chemistry Research Group (ACRG) (https://www.bristol.ac.uk/chemistry/research/acrg/) in Bristol to humanise the science of climate

research. These profiles include the scientists' thoughts on the skills needed by those scientists and a few lines about what made them engage in science the first place. Children can see that climate science research is carried out by a diverse range of people.

The last section, aimed at teachers, supports the understanding of air quality science. This contains considerable background material on climate change and atmospheric chemistry. It includes a collection of related articles originally written for teachers and secondary school students, which can, in the main, be freely accessed. An example is using aircraft for atmospheric monitoring (Leather *et al*, 2014). In addition, there are resources (PowerPoints) annotated for teacher/post-16 student use. These include a simplified mathematical treatment of the climate and a description of Stephen Pacala and Robert Socolow's theory of stabilisation wedges, a treatment of how to reduce current atmospheric carbon dioxide concentrations using existing clean energy technologies, such as wind power (Pacala & Socolow, 2004).

Apart from opportunities to report on the science research undertaken, there are additional writing activities for children. Children who work on a project based on this area of science will have many opportunities to shine in literacy and numeracy.

What sort of research can be carried out?

There are many potential and exciting investigations that can be undertaken using data from the children's own geographical area. The Atmospheric Chemistry Research Group (ACRG) at the University of Bristol has used the archive extensively with secondary school students to investigate the role of Bonfire Night on particle levels (Harrison & Shallcross, 2011). This was a project run with secondary students that later became a full academic research project (Priestley *et al*, 2018).

A much simpler starting analysis will be, for example, to look at the mean (average) value of a specific pollutant on days of the week and

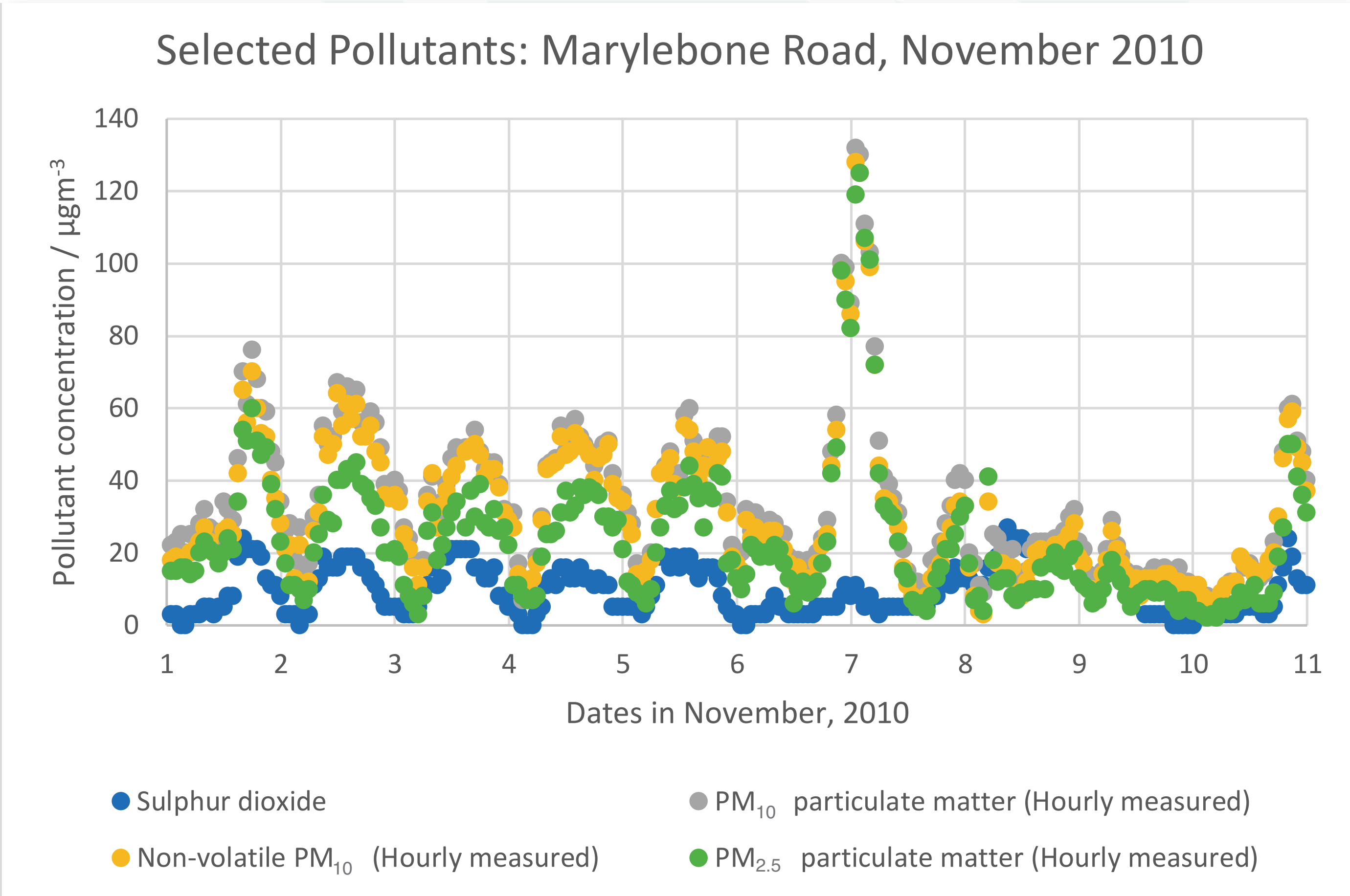

Figure 1. Pollutant data for November 2010. Note: Bonfire Night was a Friday (5th November), which would have meant most parties taking place on the Saturday evening, 6th November.

determine if there is a pattern, and why? How do these levels vary from month to month, and even year to year, or from location to location? What hypotheses do the children give before they investigate these data and for the changes they observe? What is the most polluted and cleanest day in a (named) UK city? We have asked this question with primary school children on many occasions and they predict a wide range of days for both, with excellent reasons. When they look at these data and see that the most polluted is usually around Bonfire Night (5th November) and the cleanest is Christmas Day (25th December), they make some excellent connections. The children can look at these data on an hourly scale and determine when in the day is the highest level of pollution and how this varies with month and year. These are just some of the possible investigations, and some data derived with Year 5 and 6 (ages 10/11) students from primary schools are shown in Figure 1, which illustrate how particle levels vary in the week of Bonfire Night. Data sets can be mined and pre-prepared so that teachers can use these to show to their children and for the children to investigate and explore, and avoids issues to do with using the Internet. By encouraging parents and children to investigate together, parents then have ownership of safeguarding.

For the more adventurous, or as a follow-on activity, or for an activity for children to carry out with their parents and carers, more open exploration of the database is possible. Here is a way to challenge children with an opportunity for families to carry out meaningful science investigations and for adults to engage and understand about pollutant levels in their area, and more widespread across the UK. This citizen science opportunity is not just limited to students of primary age. For those who enjoy looking at current science research in a form written for primary children, they can delve further into the *I Bet You Didn't Know* resource library (Trew *et al*, 2019; Trew *et al*, 2020).

Example activity

A student wants to look at how the COVID-19 UK lockdown has affected air quality during March 2020, compared with March 2019, in a city location. This is possible. Let us consider nitrogen dioxide

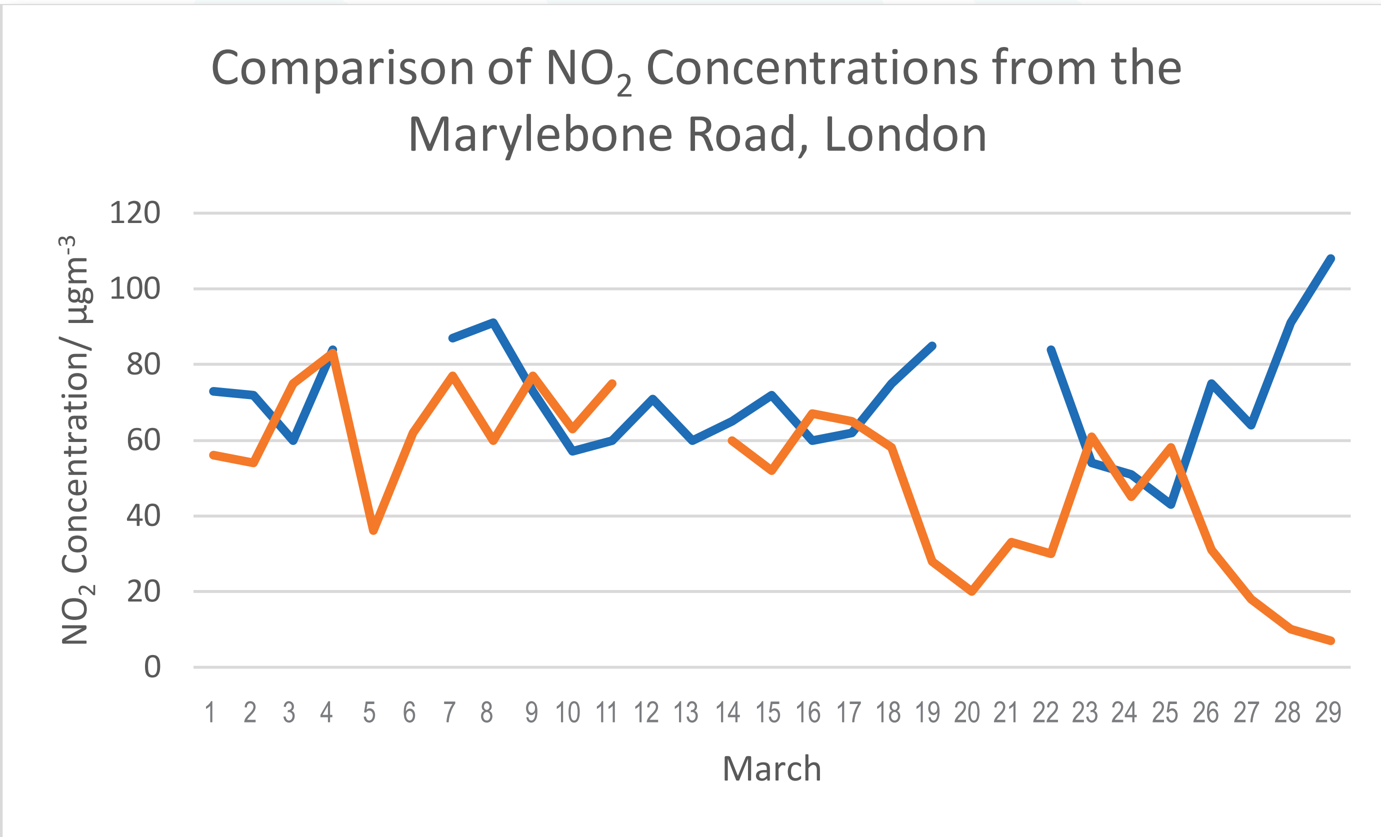

Figure 2. Nitrogen dioxide (NO_2) levels, during March 2020 (orange line) compared with March 2019 (blue line). Note the drop-off after the national lockdown mid-March 2020.

(NO_2) levels, which are associated with traffic. Let us consider a roadside location in a major city: Marylebone Road, London. The data for both months can be selected, using the *How to Use* guide on the project website. These data are extracted (copy and paste) from the tabulated data generated and pasted into a spreadsheet for manipulation.

Several questions could be asked about the levels of this pollutant from the start of March 2020 to the end of March 2020, or post the UK COVID-19 lockdown (8 pm Monday 22nd March 2020). A comparison can also be made between March 2019 and March 2020. From the spreadsheet of data, the March mean of NO_2 concentrations could also be calculated. Queries could be made in different locations and for other pollutants, and conclusions drawn.

