Primary Science

Special Issue:

Growing Science Capital

September 2021

Centre for Industry Education Collaboration (CIEC)

Celebrating 25 years of Children Challenging Industry

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

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Primary Science

Special Issue

Editor ***Dr Leigh Hoath***
Guest Editor ***Joy Parvin***

Focus on...

CIEC Special Issue

This special issue of *Primary Science*, celebrating the anniversary of CIEC, highlights the importance of working across the boundaries between education and industry. I have worked closely with one of the largest chemical companies in the world developing their educational outreach, and one of the aspects that has proved most important is unpicking the two different cultures and 'languages' between the different environments. This issue offers a number of articles that demonstrate how CIEC do this, and the benefits of this for teachers and pupils. There are many opportunities to support your teaching through getting involved with outside businesses and industries, and bodies such as CIEC enable this to happen.

A key element of working with industry is the potential to offer 'real' examples of people working in the science field who are not the stereotypical 'scientist'. This gives you a real opportunity to allow your learners to see diversity in the sciences, to realise the variety of science roles that are out there, and to apply science to their lives in a meaningful way.

It has been a pleasure to support this special issue and the wide range of articles within it.

Executive Editor and ASE editorial contact ***Jane Hanrott***

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The Association for Science Education

Introduction to the CIEC special issue of Primary Science

Joy Parvin

I am so pleased to share this Centre for Industry Education Centre special edition with you, in the 25th anniversary year of our Children Challenging Industry (CCI) programme.

Joy Parvin, Director of the Centre for Industry Education Collaboration

I joined CIEC in 1992, when CCI was a twinkle in the eye of Tom Swan (1943-2018), who seeded the idea of a peripatetic science teacher visiting schools in the north of England to inspire primary children about science. Tom was the Chair and owner of Thomas Swan & Co., long-term supporter of CIEC and the initiator of the Children Challenging Industry programme. Tom's son, Harry Swan, continues to support CIEC's activities, and his generous donation has made the publication of this special edition possible.

In my first four years at CIEC, before CCI began, my job was to write curriculum resources and deliver CPD to primary teachers. CIEC's ever-expanding range of resources are all now free-to-download PDFs, with industry contexts for practical problem-solving activities at their heart. Our dedicated team of primary science experts ensures that the publications have moved with the times, in terms of supporting the changing National Curriculum and with particular emphasis on carrying out investigations and developing the skills of working scientifically. I am excited to share the news that our downloadable activities are available on a new area of our website, which will be live by the time that this journal is published (fingers crossed!). Design is in its infancy as I write, but all our 150+ activities will be fully searchable by age range, science topic enquiry type, and by other search terms (e.g. scientific concepts and key vocabulary) – something I have wanted to do for many years, so it is wonderful to see this come to fruition in our special anniversary year.

The CIEC team ensures that our CPD, which has supported thousands of teachers over the years, continues to help teachers to become more confident to deliver the curriculum, to develop children's science capital, and to increase teachers' knowledge about STEM careers in their locality and beyond. In this special edition, members of the CIEC team have written articles about the various aspects of our work, to provide further guidance and to signpost you to where you can find out more. For an example of our CPD, **Clare Docking**'s article provides an insight into our approach to developing children's science capital.

To learn more about how to arrange visits to industry, read **Mackayla Millar**'s article; **Jane Winter** shares her tips for working with ambassadors in school; and for an inside view from industry ambassadors, take a look at the article by **Lucy Butler *et al.*** If an international perspective of CIEC is of interest, please read **Guirong Wang**'s thoughts on her year spent away from Beijing travelling around our CCI regions for a year, with the hope of establishing CCI in China in 2022!

The topic of sustainability is close to the hearts of many of us, the children whom we teach, and our industry partners. **Nicky Waller** shares the work that three teachers have carried out following the CPD that she delivered, highlighting their use of CIEC's publication *Sustainable Stories for a Sustainable Planet*. It is gratifying to allay children's growing concerns about the planet that they will inherit, through sharing the stories of scientists and engineers who are working to solve the problems that we face today and will face in the future. Using this resource, you can encourage more children to

The late Tom Swan OBE (1942-2018), Chairman and owner of Thomas Swan & Co. Ltd.