Even if these data are not used for research, many of the graphs and other charts can be used in real life examples of the representations of data.

From graphs such as that shown in Figure 3, children can be asked many questions:

- Example 1: Why does Figure 3's caption state that 'air quality is heavily influenced by traffic, with morning and afternoon peaks associated with rush hour traffic'? From the graph, what suggests this?
- Example 2: Which of the 3 pollutants is present the most?
- Example 3: At what time in the morning is pollution the highest?

Key skills

There are many ways in which to set out the intended learning outcomes in primary science, as exemplified by the national curricula of England, Wales, Scotland and Northern Ireland. Programmes of study describing learning requirements differ. However, all share the aim

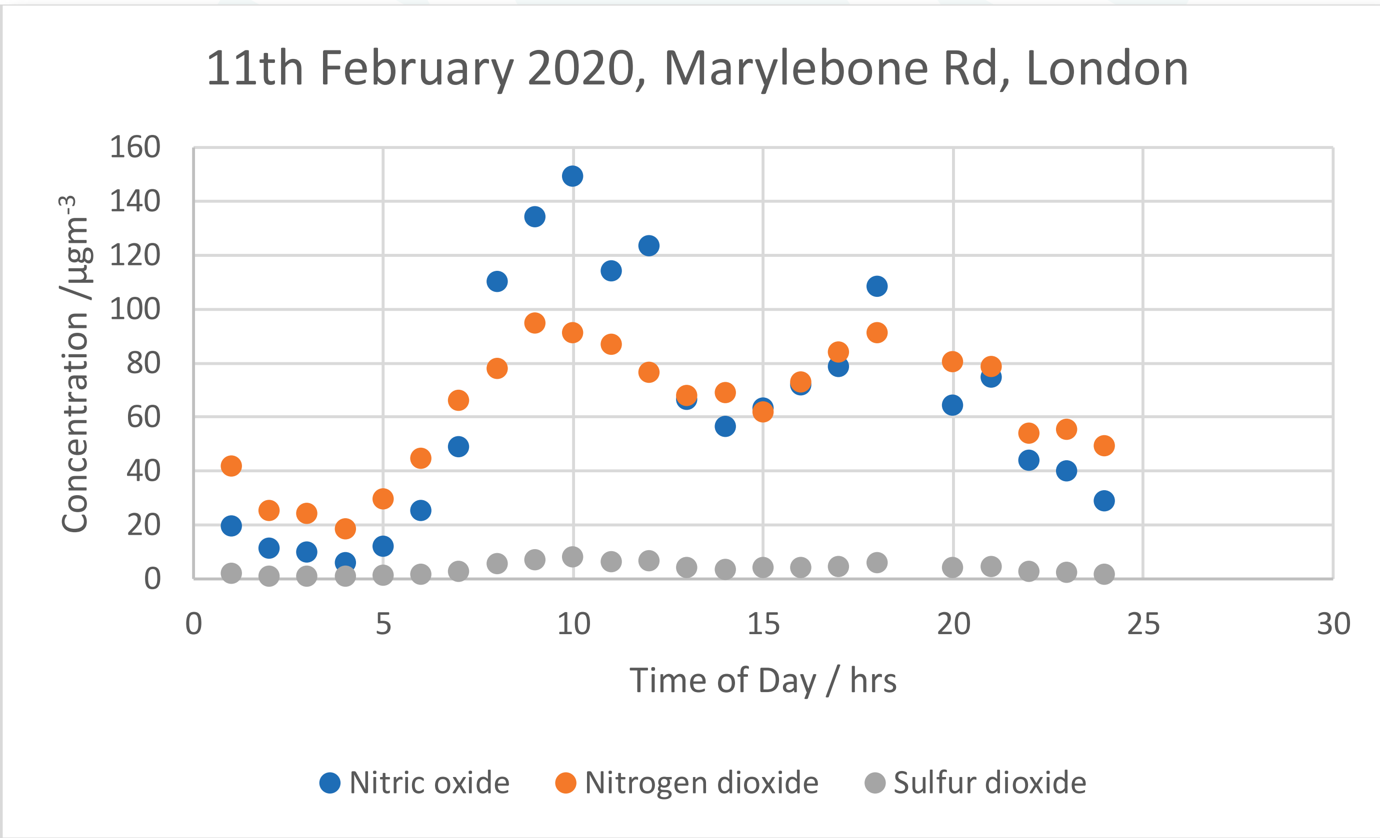

Figure 3. Nitric oxide, nitrogen dioxide and sulfur dioxide concentrations in air measured at Marylebone Road, London during Tuesday 11th February 2020, observed at the kerbside site, showing that air quality is heavily influenced by traffic, with morning and afternoon peaks associated with rush hour traffic.

of making science more relevant to children's everyday lives and of developing children's scientific enquiry skills (Harlen & Qualter, 2018). All primary children are expected to carry out practical investigations that involve setting up a range of types of enquiries (for definitions, see https://pstt.org.uk/resources/curriculum-materials/enquiry-skills), asking questions, making predictions, observing and measuring, recording and interpreting data, and evaluating (reflecting on the success of the enquiry approach). To identify questions for further enquiries and to interpret require data and this can be difficult in the primary classroom, because children's practical activities do not always generate large data sets for children to work on. Having access to the Air Quality data provides large data sets with which, with a little guidance, children can interpret and develop these skills. Children using these data will also develop their maths skills (calculating mean averages, knowing when it is appropriate to find the mean of a data set, plotting and interpreting graphs) and computing skills (using spreadsheets). Young people are increasingly aware of climate change and the challenges that this presents. The Air Quality data also provide an opportunity for children to carry out original research that is local and relevant to real life issues.

Summary

This expansive resource will allow children, teachers and their carers to use their numeracy skills to participate in science research using real atmospheric data. At a minimum, the children will be able to explain the trends and extrapolate information from pre-prepared graphs and other charts. At best, the resource will facilitate children's science curiosity and produce valid research outputs that may not have been previously explored by the older, professional scientists. The additional bonus is that these young scientists will have an increased understanding of some of the complexity of climate science, one of the world's greatest science challenges.

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Tim Harrison is the School Teacher Fellow at Bristol ChemLabS, University of Bristol.
E-mail: t.g.harrison@bristol.ac.uk

Alison Trew is a Doctor of Science and was a primary school teacher for nine years. She is currently a Fellow of the Primary Science Teaching Trust, an Area Mentor and Website Resources Developer for PSTT.

Anwar H. Khan is a Doctor of Atmospheric Chemistry and Senior Research Associate in the Atmospheric Chemistry Research Group at the University of Bristol.

Rayne Holland is a Doctor of Philosophy student in the Atmospheric Chemistry Research Group at the University of Bristol and works with PSTT to develop outdoor and environmental-based resources.

Dudley E. Shallcross is the Professor of Atmospheric Chemistry at the University of Bristol and the CEO of the Primary Science Teaching Trust.

What are the barriers to creativity in primary science lessons? A qualitative examination of Irish primary school teachers' views

● Patrick MacAogain

Abstract

Creativity within the teaching of primary science offers the potential to transform children's understanding of and engagement with the subject area. This perspective is not universally shared and, as such, feelings exist that there is not enough emphasis being placed on the importance of creativity in the teaching of this subject. As a result, opportunities to engage the younger generation with the wonders of science are being missed. This is where the crux of this paper is to be found. Through seeking to increase knowledge of the components of creative science lessons, and to assess the impact of benchmark testing on creativity in pedagogical practice, this article is sympathetic to a view that there is a place for creative strategies within the science discipline.

To do this, this current study seeks to examine the perceived barriers to teaching creatively in primary science as told by teachers who are currently engaged in the process; and, using a small scale study, twenty primary school teachers from rural Irish schools partook in semi-structured interviews to elucidate their experiences. Data from these interviews were subjected to phenomenographic analysis, and two broad themes were developed. These themes indicated that there were systemic barriers to creative teaching, which consisted of the tension between creativity and teaching for assessment, and the perceived constraints placed upon teachers by the curriculum to which they are asked to teach.

Keywords: Creativity, primary science, primary teachers, assessment, curriculum

Introduction

The act of teaching creatively in classroom settings is considered to be teacher-centred as opposed to child-centred, and is quite common (Cremin, 2015; Ulger, 2017) – an opinion held by many teachers around the world, but not all (Newton, 2010). For creativity to thrive in the classroom there must be a degree of creativity from the teacher, but there is also a sense that sees creativity being for the Arts rather than science delivery (Newton, 2010). With this, it is of note that Cremin and Barnes (2010) list common characteristics that most creative teachers appear to possess. These include enthusiasm, passion and commitment to teaching; a degree of risk-taking; a deep curiosity or questioning stance; willingness to be intuitive and retrospective; a clear set of personal values; and an awareness of self as a creative being. Cremin and Barnes (2010) argue that all of these are critical to any good teacher, but knowledge of oneself as being creative is what resonates with teachers who are considered to be creative.

There are countless documents and research that highlight the attributes of a creative teacher. Ofsted's (2010) work, *Learning: Creative approaches that raise standards*, examines the success of creativity within schools, whilst Wiesberg's (2010) paper focuses on cognition within the study of creativity within science teaching. The document found that, in the most effective schools, creativity was given a high level of importance within the school curriculum. Ofsted (2013), for example, found that teachers with a clear understanding of creativity increased learner subject curiosity; the teachers in question may not be able to put this understanding into words, but are still capable of modelling creativity to their students, which is another cornerstone of effective creative teaching.

This reality is indicative of Shulman's (1986) theory on subject matter knowledge, which required teachers to be expert also in pedagogy and, arguably, those who have mastered that need are those who form the backbone of the select few identified by Ofsted (2013). Burgess (2007) also found that teachers were more likely to teach creatively if they had support from senior management, giving them time to: teach, with less focus on paperwork and more focus on learning; enjoy, with less pressure on teaching; imagine, with less prescription in order to plan creative lessons; and motivate, through less pushing to connect to individual needs. These measures aided in promoting creative teaching in the classrooms significantly.

However, it is important to note that teaching creatively may hamper children's creative outlets. This is particularly relevant where there is a more summative system of teaching, which sees the use of benchmarks to test knowledge acquired (Ofsted, 2013). This perspective is of particular importance, given that there is increased recognition that it is through science where many of the skills that underpin creativity, such as questioning, challenging, making connections, keeping options open and problem-solving (DCSF, 2008), can be taught. From a constructivist perspective, generating explanations and testing them are creative processes (Newton, 2010) and meaningful learning is inherently creative (Newton & Newton, 2009). Teaching science involves the use of provocative questions in a safe and enabling environment for exploring, risk-taking, experimenting and speculating, a process that helps students to improve their creativity (Ofsted, 2013). Additionally, the notion of creativity was expressed explicitly in an earlier version of the National Curriculum for Science in England, '*that science is about thinking creatively to try to explain how living and non-living things work, and to establish links between causes and effects*' (DfES, 1999, p.21). This premise, for Caulton (2007), is intended to increase learner interest in the subject.

According to both Cheng (2011) and Unger (2017), creativity can also be generated through scientific knowledge in various forms of expression. For example, knowledge, concepts and principles can be presented in the form of role-playing, drama, music, pictures, poems, and stories. Consistent with the importance of creativity in science, creativity has been recognised as a crucial component of school science (Perking, 1992). Although creativity is not confined to any particular subject area, Torrance (1992) supported the view that science has a much wider range of activities with which to foster creativity than other school subjects. This is because the process of creativity (preparation, incubation, illumination and verification) is similar to the steps in scientific method: observation, hypothesis, experimentation and verification (Garg & Garg, 2010; Fitzgerald, Danaia & McKinnon, 2019). Here it is suggested that these approaches lead to a more enquiry-based practice and the consideration of how important it is to teach creativity within primary science. This is the process that Cutting and Kelly (2014) relate to the issue of a need for teachers to inspire learners to engage with the subject and acquire knowledge as a result. It is in this spirit that the aim of this current study is to investigate the experiences of primary school teachers with regard to their perceptions of what the current barriers are to creative teaching in primary science. The following section will outline how this aim will be achieved.

Research aims:

- To increase knowledge of the components of creative science lessons; and
- To assess the impact of benchmark testing on creativity in pedagogical practice.

Methodology

This study adopted the qualitative paradigm to develop rich and in-depth data with regard to the views and lived experiences concerning the teaching of primary science. This approach is considered to help develop a more thematic line of findings, which sees elements being grouped together as a process for gathering additional insights into the phenomenon in hand (Braun & Clarke, 2006; Cohen, Mannion & Morrison, 2013).

Study ethics

The research adhered to the British Educational Research Association (BERA)'s code (2011) addressing informed consent, confidentiality and secure data storage. The ICO (2019: 12) notes that the anonymisation of personal data, as is the case here, lies outside of GDPR and Data Protection systems. Nevertheless, this study has undertaken to build upon regulations and apply BERA code requirements, which, ostensibly, are stronger than those offered by current legal restrictions and regulations. As such, BERA (2011) is the governing system for this work and, following approval from the school's Board of Management, written informed consent was acquired from teachers who partook in this research.

Sample selection

Sampling is viewed by Anderson (2004) as a deliberate process that sees a number of people being used as representative of a greater population and, with this, a more purposive sampling system was used to recruit participants to the study. Yet, although the generalisation of samples is not a priority within purely qualitative research, the prevailing ratio of male to female teachers in primary schools was considered; this led to the recruitment of n = 20 teachers, of whom n = 4 were male and n = 16 were female. Recruitment took place from rural primary schools in Ireland. To help concretise findings, a triangulation system, in line with Stenhouse's (1975) pioneering introduction to curricular research and development, is utilised. This sees the incorporation of necessary components for creativity in education: imagination, desire and motivation.

Data collection

Face-to-face semi-structured interviews were conducted to determine the perceptions of teachers regarding aspects of creative teaching in primary science. Participants were interviewed by the study researcher under Marton's phenomenographic approach to identifying the perceptions of participants' lived experiences (Marton, 1988a). Interviews were recorded using a digital recorder and were subsequently transcribed verbatim into play-script transcripts. Each interview lasted approximately 45 minutes.

Data analysis

Following transcription of the audio files, full data analysis, following Marton's (1988b) method of phenomenographic analysis, was conducted. This involved a series of steps in which the data were categorised and sub-categorised into codes and themes. Cohen, Mannion and Morrison (2013) argue that this approach also sees a need to undertake analysis of the themes, because it is this that ultimately informs knowledge. This process began with the researcher familiarising themselves with the data – a process that began during the transcription of the audio files, and subsequent read-throughs of the play-script output – during which initial ideas about lower level codes were developed. The next phase sought to hone and refine these lower level codes and, additionally, saw similar codes be organised into thematic clusters. From these clusters, themes began to develop, at which point reference was made back to the original raw data to ensure fidelity between the themes and the actual accounts of participants. At this stage, any themes that did not match the data to a satisfactory level were discarded, whilst remaining themes were further refined and developed.

Results

Following analysis of the interview data, there were two core themes that emerged surrounding the challenges of implementing creative teaching in primary science lessons. The first of these referred to the tension between teaching creativity and working towards educational assessments, as per the evidence in the literature concerning the place of summative assessments in science (Ofsted, 2013). The second referred to the tension of having to work to the National Curriculum, though this could be a structural issue, which was felt to limit opportunities for creative thinking. These will be discussed in further detail in the following sub-sections and, where appropriate, these themes will be highlighted utilising extracts of the verbatim accounts of study participants.

The tension between creativity and assessment

Analysis of the interviews indicated that teachers found it incredibly difficult to implement creative teaching in their science lessons. One teacher stated that: *'We did not undertake any creative teaching in university, and even though I'm not great at modelling creativity, I do try to help students to see their own abilities or encourage creative problem solving. I feel that science is a really difficult subject, as you think that it should be practical, but you would need to see how individual children work out an experiment in order to access it accurately…'*

This was followed by *'...but the nature of it [science] should be a practical subject full of creativity!'*

Another teacher furthered this sentiment by stating: *'I suppose it would be easier if you orientated children to the subject. For example, sometimes I see children really engaged in the activity as in the example of electricity, and they try to work how a bulb lights in different ways...'*

The teacher gave the example that science needs to be presented in an interesting way to children, with opportunities for displaying creativity. For example, a child engaged in creative learning might express possibility thinking characterised by questions such as 'what if?' These questions are crucial to science, as they allow the children to come up with predictions, which in turn aid their learning. One teacher concurred with this as he stated: *'Within the topic of light, the children predicted where the light would reflect off a mirror by drawing it in their science books.'*

To be creative, children are required to be involved in:

- Exploration;
- Enquiry;
- Explanation; and
- Making connections.

The four abstract components, it is to be noted, relate to the fundamental ethos of the primary science programme, which allows children to explore their ideas.

Testing to benchmarks: The tension of teaching to National Curriculum Benchmarks (Testing)

Negative: One teacher described the IPSA-T (Irish Primary Science Achievement Test) that she is obliged to take with her class. There are three levels to this test, which make it possible to assess children's knowledge at the end of second, fourth and sixth class. The test uses multiple choice and short answers to respond to questions. The aim of the IPSA-T is to report pupil progress to parents.
Positive: Even though this particular teacher favoured the test, she also stated that: *'My major concern is that creativity is squashed by undertaking this test as I feel I am teaching to the test. I think that assessment gets in the way because students have to get a certain response.'* This premise is supported by the literature, which sees Cohen *et al* (2013) argue that the adoption of such approaches can be used to help inform the transfer of knowledge between teacher and class.

One teacher expressed disappointment that his experience in teaching science had resulted in pupils becoming unwilling to be creative and preferring a set structure of teaching and learning science. He agreed with the above statement and wondered whether a constructivist approach, as propagated within the curriculum, would encourage creativity: *'I feel if we use the constructivist approach to teaching science, as we learned in university and as proposed by Howe et al, of orientation, elicitation, experiment, reflection and application, this could promote independent thinking and creativity.'*

An assessment system predicated on a behaviouristic view of teaching and learning is one that is currently used in the assessment of learning by paper and pencil (Knight, 2011). The aim is to determine how much of the core curriculum learned from the teacher is still an important part of the curriculum in Ireland. Some teachers may argue that this testing approach is contrary to the needs of creative lessons. Furthermore, summative pedagogical practice only serves as a measurement approach, which is more theoretically consistent with earlier forms of the curriculum and their associated beliefs about learning. With this in mind, one teacher stated that: *'If [only] we could bring the enjoyment back into science and assess the children based on their levels of enjoyment and not their levels of achievement.'*

Discussion

Assessment within education is crucial to learning, as it *'activates outstanding learning, develops students' abilities and promotes further thinking'* (Cremin & Arthur; 2014). The encouragement of using thinking skills to develop creativity are key values, but if we are to deliver purposeful teaching, we must have the capacity to evaluate it, as anticipating innovativeness will be inadequate. Assessing creativity is as complex as defining creativity, which can be attributed to the numerous theoretical approaches. A key dispute about assessing creativity is the subjectivity of it (Inoue, 2016); what one teacher may deem as creative may not be viewed in the same light by another. This results in work being open to the cultural disposition and, at times, work being devalued. As creativity is more of a pedagogical issue rather than a subject one, teachers can view such assessment as challenging, as there are no set guidelines to relate to children's work. It is evident that, as creativity is being rooted in all curriculum subjects, there is a greater need for an assessment tool that is inclusive and applicable to the new curriculum. The tension that exists between creativity and assessment is therefore a matter that requires further examination, and the final section of this paper will pay further attention to this matter.

The constraints of teaching to a curriculum

There were some contentions regarding creativity in primary science. Fifteen of the teachers interviewed argued that the National Curriculum places scant emphasis on the importance of creativity, therefore making it difficult to incorporate creative approaches into a teaching programme that had been structured independent of front line staff. With this, one teacher passionately stated that: *'When we went on our in-service days, it would appear that creativity is only relevant to the subjects of ICT, art, design and technology, and music. I wondered why it was not extended to other aspects of the curriculum such as science.'*

Another teacher felt that learning needs to be fun and thus creativity should have a higher value placed upon it: *'A teacher's role is not only to teach children what they need to know, but also to make learning fun and exciting so that the children can remember and enjoy what they have learned.'*

Ofsted (2010) argue that creativity is fundamental to successful learning and therefore teaching for creativity should not be dismissed or deemed 'unimportant' under the pressures of the National Curriculum (Davies *et al*, 2013). Teachers find that the pressures and expectations for high attainment and rapid progress often cause them to neglect creativity. This pressure to produce high levels of achievement is especially prominent amongst fifth and sixth (aged 9-11) class teachers: *'Many sixth class teachers feel that there is no time to teach anything other than mathematics and English due to the constraints and high expectations of parents and children as they enter the second level. These expectations not only leave teachers feeling stressed and nervous, but the children are also left feeling anxious and unhappy rather than excited or inspired.'*

Some teachers felt that the curriculum did not provide them with enough scope to be creative and felt that they were supposed to teach too much to the curriculum. One teacher said: *'I like the idea that the curriculum is there as a tool, but I sometimes feel that in my school we are supposed to follow it like the Bible!'*

With this, it would appear that the attributes of a creative teacher should include an ability to encourage children to produce creative outcomes, both within everyday life and within schooling. In order to do so, they must provide pupils with the chance to explore and examine a range of subject areas in suitable teaching climates. It can, however, be difficult for teachers to incorporate creativity into the expansive and continually changing curriculum. The major findings highlight the fact that, although teachers are not able to change the content of the curriculum, the way in which they deliver lessons is altogether down to the individual teacher. Teachers should be encouraged to use the National Curriculum as guidance in order to promote original and creative outcomes.

However, it is clear from the analysis undertaken in this study that the curriculum, far from providing an environment in which children can learn creatively, actually has the opposite effect and stifles the manner in which teachers feel that they can teach. This is an aspect supported by Ofsted (2010), who found that the most high performing schools were those with which there was little or no *'conflict between the National Curriculum, National Standards in core subjects and creative approaches to learning'* (Ofsted, 2010, p.5). This highlights the need to ensure consistency between government requirements and teacher creativity in order to promote achievement both academically and creatively.

Discussion and conclusion

This final section focuses on the barriers to creativity within primary science lessons, in respect of the need to increase knowledge of the components of creative science lessons and to assess the impact of benchmark testing on creativity in pedagogical practice. As such, the research considers the limitations of the current study, places the findings described above into context, and concludes with recommendations both for future practice and future research:

- To increase knowledge of the components of creative science lessons; and
- To assess the impact of benchmark testing on creativity in pedagogical practice.

Limitations

Prior to discussing the above findings in further detail, it is prudent at this stage to discuss the limitations of the current research that yielded these findings. The analysis itself is a laborious process, particularly when working alone. This is an issue that sees the researcher relying on his or her own instincts and interpretations of the available literature. However, there is a need to adhere to a pre-developed set of analytic steps to ensure that the themes that were identified were firmly grounded within the data that were collected and are indicative of the experiences that were reported by participants. However, it must also be noted that, although qualitative research does not seek to make sweeping generalisations, the themes reported may not reflect all the experiences of this particular participant group or even their wider group of peers in education. It must also be noted that this work was carried out by a single researcher, raising the possibility of unconscious researcher bias being a factor in the theme development (Noble & Smith, 2015). Nevertheless, the rigorous nature of the analytic process was designed to minimise the chances of this.