Harry Swan, CEO and owner of Thomas Swan & Co. Ltd. and Chair of CIEC's Advisory Committee

become inspired to join STEM teams in the future, and to continue the good work of today's scientists and engineers.

An important pillar of CIEC's work is the evaluation of the impact of work on children and teachers. It is crucial that the support that we offer schools does meet a real need, and that our programmes are valued by all concerned. **Agata Lambrecht**'s piece, *Not another questionnaire!*, explains why those dreaded feedback requests are so important to us in ensuring that high-quality publications, CPD and programmes wend their way to you.

I am delighted to share an article written by **Kate Sutton**, an energetic science subject leader, who teaches on the Yorkshire coast and who is an active member of the primary science community – including the Editorial Board of *Primary Science*! Kate shares her school's experiences of taking part in CCI in summer 2021, when we operated the programme quite differently, but still with amazing support from our industry partners, and with great dedication from all the teachers, engineers and scientists who took part.

That brings me back to CCI, and its beginnings in 1996, when I worked with children and teachers across County Durham, from ex-mining towns such as Easington Colliery to the rural farmlands of Teesdale and Weardale. Whether a child's environment is the sheep-covered hills of rural England, towns with high unemployment and shuttered shops, or the leafy lanes of Durham or Cambridge, raising their awareness of where science can take them is what excites us all at CIEC. Children with whom we have worked have gone on to study science at university, taken up apprenticeships in their locality, or become more aware that science has applications in the 'real word' beyond that which is familiar to them.

I hope that you enjoy reading about CIEC, take many ideas from this edition into your classroom, and join us over the next 25 years to inspire scientists and engineers of the future!

Joy Parvin is Director of the Centre for Industry Education Collaboration, and Guest Editor of this special issue of *Primary Science*.
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Why 'Children Challenging Industry' is so important

Kate Sutton shares her school's recent experiences of participating virtually in Children Challenging Industry (CCI)

Figures 1 & 2 Pupils collaborated to filter muddy water as efficiently as possible

I became aware of CIEC and Children Challenging Industry (CCI) whilst undertaking the Primary Science Quality Mark (PSQM) in 2017 as a new Science Co-ordinator at my school in East Yorkshire, and was really impressed by the organisation. In the years that followed, I came to understand the pivotal role in primary education that careers learning has and the vital element of children learning about local industry and being 'hands-on' to make their experiences relevant to enhance learning. I also feel passionately about the need to work towards overcoming the STEM skills gap (RAEng, 2017), i.e. the low take-up of Science, Technology, Engineering and Maths careers due to a decline in interest in these subjects during education, particularly in girls. Making learning local, relevant, achievable and accessible are seemingly the strategies to building knowledge and understanding for our pupils (OECD, 2020).

At my school, Burlington Juniors, we have been working hard over recent years to develop STEM teaching and learning and have become involved in various incentives in this regard. We are in a low socio-economic area; therefore, it is of great importance that we support all our pupils to have access to as many opportunities as possible to enhance their social mobility. Science capital is low (Archer *et al*, 2016) – the children have not had enough science experiences out of school to develop an affinity or interest in the subject. It is vital that these children learn how to engage with the world and value that we, the world and everything in it, have a science base. Many of our students rely totally on school in this endeavour.

I completed a Master's in Education last year. During that time, I used brilliant resources from the CIEC website, including the Careers Cards and accompanying PowerPoint presentation. Our school also participated in the Primary Careers Mark (after developing careers education in our school over quite some years), which was most successful, funded by Skills Support for the Workforce project (SSW), European Social Fund (ESF) and Local Enterprise Partnership (LEP) and in conjunction with Complete Careers. An important goal for our school going forward was to become a CCI school; however, lockdown hampered our ability to be able to participate in such activities, which had to be postponed.

Virtual CCI

We were so pleased when we heard that CIEC were developing a virtual CCI package and that our school was to participate in the funded activities in Yorkshire and the Humber, in collaboration with PX Group's Saltend Chemicals Park (SCP), Hedon. Our Year 5 (age 9-10) pupils were really excited to welcome CIEC and SCP into our school,

Key words: Industry ■ Teamwork ■ Resilience

particularly as CIEC celebrate 25 years of Children Challenging Industry this year.

Extensive resources arrived and were left to quarantine to comply with COVID-19 requirements. My Year 5 colleague, Sarah Caulfield and I had pre-visit meetings online with Mackayla Millar from CIEC, and she talked through the lessons, slides and everything we needed to know before we participated. We were supported throughout the whole process. We were provided with parent information and consent forms, the COVID risk assessment, lesson risk assessments and a kit list (which included a minimal number of items that school needed to provide, such as plastic cups). We were also given a link to initial online questionnaires for the pupils and teacher to complete.

It is so important to enthuse children and teachers alike. Teachers have felt less confident about teaching science and STEM (Wellcome Trust, 2018). One colleague stated in a questionnaire, with regard to STEM: '*Giving children full and varied experience in STEM/science subjects is essential to ensuring that they feel happy, engaged and confident, so that "I can..." and "I love..." become their opinions. Lifelong loves start in childhood*' (Anonymous respondent, staff questionnaire, 2019).

Water for Industry – our experience at Burlington Juniors

The children participated in three lessons based on CIEC's resource *Water for Industry* (freely available for anyone to download). The first was all about Leaky Pipes. Pupils developed their collaborative skills and enhanced working scientifically skills whilst undertaking a problem-solving investigation. The 360-degree virtual industry visit to Saltend Chemicals Park was a great way to put the learning environment into context for our pupils. The activities really encouraged the mindset we hold at school that all of us are scientists: the children being treated in a mature way and as young individuals. The way that the tasks were presented – as requests from the company for help – gave them a feeling of what it would be like to address these problems from a business/employee point of view. Through active involvement and fair testing, they were able to deduce, through trial and error, which sealant was the most effective for sealing 'water pipes' (empty food tins) together and what was the best way to join them. They worked to timeframes in conjunction with the lesson, presented live and remotely by CIEC, and facilitated by their teacher. It was really encouraging to see their mature attitude and collaborative skills. They used their experience and the first set of results to ensure that a second attempt was more successful. They were also very engaged with the STEM professionals from SCP and enjoyed the online discussion and engagement with them. Having contact and interaction with real STEM employees helped them to link their experiences to the wider world. They were fascinated by the industrial site and many were enthused about STEM subjects going forward. We were so proud to receive comments from the experts involved regarding the thoughtful and probing questions that our children asked. I firmly believe that it is so important to expose children to a wide range of careers and industry, to broaden their understanding of the wider world. The children were extremely positive in their feedback regarding their first interactive lesson:

'*What I thought was interesting was when we put the tape on and saw how much it leaked. I liked watching how much we improved*' (Leah).

The autonomous nature of the activities meant that children had much more say as a group about the direction of their investigation:

'*I liked when Callum* [from SCP] *was telling us where the water went after it rushed out of the pipes. I liked it because when one of us was holding the tape the other was holding the tins and we were all working as a team*' (Mia).

'*I liked when we watched the videos and I liked that we got to pick our own tape*' (Bradley).

'*I enjoyed the experiment because I liked timing it and seeing how much water leaked out of it*' (George).

The second session was teacher-led, supported by CIEC through discussion prior to the lesson. This was related to filtering, which fits in perfectly with the Year 5 National Curriculum for England unit 'Properties and Changes of Materials'. Once again, the pupils were really engaged and increasingly confidently used equipment, expressing opinions and developing teamwork skills, and these all built on prior knowledge learned earlier in the academic year. They were surprised that filter paper didn't actually completely clean the water. This really made them think about less developed countries and the unclean water that some communities, including the young and vulnerable inhabitants, have to consume. I thought that this showed a very mature and outward-thinking, thoughtful and empathetic attitude from our pupils. This made me really proud, as I reflected on how this activity had helped children to gain these valuable attributes.