Structural issues for this study related to reliability as, essentially a small-scale study, the paper cannot claim universality of meaning in regards to the findings because, ostensibly, the research offers only a snapshot of teacher and practitioner thinking. But in order to help bypass this issue, triangulation with regard to imagination, desire, and motivation was considered to be crucial because, in essence, it is difficult to create rogue summaries when different components yield the same results (Stenhouse, 1975).

Discussion of findings

The findings of this study conclude that testing in primary education is hampering the teaching of creativity. This finding is coherent with Luzer (2013), who believes that standardised testing is destroying students' creativity and their desire to learn. With the IPSA-T and other standardised testing being introduced to younger and younger children, many teachers are worried about how this might affect the children's creativity. Arthur and Cremin (2014) recognise the constraints that standardised testing impose on creativity; they consider the argument that, through removing national statutory testing of children, we could achieve more creativity. However, many educators argue that the constraints of SATs and other standardised tests can be overcome through teachers' confidence and the willingness to enforce creativity in their classroom (Fisher & Williams, 2004). The teachers in question generally found it difficult to suggest ways of assessing creativity in teaching science in the classroom. For many teachers, they were thinking in terms of pen and paper assessment, as opposed to more creative assessment methods.

Arthur and Cremin (2014) believe that the scant attention paid to creativity, compared to that in the previous National Curriculum, is the reason why teachers discourage creativity in their classroom. However, the National Curriculum (1999) should be seen as a basic structure to support teachers and help them with planning. According to DfE (1999), it was not established to restrict teachers' creativity, but simply to provide the framework that they can use to develop exciting lessons. Fisher and Williams (2004) argue that teachers should do more than just restrict their teaching to the National Curriculum standards; however, as this current study has shown, the perceived constraints of the National Curriculum are felt by teachers to be limiting to their teaching; the implications of these findings shall be discussed below.

Conclusions and future implications

This study set out to examine, in an in-depth manner, the experiences of primary school teachers in relation to the current barriers to teaching creativity within primary science. This was achieved via the conducting and subsequent analysis of semi-structured interviews of twenty teachers who have recent experience of this issue.

The analysis pointed to two core barriers to teaching creativity in primary science. These were created by the tension between creativity and teaching for assessment and also maintained by the perceived constraints of the National Curriculum, which teachers felt placed little emphasis on the role of creativity within learning.

It must be noted at this point that the two key barriers to teaching creativity are systemic issues relating to the 'machinery' of teaching, and the frameworks under which teachers are required to work. It is possible that this 'outward' identification of issues fails to pay heed to the individual characteristics of teachers, or even of school environments, which may limit the use of creativity in class. Indeed, there was very little internalisation of issues, or identification of personal characteristics, such as levels of confidence in teaching creativity, by participants.

This could reflect that it is in fact the external machinations of the educational system that hinder creativity, but future research should focus upon possible personal factors within teachers that may have an impact on this matter. Future research could also further expand upon the findings of the current study and examine the issues outlined above in a large-scale survey of teachers, to gauge the extent of the perceived problems with assessments and curricula within primary science. In a practical sense, schools must support teachers to place importance and emphasis on creative learning within science, free from the tensions and constraints that teachers within this study have identified – this is in line with Ofsted's (2010) recommendations, but, clearly, based upon the evidence of the current study, more needs to be done to support teachers and schools in relation to this most important of areas.

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Patrick MacAogain is a primary school teacher in a rural school in Ireland. He is currently studying for a Doctorate in Primary Science Education.
E-mail: PatrickMacaogain@hotmail.com

Making environmental studies engaging for elementary school students

● Rupali Shinde ● Adithi Muralidhar ● Sugra Chunawala

Abstract

This article describes our attempt to engage Grade 5 (aged 10-11) students in a meaningful discussion in an inquiry-based science classroom on the topic of food chains and webs. Students were encouraged to speak, write and draw their ideas on a worksheet used as a pedagogical tool to elicit students' conceptions about the topic. This paper reports on students' responses to the worksheet and some preliminary analysis of their talk. We found that the worksheet promoted classroom engagement and discussion among students and revealed their ideas about the environment. Our work is particularly relevant in the context of Indian classrooms with large numbers of students (up to 65 students in this case), where the student population is heterogeneous.

Keywords: Environment, teaching/learning, food chains, student engagement, science education

Introduction

An important consideration in teaching is keeping students engaged and yet being aware of opportunities where learning can take place. In a review of over 200 research studies Aloisi *et al* (2014) suggest that teachers' content knowledge as well as their abilities to understand students' thinking and conduct formative assessments are closely tied to students' academic attainment. They highlight the importance of teachers encouraging students to raise questions during activities in lessons. In science classrooms, some of the strategies to engage students meaningfully include encouraging classroom talk and promoting individual or collective expressions (Mitchell, 2010), and contextualising science for students with their environment by emphasising science and society linkages (for example, see Sjøberg & Schreiner, 2010; Science Education for Diversity, 2012). Of particular interest to us is the need to promote classroom talk, students' questions and self-expression.

Numerous studies have highlighted that student questions, which can emerge from classroom discussions, are an important part of teaching and learning science (Dillon, 1988). These questions can be a resource for teachers (Chin & Osborne, 2008). In Indian schools, however, classroom talk, dialogue and questioning are generally missing and various researchers have suggested that teachers should find ways to create more opportunities for student interactions (Singh, Shaikh & Haydock, 2019; Sengupta, Chandrika, Dey & Ramadas, 2020). Encouraging questions in a classroom provides space for student voices. Classroom talk between teacher and pupil/s or between pupils (Barnes, 2010) can result in hypothesising, debating and exploring issues.

Literature over the years has highlighted that, besides classroom talk, well-designed worksheets are a means to construct knowledge, elicit students' interests, enhance development of skills, assess students' prior knowledge and identify and address students' misconceptions. However, scholars have also cautioned that poorly designed worksheets and a lack of pedagogical knowledge may hinder the effectiveness of worksheets for learning (Griffin & Symington, 1997; Che-Di Lee, 2014). The current study uses worksheets to spark students' expression and engage students with a topic in a science classroom. In India, the National Curriculum Framework (NCF) (NCERT, 2005) has adopted the constructivist framework and recommends that learners be presented with authentic experiences to actively participate in science classes. It is in this background that we place our study of engaging students of Grade 5 (ages 10-11) learning 'Environmental Studies' (EVS) as part of their school curriculum.

Environmental studies, also labelled as Environment Education (EE), has been gaining worldwide importance over the last few decades (United Nations, 1972; Tbilisi Declaration, 1977; UNEDP, 1992). The NCF suggests that environment should be emphasised in every subject and through a wide range of activities (NCERT, 2005). In India, EE became a mandatory component of school education and is 'integrated' with science and social studies. Currently in the Indian state of Maharashtra (where this study is conducted), EVS is presented as an integrated subject (includes science and social studies) for Grades 3-5.

Context of the study

A collaborative project

We are members of a centre for science education involved in a longitudinal collaborative project with a neighbourhood school where the instructional language is Marathi (official language of Maharashtra State). The study is based in Mumbai, the capital of Maharashtra State. The broader aim of the project is to improve students' classroom learning experience of EVS. This is done by collaborating with schoolteachers to develop lesson plans and implement them in the classroom for each chapter of the EVS textbook. The school timetable, on average, schedules a chapter to be completed in a week (6 working days), with a class of 35 minutes' duration daily.

The number of students in the class is around 70 (about 65 may be present on any one day). The classroom sessions are conducted by us, or the schoolteacher, or both together, and mutual feedback is sought and exchanged before and after each class. In addition, there is a non-participatory observer who provides feedback on all the sessions. The EVS teacher appointed by the school for this class happens to be a language teacher with no formal science or social studies background. Educationalists have emphasised the importance of subject (SCK) and pedagogical content knowledge (PCK) in shaping the classroom practices of teachers (Shulman, 1987; Appleton, 2013). In our context, this teacher with an educational qualification in languages has some challenges in teaching the EVS curriculum and generally resorted to getting students to read paragraphs from the textbook and learn the new words and terminologies.

The revised approach adopted by us and the teacher focused on transacting this curriculum through activities that relate the topics to students' lives. This approach also provides opportunities for students to raise questions (Chin & Osborne, 2008) as a means to foster student engagement. The focus of this paper is on those sessions that were conducted to transact the topic of food chains and food webs.

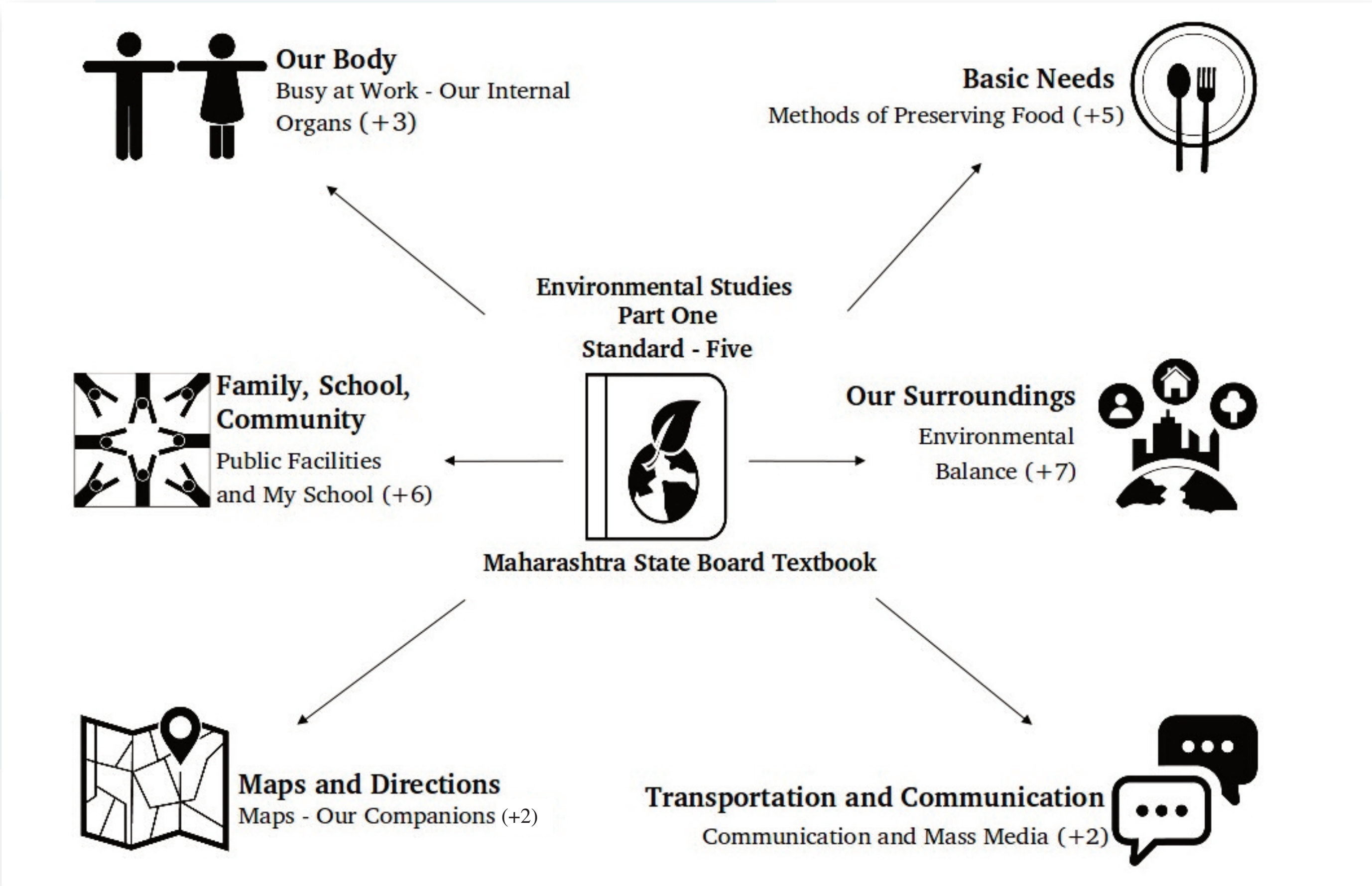
Chapters in the EVS textbook

The EVS textbook (Part 1) for use with Grade 5 in Maharashtra State (2015) has 25 chapters spread over themes, which we have categorised as *Our Surroundings; Family, School and Community; Our Body; Basic Needs; Maps and Directions;* and *Transportation and Communication.* Figure 1 presents details of themes and chapters of the Grade 5 EVS textbook.

In this article, we report our work with respect to the chapter entitled *Environmental Balance,* which is a part of the theme, *Our Surroundings.* While we are aware that the concept of 'balance' in the environment is fluid, complex and contested (Haydock & Srivastava, 2017), our focus was on the textbook content that does not deal with the differing interpretations existing around the term. It is also to be noted that the textbook used in the class was in the Marathi language and the terminologies do not map exactly to the terms in the English textbook.

Rather, we have focused on specific concepts (for example, food chains, food webs) mentioned in the chapter and have attempted to address these in the classroom. Earlier studies on students' understanding of food chains and food webs have discussed students' preconceptions and emphasised the need to facilitate a clear conceptual development on these topics at school (Webb & Boltt, 1990).

Figure 1: Themes in the textbook (in bold), with one representative example of a chapter. (The number in brackets denotes additional chapters under the same theme.)



Methodology

This study aligns itself with a Design-Based Research (DBR Collective, 2003) approach, which addresses complex issues or problems in real-life contexts. Our study is interventionist, and carried out in collaboration with practitioners, that is, the teachers in the school. A DBR approach involves a reflective inquiry process to evaluate the learning environment, which in turn helps to revise the solutions (Christensen & West, 2018).

Our initial interactions with the students (July 2017) led us to realise that worksheets aided the students' expressions of their ideas through writing or drawing, specifically as the classroom size often prevented students from being able to voice their thoughts. Our decision to use a worksheet was informed by literature (Kaymakcı, 2012; Kisiel, 2003) and our experiences and learning from classroom observations (Deshmukh *et al*, 2018; Karandikar & Shinde, 2020). We designed a worksheet for use in the classroom and, based on students' responses and our own reflections, it was revised and trialled with a smaller group of students in a summer camp (May 2018). These summer camps are organised by us each year, for students of the school and of the grade with which we are interacting in the academic year.

Our reasons for using a worksheet were multifold. Apart from the positives of using worksheets, such as their usefulness in revealing students' previous knowledge (Sasmaz-Oren & Ormanci, 2012), and functioning as advance organisers, helping students to organise their observations and knowledge (Kisiel, 2003), we felt that these may be particularly useful in classes with a large number of students (Gupta, 2004). A large class size poses additional demands on a teacher for classroom management as well as to get across the key aspects of the concept being taught. Typically, we found that, with a class size of around 70 students, which is well beyond the class size recommended by the government (Right to Education Act, 2010), and within the constraints of the infrastructure in the classroom that make it difficult even for the teacher to move around, student participation and group work were challenging. Basically, in such situations, we found it difficult to respond to student voices and questions, and hoped that a worksheet would help in capturing students' ideas.

It is to be noted that the use of worksheets to enhance learning and increase student engagement is not common in the Indian public school system, and especially the schools with Marathi as the medium of teaching/learning. The worksheet we designed for our session allowed for multiple modes of expression, involving writing, drawing or both, and gave students space to express their understanding of the topic. Visualising and drawing contribute to knowledge formation by the learner and help to create environments that invite students to engage in reasoning, experimenting, communicating and reflecting (Evagorou, Erduran & Mäntylä, 2015; Ainsworth *et al*, 2016). Drawing may also serve to bring forth the alternate conceptions held by students (Köse, 2008). Besides, we were aware that drawing tasks were engaging for students (Deshmukh *et al*, 2018). In this article, we discuss students' responses retrieved from the worksheet or during their classroom talk when they shared their ideas and experiences.

Observations

An overarching objective of the classroom sessions for the chapter on 'environmental balance' was to help students reach conceptual understanding of the topics of food chains and food webs in an engaging manner, through asking questions, and exchanging as well as expressing their ideas and understandings as they undertook the worksheet-solving experience.

Pre-worksheet activities: Classroom sessions with a game on food chains (July 2017)

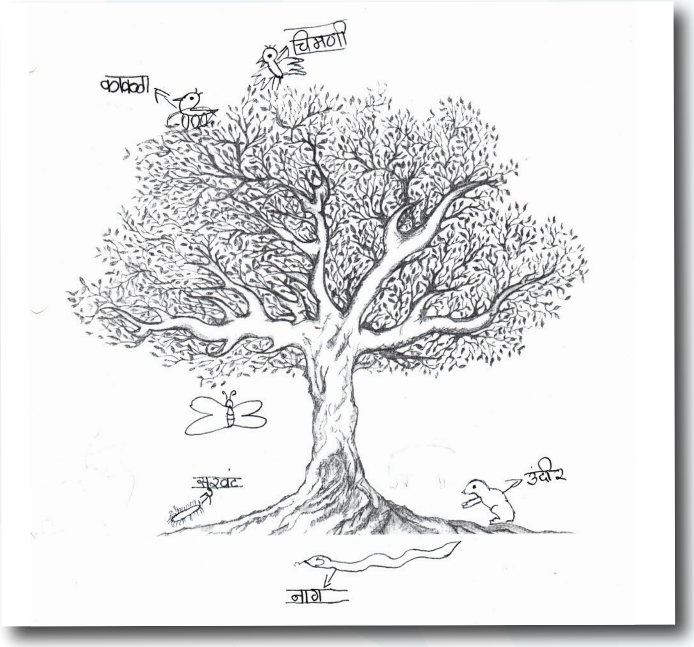
The concept of food chains is important in understanding the dynamics of the environment and is also emphasised in the EVS textbook. Food chain dynamics is also a key theory of ecology and having a sound understanding of this concept can provide insight into the factors that affect population regulation and cycle, competition, stability and diversity, evolutionary ecology and biogeography (Fretwell, 1987).

Our preliminary attempt to start the lesson was by posing a number of questions, but we were unable to make sense of the chorus of replies given by the students. Our intention was to create learning spaces where students could discuss their ideas and express their opinions, because listening to and responding to peers can help to build interest (Lewis & Burman, 2008; St. John & Briel, 2017). However, with a large number of students, the chorus responses quickly translated into 'chaos'. Teachers often are inhibited from implementing their ideas of student-centred learning in large classroom populations because of such reasons. We realised that we would have to engage the students in other ways if we wished to attain our teaching and learning goals, and hence we planned to introduce the concept of 'food chains' through a game. This game involved giving a picture card to a pair of students. Each picture card depicted some living form (animal, bird, plant, micro-organism). Students were given time to familiarise themselves with the card. We then called a pair of students at random to the front of the class, asked them what was depicted on their picture card and wrote it on the board: for instance, 'rat'. We then asked the class to refer to their picture cards and answer whether their card depicted a prey or predator of the original card (rat). For example, we asked, *'Do you have a card of something that eats, or is eaten by, a rat?'.* The responses led to another pair of students sharing their card with the class, for example, 'owl'. We then asked *'who eats owls?'* or *'what else does an owl eat?'* Thus we drew 'food chains' on the blackboard corresponding to students' responses based on the picture cards.

Students' alternative conceptions emerged during the course of the game. For example, one student remarked that *'There are thorns (scales/spikes) on a crocodile's body so nobody in the environment can eat a crocodile'.* Possibly students were thinking of predators for animals such as crocodiles and reasons for why there are none or very few. Though seemingly large and bulky animals such as crocodiles and elephants can be predated upon, it was interesting to see how students made links between body size and structure and vulnerability to predation (Gallegos, Jerezano & Flores, 1994). Another student commented that *'if the snake eats a lizard, the snake dies because the lizard is poisonous'*. Here too was an opportunity to discuss differences between venomous and poisonous

Figure 2 (L): The labels written for the organisms drawn by the student on the worksheet have been translated into English. In a clockwise manner, starting from bottom left, are: *Millipede, Butterfly, Crow, Sparrow, Rat, Snake-Cobra.*
(Image credit: Tree Sketch Easy by Brandie Bell, used under CC BY-NC 4.0 License.)

Figure 3 (R): The labels written for the organisms drawn by the student have been translated into English. In a clockwise manner, starting from bottom left, are: *Snail, Snake, Earthworm, Squirrel, Millipede.*
(Image credit: This 'cut tree' is a derivative of *Tree Sketch Easy* by Brandie Bell used under CC BY-NC 4.0 License. 'Cut tree' is licensed under CC BY-NC 4.0 License by P. Nawale.)



animals and a predator's immunity against certain poisonous prey species. Overall, we found that the game was successful in engaging the students and helped to bring forth the alternate conceptions among students. The subsequent session was planned to introduce students to think of multiple life forms and interconnections between food chains.

Worksheet development (July 2017)

In the game discussed earlier, students had only one organism/life form to think about at a time. In the next stage, we developed a worksheet where students had to consider multiple life forms simultaneously, thereby bringing in the complexity of the phenomenon. These multiple life forms were utilised by the instructor to draw a food web on the board. This worksheet displayed two drawings, one depicting a full-grown tree and the other a stump ('cut' tree). Students were asked to write or draw the living organisms found under each on/around/under the drawings of the tree and the stump. This worksheet attempted to relate classroom experience to students' daily life experiences about the environment and to get them to make connections between organisms and their habitats. We hoped that the contrast between the two drawings, a full-grown tree and a stump, would spark students' curiosity and elicit questions and expressions of students' ideas (Chin, 2001).

Students' responses to and the resultant redesigning of the worksheet

Students' responses to the worksheet

The majority (89%) of students (60 of the 67) drew or listed more living forms in and around the full-grown tree when compared to the stump. We also found 56 discrete/unique indications of living and non-living components, which may have otherwise not found a place in the classroom if verbal expression only were to take place. Examples of living organisms included earthworm, monkey, cow, insects and snakes, while non-living components included drawings or mention of the Sun, oxygen and carbon dioxide around the tree. These responses provide a range of examples with which students are familiar and can be used by a teacher in further conversations during the lesson. Figures 2 and 3 depict one student's work as a sample of the responses received.

In our discussion with the entire class, we focused on the fact that, if trees are cut, one may observe changes in food chains. For example, one student drew birds on the tree but not on the drawing of the stump, and depicted a snake in both contexts. Thus there were multiple opportunities to discuss concepts of interdependency of elements of a food chain, prey base, predator-prey relationship, etc., using the responses derived from students. Despite the fact that the worksheet permitted multiple modes of expression, we found that writing was more popular among students. Of the 67 worksheets received, all students wrote on the worksheets and about 86% of these worksheets depicted writings exclusively. Only 13% of worksheets had students communicating through both drawings and writings. We had requested that students add labels to their drawings and had assured them that they need not worry about the aesthetic aspects of their drawings. Our findings suggest that students write rather than draw on worksheets and this had been reported earlier by Mathai and Ramadas (2009) in their study of visuals. One possible explanation for our findings can be that the practice of writing, which is *'a language-dependent mode of representation'*, tends to be privileged or prioritised over other forms of representation from a young age (Kendrick & Mckay, 2004). Other possibilities are that students associate drawing activities with art classes and may not relate them to science or environment education, despite studies highlighting the usefulness of drawings in science classrooms (Shaaron, Vaughan & Russell, 2011).