Session 3 was all about cooling systems and we, me included, were all fascinated to learn more about how cooling towers actually work. I have lived very close to the SCP industrial site for many years and still found this really informative. Children participated in groups to test, measure, analyse and evaluate results of their findings related to their water-cooling task. Once again,

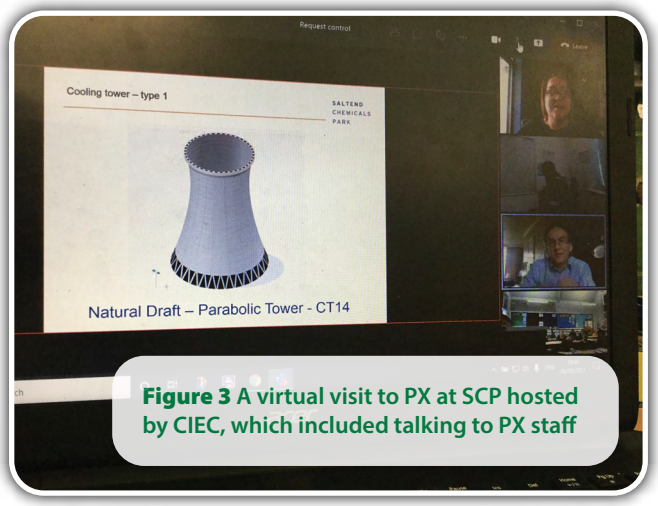

Figure 3 A virtual visit to PX at SCP hosted by CIEC, which included talking to PX staff

it was wonderful to see the children interacting with visitors, albeit in this virtual way. It was a brilliant idea to get around COVID-19 issues and bring CCI to pupils who otherwise would certainly not have participated. This session evoked much thought from our pupils relating to the heat exchange between the hot and cold water and really deepened their understanding.

On reflection

Reflecting on the sessions with the children was very informative, pleasing and exciting as a teacher. They had really taken the experience on board and felt privileged to be part of the incentive. They expressed real enjoyment and engagement and many pupils displayed true interest in science going forward, enjoying the collaborative nature of the sessions and the challenge and sense of competition between groups within the session. It was also great to see pupils who do not normally participate being so engaged and enthused:

'*I enjoyed the videos and when Callum and Jason talked to us about what their work was. I liked that when we did the experiments, we were experiencing what it might be like in the real world*' (Blanka).

'*I liked the experiment part because it was satisfying when you retrieved your score, especially when it was better than last time*' (Molly).

'*I liked hearing about their jobs and all the things like that*' (Braidan).

Mrs Caulfield, teacher of the Year 5 class involved, commented:

'*It was an amazing opportunity with excellent resources. The whole event was professional and gave our pupils a window into [a nearby industry], SCP, making learning local, relevant, developing STEM interest and challenging gender stereotypically-held views. Instructions for teachers and learners were clear, safe, personal and had links to extension activities. There was real expertise displayed, and time to talk directly to guests allowed queries to be answered; this was excellent. Developing enthusiasm and science capital, allowing the pupils to realise that this can be something they could achieve and in their own locality, was such a wonderful thing. It also helped children to see how resilient they must be and the need for accuracy and attention to detail as they travel along their learning journey*'.

Having a programme that combines tailored training for both industry partners and primary school staff, and the fully resourced problem-solving classroom activities, provide such a wonderful way of developing engagement with industry for our pupils. A fantastic resource for schools and pupils alike, these lessons are professionally produced by experts to ensure outstanding experiences. As part of the incentive, a staff meeting regarding 'A whole school approach to Science Capital' is provided, which really supports teachers to understand and enhance their own science capital as well as that of their pupils. We will be supported to carry out and complete further work, developing staff science capital further, over the coming year. This really enhances the attitude and science ethos in school. Perceptions about our local chemical industry were certainly challenged and demystified, the blended learning really bridging the gap between industry and education, which is a vital requirement. Many colleagues and acquaintances have been asking us how this came about for our school and if they can take part: we feel very lucky.