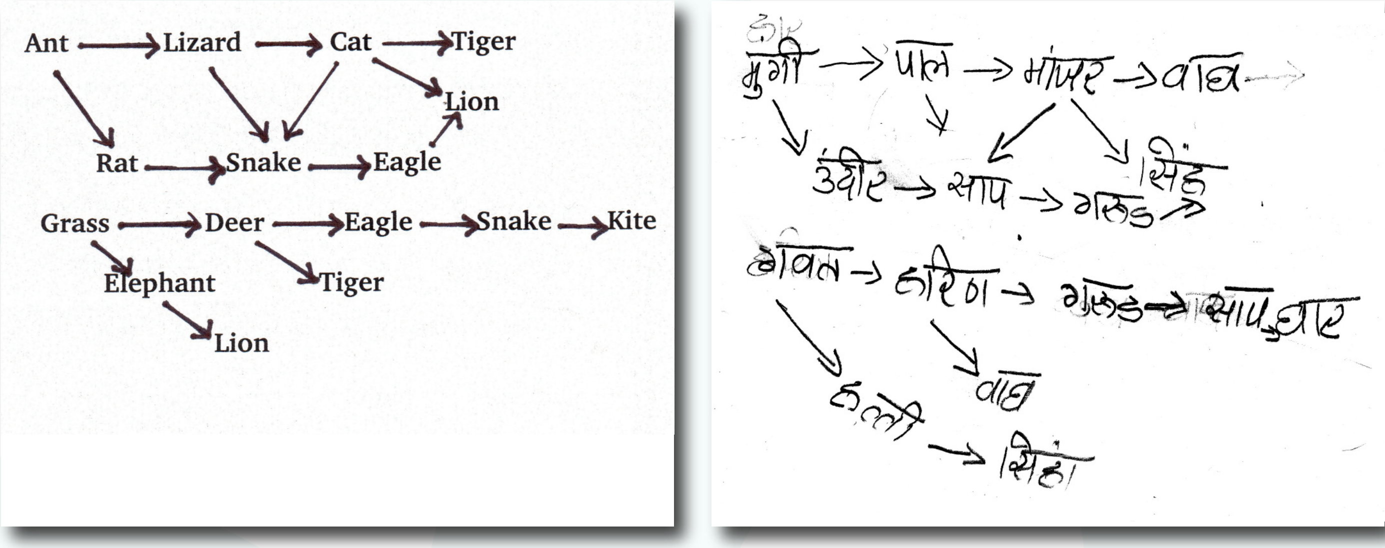
Summary of observations

Students were quite animated and a great deal of classroom talk was generated when the

Communication (type)	Excerpts of talk
Asking questions (Chin & Osborne, 2008; Singh, Shaikh & Haydock, 2018; Sengupta *et al*, 2020)	*Boy: What would happen to small plants (saplings) growing under big trees if we cut the tree? Girl: If an elephant does not eat any animal, then where does it feature in the food chain?*
Ethical concerns and environment(Baker *et al*, 2019; Dutta & Chandrasekharan, 2015; Jickling, 2005)	*Boy:...unnecessarily we cut the trees! Where there is a full-grown tree, many birds come and stay, many animals also stop by and we can write these in the worksheet. But there are very few things to list when it comes to the half-cut tree. So we should not cut trees.*
Relating to own experiences (Sjøberg & Schreiner, 2010; SED, 2012)	*Girl: In our village, we can see different birds and also birds eating insects, but here in our surroundings (in Mumbai), we don't see them much. Girl: In rainy season, trees look greener and there are many insects hovering around.*
	Girl: Snakes stay below trees and, when a snake is hungry, it eats eggs from birds' nests [referring to an incident she heard in her village].
Alternate ideas (Munson, 1994; Gallegos, Jerezano & Flores, 1994; Natarajan *et al*, 1996; Chunawala *et al*, 1996; Tekkaya, 2002; Köse, 2008)	*Girl: There are thorns (scales/spikes) on a crocodile's body so nobody in the environment can eat a crocodile. Boy: If the snake eats a lizard, the snake dies because the lizard is poisonous.*

Table 1: Students' conversations during the game and worksheet session.

Figure 4: Sample of a set of food chains made by a pair of students (translated version is on the left).



worksheets were used. These interactions provide insights into students' ideas about the environment. Table 1 presents a few examples of students' talk (translated from Marathi), indicating their questions and their attempts to relate contextual information to their prior knowledge and observations. The categories in the table are informed by the literature mentioned in the introduction and below.

After students had completed the worksheet, we summarised the activity by making food chains and food webs on the blackboard using the organisms listed or drawn by students. While reflecting on the session, we felt that, instead of us drawing the food chains and webs, we could have incorporated this aspect in the worksheet so that students could be more involved. This inspired us to include an additional task in the worksheet. However, since the regular class schedule had to be maintained, we undertook the implementation of the redesigned worksheets in a summer camp.

Redesigning the worksheet (May 2018)

The redesigned worksheet retained the earlier tasks but added a new task wherein students had to make use of the organisms drawn or listed on the sheet to make food chain/s or webs. We hoped that undertaking this activity would help students to consider the connections between organisms by themselves as opposed to the teacher explicating these ideas. Also, if students made their own food chains/webs, it would bring attention to the prey-predator concept. Students worked collaboratively in groups of two or three on this task. The redesigned worksheet had more blank spaces available for students' writings and drawings of food chains/webs and it was used with students in a summer camp (organised around 10 months after the classroom session). In this camp, some students from the same school and same grade participated voluntarily. When they were making the food chains, we subsequently introduced them to the idea that one organism may be part of more than one food chain, leading to the formation of a food web. We posed questions such as '*What would happen if one component of this food chain is removed?*' A student responded by writing '*From this food chain, if a sparrow is removed then the population of grasshoppers will increase. Also, as eagles eat sparrows and sparrows are destroyed, then eagles will no longer be there'.* This response is not entirely accurate (since eagles and sparrows have multiple food sources), but the response reveals an understanding of interdependency and interrelations between animals.

The redesigned worksheet helped to bring to the fore students' difficulties with the topic related to food chains/webs. We noticed that students were confused about the placement of dead organisms and decomposers in a food chain. Even though the topic of decomposers and decomposition is introduced for the first time to these students in this chapter, students reported being familiar with 'decomposers' owing to their prior experience of *seeing* small ants and other insects feeding on a big dead animal. However, they were confused about where to place them in the food chain.

Discussion and implications

Environmental studies is a subject that can be related to lives of students and offers many opportunities to learn the subject beyond classroom walls (Grimshaw *et al*, 2019). Unfortunately, we know that EVS sessions take place only within closed classroom environments, often due to practical reasons (Bhide & Chunawala, 2017). Furthermore, large class sizes with limited opportunities to learn outdoors pose challenges to ways in which young minds can be engaged with the subject. Keeping these structural constraints in mind, we sought to improve students' classroom learning experience of EVS by creating several opportunities where students at least can observe, analyse and reflect on their outdoor life experiences and discuss these within the class. These discussions can help students to perceive more complex connections of human existence and their actions/processes with the ecosystems. The current study focuses on students' understanding of food chain/web concepts and efforts to facilitate discourse about these concepts through a worksheet-based class intervention.

The development and implementation of the worksheet in this study can be explained along the lines of progressive refinement in educational resource-building. We started with a simple inquiry through direct questioning and soon switched to a coherent game activity followed by a worksheet. An iteration to the worksheet was done following the participant students' inputs, performance in activity, and reflective feedback of teacher, authors and observers. Each time, students' observations about the chosen living systems and surrounding environment were made explicit to the class by encouraging them to engage with the practice of drawing, writing and discussing with appropriate probing.

In our experience, the activity coupled with the worksheet added value to the everyday classroom situation. Firstly, the worksheet allowed students to express themselves through multiple modes of expression such as writing/drawing, or both.

Encouraging drawing would also allow a shift from exclusively verbal modes of communication and make available creative spaces in the classroom for students to present their ideas. While we bemoan the fact that the school system does not encourage students to draw in academic subjects, we noticed that, by Grade 5, students seemed to prefer writing over drawing. This is despite the fact that drawings (of the tree and stump) already present in the worksheet were central to eliciting responses from students. Having said that, it can be a worthwhile exercise for teachers to design worksheets in order to increase opportunities for communication in their classrooms. This is despite the fact that the already overworked teachers may need to research the concept, conceptualise the lesson plan accordingly and find ways to develop a writing/drawing task for a particular concept in the form of a worksheet.

Moreover, assessing responses to a worksheet and addressing those would require sustained efforts from teachers. In our earlier discussions, we highlighted two such exemplar occasions where probing provided additional opportunities for discussion, firstly when the differences of habitat around 'fully grown' and 'stump' were seen as different by a student. It is worthwhile to note these observations made by students and discuss them in the class. Another occasion was when a student's response to the redesigned worksheet revealed an understanding of the interdependency of organisms, which could aid in explaining food webs.

The introductory (game) activity and the worksheet elicited questions from students and generated informal talk in the class, which helped to bring to the surface students' alternate ideas about their surroundings and environment. We feel that the talk generated could give teachers pointers for which examples to use when introducing and teaching this topic (Sasmaz-Oren & Ormanci, 2012). Thus worksheets can give insights to a teacher if s/he attends to the responses of the students. The redesigning and implementation of the worksheet helped to reap dividends in terms of reaching out to students, engaging them, bringing about opportunities for discussion and helping to uncover their ideas about environmental interrelationships.

Our way forward would be to understand, in depth, which classroom situations call for using worksheets and how worksheets can be made and transacted effectively. We tried to learn from our failure in our first attempt of inquiry through direct questioning and this led to introducing the activity at the start of the class. Similarly, the details of iteration in the worksheet and the background conversations are made explicit to indicate that the worksheets were thoughtful pedagogic interventions and were revised following students' interactions with them, in a progressive manner. This messaging is particularly relevant in the Indian context, where worksheets are not commonly used for teaching/learning in the classroom.

We believe that several concepts in EVS can be introduced through worksheet activities as described in this paper. Furthermore, probing conversations about ideas such as interdependencies among environmental components can help students to see the connections between the environmental science learned in the classroom and their daily lives. We hope that Indian teachers in elementary schools explore and develop context-dependent educational resources in their regional languages to deepen inquiry in their classrooms.

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Rupali Shinde, Project Scientific Assistant, Homi Bhabha Centre for Science Education.
E-mail: rupali@hbcse.tifr.res.in

Adithi Muralidhar, Scientific Officer, Homi Bhabha Centre for Science Education.
E-mail: adithi@hbcse.tifr.res.in

Sugra Chunawala, Professor, Homi Bhabha Centre for Science Education.
E-mail: sugrac@hbcse.tifr.res.in

Real scientists argue: Bringing science and engineering practices to life through trade [picture] books

● Amy Broemmel ● Kristin Rearden

This is a new style of article, aiming to add some useful background to readers interested in reading and reviewing suitable educational picture books, putting into context how such books can enhance science learning for young children.

Abstract

Margaret Knight designed solutions. Sarah Campbell asked questions. Thomas Edison and Nikola Tesla argued. What do these people have in common? They are all scientists whose depictions in trade books [for non-US readers, 'trade books' roughly translates to 'picture books'] can provide real-life examples of science and engineering practices, particularly those identified within the Next Generation Science Standards (NGSS Lead States, 2013). Although these specific practices are aligned with the US-based NGSS, they are standard practices within the field and therefore serve as meaningful ways to bring scientists and what they do into focus within elementary [primary] classrooms.