Making information relevant and receiving it from trusted individuals, in an active way, enables a greater understanding and subsequent internalisation regarding the reality and actual suitability of a profession. Dealing with unrealistic career aspirations, and supporting pupils to understand that these may be challenging to attain, are vital steps towards them considering a wider range of careers opportunities.

Andreas Schleicher, Director for Education and Skills at the OECD, states that:

'*Giving children a better sense of the world of work is not just a matter of social justice. It is also a matter of bringing the potential of the next generation fully to bear. At a time when our economies count on everyone's contribution, we cannot afford that disadvantaged youths rule themselves out of careers*' (Chambers *et al*, 2018, p.7).

Good careers information starts early and connects relevant learning with future economic life. Children need trustworthy information sources and stereotyping must be addressed; this broadens understanding, whatever the socio-economic background (OECD, 2020).

'*It is about ensuring young people emerge from the education system with the skills and knowledge that enable them to participate in post-compulsory education, in working life, and to become the workers, leaders, entrepreneurs and citizens of the future*' (Andrews & Hooley, 2018, p.3). I certainly hope that we will continue to develop links with CIEC and industry in the future to ensure personal progression of our pupils, including careers learning and vital transferable skills going forward.

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Medicines from microbes

Lucy Butler, Maria O'Hanlon and Dominic Gilchrist examine how the scientists of tomorrow are developing medicines of today

Figure 1 Lucy preparing samples that will be used to biosynthetically produce antibiotics within bacteria

Questions often heard echoing through classrooms are: '*Why do I need to know this?*' and '*When will I use this in real life?*'.

As three PhD students working at the National Horizons Centre (NHC), we were able to take these questions and answer them, using our own research as examples, with the help of CIEC (Centre for Industry Education Collaboration).

CIEC are involved in increasing children's and teachers' awareness of STEM careers through outreach activities with scientists in research or industry. They work between schools and industry to build links between science education and its application in STEM, with the aim to increase the number of local children considering a future in that area. We worked with CIEC to create a hands-on session for three local primary schools, talking all things science and research!

We all have different scientific backgrounds, with our research spanning across investigations into the antimicrobial resistance crisis, host pathogen interactions, and therapeutics for neurodegenerative diseases. Therefore, when we were asked if we would like to take part in an outreach programme with some local primary schools, we wanted to convey our own research interests to the classroom during the session. Working with CIEC, we decided to choose a curriculum segment that aligned with some of our research – microorganisms: how they can harm us, help us and how we can use them to our own advantage.

Our aim was to put this concept into a real-life context for the students to understand the application outside the classroom. We introduced the concepts of biotechnology and the development of new medicines, all within the classroom, whilst demonstrating the inclusivity and accessibility of science.

'We need your help'

Our session was based on CIEC's *Medicines from Microbes* resource (2003), where the overarching goal is to give insight to microorganisms and how they can produce beneficial medicines for us.

We brought the lab to the classroom using a fictitious newspaper article, requesting the help of young scientists to solve the NHC laboratories' question – how do you grow mould? We asked the children to help us, explaining that their findings were 'urgently required' by the lab to uncover the conditions that might encourage the mould to grow. We stated that this mould could then potentially be used to produce medicines in the lab.

Classroom to laboratory

As social media platforms are growing in popularity due to increased accessibility and, more recently, the COVID-19 pandemic, they have become more relied upon for child engagement. The sessions that we planned for this activity were originally intended to be in person; however, due to the pandemic and subsequent restrictions, the whole session moved to virtual presenting, with the question & answer (Q&A) taking place over Zoom. We decided to take full advantage of this to give the most attention-grabbing session that we could. Therefore, following training that we received from one of the CIEC team, we made three 'vlog'-style videos for the children

Key words: Medicines ■ Microbes ■ Children ■ Industry ■ Engagement ■ Science ■ Practical session ■ Education

News Post

Wednesday *48p*

Mouldy food produces new medicine!

Funding worries put breakthrough at risk

New discovery

A small local company at the cutting edge of new bio-technology has run into difficulties with the development of its latest discovery. The company, NewBioTech (NBT), has been working for some time with different plants and foods to try to extract ingredients which might make new medicines.

The Director of NBT, Dr. Smail, explained "Everyone knows that many common plants contain ingredients which can help us. If you are stung by a nettle, you can rub it with a dock leaf to take the itch away. Once upon a time, willow bark was boiled in water to make a drink which cured headaches. Even bread was used in poultices in some cases!"

In the latest discovery, NBT found that a mould growing on food seemed to stop other micro-organisms growing around the mould. "We wondered if this mould could be used as a medicine," said Dr. Smail. "If it stopped other micro-organisms growing, we wondered if it would stop bacteria, which are micro-organisms too. This could be a break-through in treating things like simple cuts, which so often get infected by bacteria in dirt. We think this mould might produce a new antibiotic."

Funding

However, NBT have run into difficulties. They only have a small research fund for developing new ideas, and have to rely on grants from other groups which are interested in their work. "If another firm thinks that our discovery might help their work, then they will give us some money to help develop the ideas," explained Dr. Smail. "Sometimes the government will help, too."

Unfortunately, this time no-one has come forward with offers to help with the development costs.

Appeal

The firm is looking for assistance from other groups. "We have been able to grow the mould, but we need to find the best conditions for growing it. We will need to produce large amounts to make antibiotics," said Dr. Smail.

One suggestion is that school research groups could help. Unlike small firms like NBT, who can spare just one or two people to experiment, school groups can gather lots of data very quickly. Dr. Smail was enthusiastic. "We would love to hear from a school, if they can help us find the best conditions for growing moulds. It does not matter what food is used either. Every piece of information is helpful! If the information gives us an idea of the actual amount of mould produced for each condition, that would be really useful."

Figure 2 Example of a CIEC fictitious newspaper article that is shown to the children

Figure 3 Dominic examining agar plates for bacterial colonies prior to performing a colony count

to watch during their classroom sessions, created as if speaking directly to them.

A series of practical activities took place over three sessions; the first two were teacher-led and included video guidance from us, in the lab, requesting the students' help, and the final one included a live Q&A session.

During the first session, the children were able to read the fictitious newspaper article and were virtually introduced to the problem at hand via the first video. They then were asked to come up with a hypothesis about how/where they thought that the mould would grow best (on bread, cheese, fruit, etc.). Groups of children then planned and carried out their investigation, placing their food of choice in chosen conditions (hot, cold, room temperature, etc.) to discover how best to get mould to grow.

During the second session, the children went back to their food and location of choice and recorded the mould growth by describing, drawing pictures, and measuring the size of the mould. As a group, they took note of the conditions that had the most mould. The second video was shown to the students here, where we asked the children to 'send us their results' so that we could 'use their advice' and copy their conditions in our own lab to hopefully produce medicines.

During the final session, the children were informed that their experimental data had been sent to us and that we had used their results as a baseline to grow mould. Generally, their results showing where the mould grows best are very similar to how we do it in the lab, so we showed them the parallels. After this, the final video was shown, where we discussed their findings and optimal conditions for growing mould. This video also provided a great opportunity to share insights into life as a research scientist in a laboratory. We went on to explain that the techniques that we use to replicate their results might look different, but the principle remains the same. This showed the

children how their experimental data would be used in a 'real-life' situation to produce medicine and 'make a difference'.

This session culminated in a live Q&A opportunity with us, in order to ask any questions about the task. Before answering any of their questions, we explained that their results and methods of measuring their experimental variables had been very beneficial to us.

Why is this important?

Everything that scientists do relies on communication. To receive funding, we need to communicate to potential funders why our research is crucial. To expand our research horizons and ensure that people know about our work, we rely on well-articulated communication to identify specific, detailed areas for further exploration. Communication is an essential premise for science to move forward and one of the ways to do so is to share our knowledge with wider audiences.

Starting discussions with schoolchildren about science is an excellent way to engage them while at the same time breaking down some of the barriers and stigmas that surround science, such as: all scientists are stereotypical 'eccentric geniuses' or that that they work alone in a dark laboratory late at night!