Many elementary teachers integrate science and literacy to support science content acquisition. The use of trade books to foster students' understanding of the nature of science is also supported (Kruse & Borzo, 2010). Similarly, when teachers share books about scientists' inventions or quests for understanding, students can be inspired (Brassell, 2006). By sharing the influential stories of both citizen and career scientists through trade books, teachers can provide models that help their students to contextualise practices such as designing solutions and asking questions.

For each of the eight *NGSS* Practices, we have identified two books that provide real-life examples of people engaging in that particular practice. We relied on Rodger Bybee's (2011) explanations of each practice to provide a brief synopsis; for a more in-depth look at each practice, readers may refer to the original *NGSS* document. When selecting the books, we looked at not only the potential for links with the *NGSS* Practices, but also aspects pertaining to science content and literacy. Each book we selected was reviewed for the following four features: scientific accuracy, visual features, end pages, and engagement potential.

- ❒ *Scientific accuracy*. We focused primarily on award-winning books, as they were already vetted for quality. Most of the books we selected were recognised as an NSTA/Children's Book Council's Outstanding Science Trade Book.
- ❒ *Visual features*. We looked for photographs, lithographs, and artistic representations that meaningfully supported the written text.
- ❒ *End pages*. When included, we examined aspects such as the author's note, glossary, references, timelines, and other features to determine how they extended the main text.
- ❒ *Engagement potential*. In reviewing books, we began to recognise that some were 'cut and dry', with an emphasis on facts, dates and details. Other books were more prosaic, conveying the wonder of invention and exploration. While fact-laden books have a place in the classroom, we selected books that would be engaging to either a listener or reader.

A list of the books is shown in Table 1. We have included suggested reading levels and ideas for extending the use of the books for common activities based on the practices. While we've listed

Table 1: Overview of biographical trade books of scientists.

Science and Engineering Practice	Title	Author	Suggested Read Aloud Level	Special Features	Extending the book
Asking questions	Blockhead: The Life of Fibonacci	J. D'Agnese	P, I, M	Afterword; In-book Information "Hunt"	Observe various examples of the Fibonacci sequence in nature, such as on pinecones or flowers
	Wolfsnail: A Backyard Predator	S. Campbell	P, I	Wolfsnail facts; Glossary	Research the feeding patterns of various invertebrates
Developing models	Honda: The Boy Who Dreamed of Cars	M. Weston	I, M	Afterword	Design cars with interlocking building systems and test for speed
	Into the Deep: The Life of Naturalist and Explorer William Beebe	D. Shelton	I, M	Author's Note; Beebe quotes; Glossary; Resources	Design boats from material such as straws, rubber bands and craft sticks to hold a certain number of pennies
Planning investigations	For the Birds: The Life of Roger Tory Peterson	P. Thomas	I, M	Author's Note; Selected Bibliography; Roger Tory Peterson Institute info	Create bird feeders to attract certain species and document the various species
	The Dolphins of Shark Bay	P. Turner	I, M*	Captioned photos throughout; Afterword with more dolphin information; Updates on research;	Determine the effectiveness of various tools to pick up material, such as modeling bird beaks
Analysing and interpreting data	The Tapir Scientist: Saving South America's Largest Mammal	S. Montgomery	I, M*	Captioned photos throughout; Spreadsheets, graphs, & charts; Epilogue; Selected Bibliography; Index	Collect observational data on schoolyard species or classroom pets and determine patterns
	Farmer George Plants a Nation	P. Thomas	I, M	Timeline; Washington's thoughts on slavery; Information about Mount Vernon; Resources	Compare effects of different soil on seed germination and growth

Table 1 cont: Overview of biographical trade books of scientists.

Science and Engineering Practice	Title	Author	Suggested Read Aloud Level	Special Features	Extending the book
Using mathematics	Odd Boy Out: Young Albert Einstein	D. Brown	I, M	Author's Note; Bibliography	Investigate the mathematics of music, such as creating pitches made when tapping glasses of various amounts of water
	Close to the wind: The Beaufort Scale	P. Malone	I, M	Technical drawing of a typical man-of-war; Glossary, Brief biography of Francis Beaufort	Create wind flags and develop scales to qualitatively compare wind speed
Constructing explanations	Rare Treasure: Mary Anning and Her Remarkable Discoveries	D. Brown	P, I. M	None	Match fossils imprints with animal characteristics to infer species
	The Boy Who Invented TV: The Story of Philo Farnsworth	K. Krull	I, M	Author's Note, Additional Resources (books, websites, & other media)	Observe newsprint with magnifiers or microscopes to see how the images are formed with dots
Engaging in argument	Temple Grandin: How the Girl who Loved Cows Embraced Autism and Changed the World	S. Montgomery	I, M*	Specialized end papers; Foreward by Grandin; Diagrams; Advice from Grandin; Additional resources	Design containers to protect eggs dropped from various heights
	Electrical Wizard: How Nikola Tesla Lit Up the World	E. Rusch	I, M	Detailed Notes on rivalry with Edison; Scientific info about electricity, Selected bibliography; Suggestions for further reading	Create series and parallel circuits and compare bulb brightness
Communicating information	The Man Who Named the Clouds	J. Hannah & J. Holub	P, I, M	Weather Journal; Photographs of primary source documents; Cloud photo glossary; Additional resources	Create a weather blog with photos and classifications

Table 1 cont: Overview of biographical trade books of scientists.

Science and Engineering Practice	Title	Author	Suggested Read Aloud Level	Special Features	Extending the book
Communicating information cont.	The Flower Hunter: William Bartram, America's First Naturalist	D. Ray	P, I	Afterword; Photo of a Bartram engraving; Author's Note; Bibliography	Create a field guide of schoolyard trees
Multiple	Star Stuff: Carl Sagan and the Mysteries of the Cosmos	S. R. Sissons	P, I, M	Author's Note; Bibliography; Source Notes	Record observations of the Moon over a period of time

P = Primary grades, I = Intermediate grades, M = Middle grades
* Teachers should select specific sections to share rather than reading the entire book aloud due to the extensive text.

books under specific practices, the books can address multiple practices just as the practices themselves can overlap.

Asking questions and defining problems:
Blockhead: The Life of Fibonacci by D'Agnese blends known information about Fibonacci with conjectures about his early childhood based on his inquisitive nature. Questions that the young Fibonacci might have asked about patterns in nature while gazing out his window, along with his eventual discovery named after him, can inspire young students to more carefully observe and question what they observe. Citizen scientist Campbell depicts her quest to determine the various characteristics of a creature in her yard in *Wolfsnail: A Backyard Predator*. As she details in her book, she uncovers that this particular Mississippi snail is actually carnivorous. Close-up photographs of the wolfsnail also make this book a terrific resource for learning about predatory-prey relationships. The author's website includes a short video of a wolfsnail eating.

Developing and using models:
Weston's *Honda: The Boy who Dreamed of Cars* opens with young Honda in Japan, where he had spent over a year sweeping and cleaning a garage just so he could have a chance to become a mechanic. He finally has the opportunity to develop his engineering ideas, working first to improve the metal rings that surround pistons and later using his expertise to develop a better bicycle. The Afterword section documents his tireless efforts to bring his dreams of building cars and other vehicles to life. *Into the Deep: The Life of Naturalist and Explorer William Beebe* by Sheldon describes the life of a man who was always interested in nature and the creatures within it. The book depicts problems associated with the prototypes of Beebe's eventually successful bathysphere, which took underwater exploration to new levels.

Planning and carrying out investigations:
Many of us are familiar with Peterson's guides, and Thomas' *For the Birds: The Life of Roger Tory Peterson* provides readers with a glimpse into how he first became interested in bird watching. As a young student, he was encouraged by a teacher who started a Junior Audubon Club at his school. The book describes how he used both photographic images and observational notes, samples of which are included in the illustrations.

Turner's *The Dolphins of Shark Bay* showcases the circuitous paths that scientists often take when conducting field studies. Observations of dolphin behaviour led to more questions, which in turn changed the focus of their investigations. In this case, the behaviour of 'sponging' by dolphins shifted the investigation carried out by these naturalists. This book is filled with captioned photographs and richly detailed descriptions of the procedures that these dolphin scientists have carried out over the past 25 years.

Analysing and interpreting data:
Montgomery's *The Tapir Scientist: Saving South America's Largest Mammal* contains a unique surprise: research data displayed in tables, graphs and spreadsheets. Records ranging from the relationship between time of day and tapir sightings to success rates of box trap captures allow readers to examine actual data samples. The importance of analysing and interpreting data is equally prevalent in Thomas' *Farmer George Plants a Nation.* Many recognise Washington as the first President of the US, but most will be surprised to know that he made significant contributions to the field of agriculture. His meticulous and methodical approach to mixing various types of manure into soil to determine which was most effective for planting various seeds is just one example of how he engaged regularly with agrarian-based data analysis. His quotes are interspersed throughout the text, and the End Notes provide a timeline of his life.

Using mathematics and computational thinking:
Brown's *Odd Boy Out: Young Albert Einstein* provides an interesting glimpse into the somewhat troubled life of Einstein. Despite his brilliance, he struggled to find success in school. Both the illustrations and the words support the idea that Einstein thought differently from most. Another mathematics-related book is Malone's *Close to the wind: The Beaufort* Scale, which provides a fictitious account of a voyage on a man-of-war ship by William, a 12 year-old boy from the 19th century. Woven throughout the narrative is Francis Beaufort's contribution to the maritime world: the Beaufort Scale. The Beaufort Scale for wind ranges from 0-12 and serves as an example of scaling qualitatively rather than quantitatively. A biography of Beaufort is included in the End Notes.

Constructing explanations (for science) and designing solutions (for engineering):
In *Rare Treasure: Mary Anning and Her Remarkable Discoveries*, Brown tells the story of a young British girl who withdrew from school at the age of 11 and spent her life finding and explaining fossils of long extinct animals. From the ichthyosaur fossil that she found at the age of 12, to the pterodactyl fossil that she found at the age of 29, discovery was never enough; she always attempted to make sense of what she found by reading scientific books of the day. Her efforts were rewarded with wide recognition and respect throughout Europe. Krull's *The Boy who Invented TV: The Story of Philo Farnsworth* is an example of a little-known scientist who used nature as an inspiration for an engineering solution. Farnsworth read everything he could about television and the failed prototypes and ideas that did not make it to fruition. When he was ploughing his family's potato fields, he envisioned creating pictures by a means similar to the parallel lines of planted fields. The book describes Philo's trials and tribulations to translate his engineering vision into reality, along with the difficulties of patenting an invention.

Engaging in argument from evidence:
Montgomery's *Temple Grandin: How the Girl who Loved Cows and Embraced Autism Changed the World* explores Grandin's life as both a scientist and a person with autism. Though Grandin had to argue for equal access throughout her life, the most compelling narrative surrounds her quest to create a humane dip-vat pool. She identified why cows were literally scared to death and designed a new dip-vat that would make them feel more secure, and had to argue her point to prove that her design was superior. Rusch's *Electrical Wizard: How Nikola Tesla Lit up the World* is a biography of Tesla and his journey to build machines based on alternating current (AC). The friction between Tesla and Thomas Edison, the primary advocate of direct current (DC), is an important component of the story. Tesla had to argue against the popular theory of the day in order to secure the honour of powering the Chicago World's Fair. A detailed Author's Note provides even more details on the rivalry between Tesla and Edison.

Obtaining, evaluating and communicating information:
Hannah and Holub write about little-known Luke Howard in *The Man who Named the Clouds*. Born in the 18th century, young Luke was fascinated by clouds, but found it hard to describe his cloud observations. He decided to develop a means of classifying clouds using Latin names. His organisational method is still the basis of our current cloud classification system. The book includes not only photographs and illustrations of clouds but also examples of weather journals written in child-friendly formats. Ray's *The Flower Hunter: William Bartram, America's First Naturalist*, also includes text formatted as a journal. The story

of this naturalist is told in first person through the eyes of William as he travels with his father, a noted botanist, around what would become the southeastern part of the United States. The Afterword includes details on the travels, accomplishments and writings of this father and son pair, as well as a reproduction of one of William's hand-coloured engravings of the tree that they discovered together.

Final notes

Though we have identified the previous books according to one specific *NGSS* Practice, we have also noted that many of the books could support more than one. *Star Stuff: Carl Sagan and the Mysteries of the Cosmos* by Sisson (2014) starts by following an imaginative and curious young Carl to the 1939 World's Fair, where he is amazed by the technology and inspired to begin asking questions about space, and stars in particular. It explains how he studied to become a professor and worked with others to collect data from the planets nearest to us, and depicts how he used television to communicate information to the general public.

Finally, Sisson includes information on how Carl planned and carried out his idea to include multiple messages from our world to others in the form of sounds, music, pictures and more, via Voyagers 1 and 2 as they travelled through space. Thus, four *NGSS* practices are clearly depicted in this well-written picture book biography, appropriate to read aloud to just about any age level.

Although we have identified specific books, we encourage teachers to utilise not only these but also other books, to provide real-life depictions of science and engineering practices in action.

Bringing these practices to life through the stories of both citizen and career scientists can demonstrate the integral role of these practices.

References

Brassell. D. (2006) 'Inspiring young scientists with great books', *The Reading Teacher*, (60), 336–342

Bybee, R. (2011) 'Scientific and engineering practices in K–12 classrooms: Understanding *A Framework for K–12 Science Education*', *The Science Teacher*, **78,** (9), 34–40

Kruse, J. & Borzo, S. (2010) 'The people behind the science', *Science and Children*, **48,** (4), 51–55

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Amy Broemmel, Associate Professor of Elementary and Literacy Education, University of Tennessee, USA.
E-mail: broemmel@utk.edu

Kristin Rearden, Clinical Professor of Science Education, University of Tennessee, USA.
E-mail: krearden@utk.edu

Resource Reviews

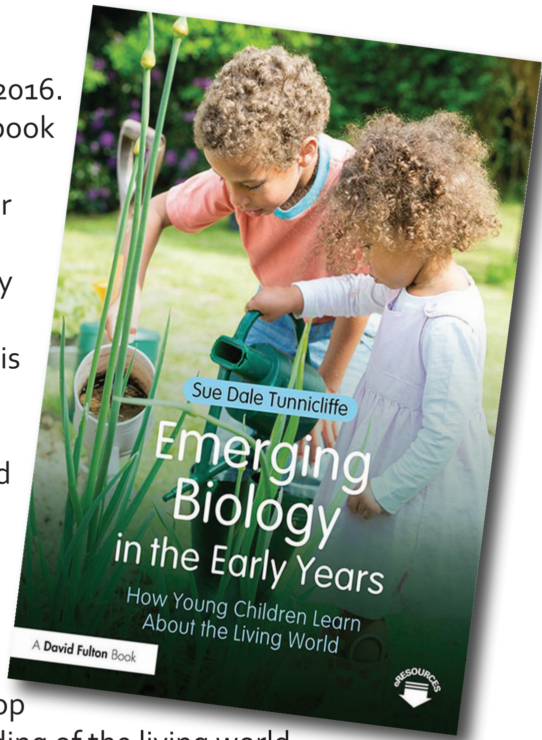
Emerging Biology in the Early Years – How Young Children Learn About the Living World

By: Dr Sue Dale Tunnicliffe

Published in 2020 by Routledge

Price: £19.99

ISBN: 978 0 81537 710 8



This interesting, informative and highly accessible book puts the agency of the child at the heart of becoming an emerging biologist. Written by an expert in the field of early childhood science education – Dr. Sue Dale Tunnicliffe, Reader in Science Education at UCL Institute of Education – this book demonstrates how young children can be scaffolded and supported to become emerging biologists, via a number of age-appropriate activities steeped in good pedagogical practice for science education in the early years. Sue Dale Tunnicliffe explains that this book is the result of a question that has driven her own reflections and research for 50 years in science education: where do children aquire their knowledge of biology and how do children interpret their world? She notes that the answer is found in children's understanding of their home and community, prior to any formal schooling, and this reflection I am sure will resonate with effective early years practitioners.

She goes on to explain that this book is also the result of conversations about how children establish the foundations of their biological knowledge in the early years with her friend and fellow biologist Ann Wright, Professor at Canisius College, Buffalo New York, who unfortunately passed away in 2016. Therefore, this book is a poignant dedication to her and their shared vision for biology education in the early years, and is written for teachers, practitioners and parents to support them to enable the children they teach and raise to further develop their understanding of the living world.

Recognisable themes in biology run through the book, underpinned by key information about research, scientific concepts and ideas, as well as suggested activities and discussion points highlighted as 'Talk science'. The book is compartmentalised into 8 chapters, focusing on learning about:

- The living world, from the perspective of young children themselves – their interests;
- Ourselves;
- Animals;
- Plants;
- Observing changes in the living world;
- Naming living things;
- Earth science; and
- Interactions between physical science and living things.

All the activities and pedagogical approaches suggested would fit well into delivering the EYFS curriculum as well as Key Stage 1 (ages 5-7); however, Dale Tunnicliffe cautions that very young children will not necessarily manage to carry out the activities in the same way as older children and so it is important for the adults supporting them to see how their 'emerging biologists' respond to the activities presented, because the methods described in the book may not be the best way for *every* child to tackle each activity. This reflects a personalised learning approach as well as the importance of assessment for learning, both of which are recognised as integral to effective early years education (Colwell *et al*, 2015). I also think that this is sage advice for parents and teachers, given that sometimes activities can be disregarded as not appropriate or inaccessible for younger children, rather than being adapted.

The author also clearly emphasises that early years educators should seek to facilitate active learning and encourage children who, she argues, are all intuitive scientists, to ask questions. Therefore, insights into the crucial role of adults as facilitators and scaffolders of learning are given – it is clear that the author believes that adults do not tell children what to do, nor provide detailed scientific information (this is the remit of formal learning much later on in the school setting, she argues); instead, the role of the adult is to encourage children to *'think, and wonder and work on their own initiative, rather than be dictated to'* (2020:3) by adults.

For me, the power of this book lies with the focus on the importance of 'play' to promote challenging and positive opportunities for emergent biologists to explore, interpret and understand their world.

In today's political climate, teachers and facilitators are held highly to account, and rightly so – all children deserving the absolute best education undertaken in a safe and stimulating environment. However, there still unfortunately exists the attitude, from some, that 'play' is 'just playing', thus taking a negative approach to 'play' and failing *'to understand its essential and critical value'* (2020: 5). Experiential learning and learning through play are key early years teaching pedagogies, which, when facilitated well, lead to effective learning outcomes for young children. This absolutely resonates with the idea of teacher-initiated activities leading into child-initiated exploration (and vice versa), incorporating observation, questioning and problem-solving: a clear reflection of good practice in teaching science to young children.

Therefore, all educators in the field of early years education would certainly benefit from reading this book, but I would also go as far to say that this book could inspire teachers and science co-ordinators of older children within the primary age range to utilise play and opportunities for talk to support the development of their emergent biologists throughout their primary school career.

References

Colwell, J., Beaumont, H., Bradford, H., Canavan, J., Cook, E., Kingston, D., Linklater, H., Lynch, S., McDonald, C., Nutkins, S. & Ottewell, S. (2015) *Reflective teaching in early education*. London: Bloomsbury Publishing

Amanda McCrory

Resource Reviews

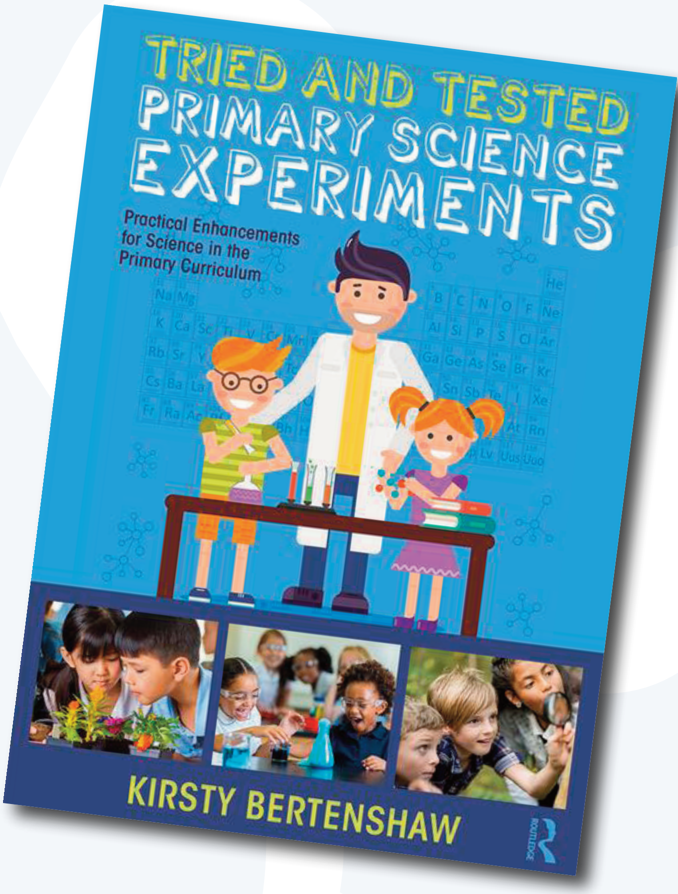
Tried and Tested Primary Science Experiments – practical enhancements for Science in the Primary Curriculum

By: Kirsty Bertenshaw

Published in 2019 by Routledge

Price: £18.39

ISBN: 978 1 138 31782 6



This book provides examples of practical step-by-step science experiments for teachers to follow and organise with primary students. The science activities cover all the primary years (ages 5-11). The experiments are simple and safe to implement and are designed to engage children when learning science. The experiments are aligned with the National Curriculum for England Statements. Topics covered include: plants; materials; seasonal changes; living things; sound; light; electricity; Earth and space; and evolution, catering for a wide range of topics. Each activity is pegged with the National Curriculum Statements and Assessment Indicators. The equipment needed is listed, together with instructions. Health and safety issues are also covered and black and white pictures of equipment are included.

The book provides many good ideas for primary teachers who wish to include plenty of hands-on activities when teaching science to their students. Many of the experiments use everyday materials. This helps teachers to design experiments with little difficulty in finding the materials needed. While the book would have benefited from photographs in colour, it can still be considered as a good aid to planning science experiments.

The book is thus a good companion for enthusiastic primary teachers, who can regularly consult it to be inspired to find experiments to augment the learning science experience. It can also be used by student teachers, who need to have practical ideas at hand and access to simple experiments that are easily implemented.

Suzanne Gatt

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

Piaget, J. (1929) *The Child's Conception of the World.* New York: Harcourt

Vygotsky, L. (1962) *Thought and Language.* Cambridge. MA: MIT Press

Chapter in book

Piaget, J. (1976) 'Mastery Play'. In Bruner, J., Jolly, A. & Sylva, K. (Eds) *Play – Its role in Development and Evolution*. Middlesex: Penguin. pp 166-171

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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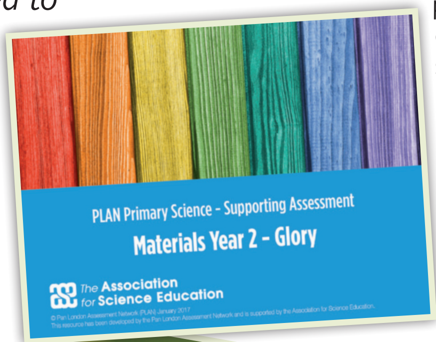
Primary science assessment (PLAN)

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!**