Young children are naturally inquisitive. By asking them to 'solve' a task on an important, age-relevant topic, such as making medicines, we are engaging them with contextualised scientific research. Similarly, giving them the opportunity to ask real-life scientists questions about our work and our day-to-day activities captures their curiosity and further engages them in science. To develop this interest, our session combined critical thinking with fun. We utilised hands-on activities that were short and varied to ensure plenty of active involvement within the classroom.

Engaging children with key subjects

Sessions such as *Medicines from Microbes* enhance the classroom learning experience and bring the curriculum to life. By equipping children with other skills, such as problem-solving and creative thinking, these sessions provide transferable skills, a foundation for future prospects.

The session was challenging, but accessible, allowing the children to develop their understanding around some complex scientific concepts whilst thinking outside the box. They demonstrated clear understanding and scientific development by asking plenty of technical questions during their Q&A session. Their questions ranged from 'What's the purpose of the medicine ingredients?' and 'Does the viscosity of the medicine matter?' to more general questions including 'What is the best and worst parts of your job?' and 'What's that big machine behind you in the lab?'

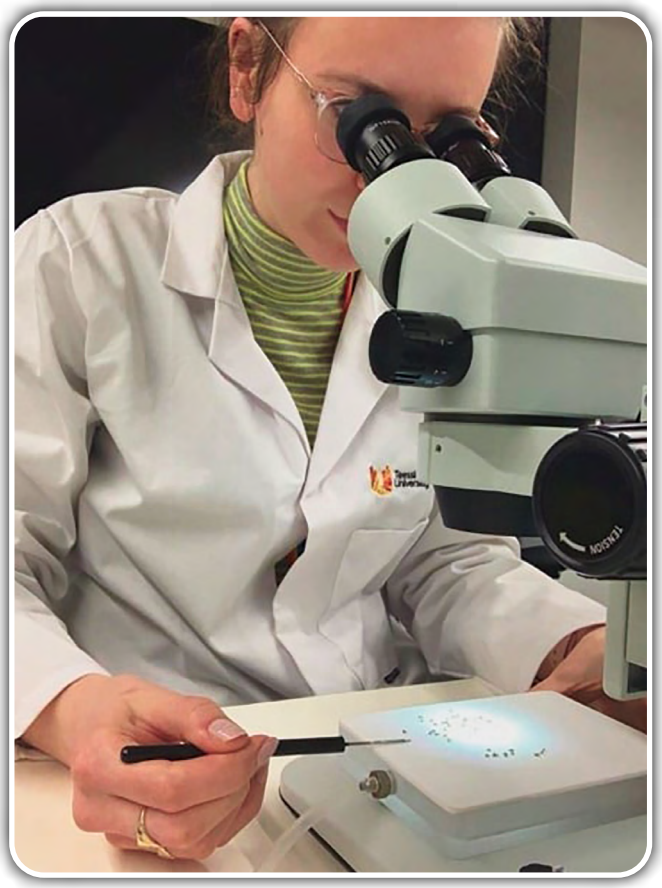

Figure 4 Maria using a microscope to examine fruit flies that have Parkinson's disease

The impact of scientific discussions

Real-life application sessions, such as those sessions run with the schools, are essential to contextualise science within education.

Science is the study of the natural world through observation and experiment. Within this are many different specialities and disciplines. By talking to scientists from different fields, children get to experience the vast diversity and inclusivity of their curiosity. Therefore, students develop and discuss their own ideas while contributing to and developing a scientific method. Science also incorporates several subjects, allowing this session to improve on multidisciplinary knowledge: for example, the use of mathematics during dilutions; or the role of chemistry and physics in microbiology, by the use of a spectrophotometer to determine the level of bacterial or 'mould' growth.

The underlying foundation of these activities allows children to draw comparisons and experience the similarities in their own work to that carried out in a professional setting.

Could this influence future career choices?

When deciding on a career, it is daunting to think about what opportunities may be available, especially for young people who may have limited understanding of the workplace. However, providing children with opportunities to meet with people working in different fields allows for some common misconceptions surrounding gender bias and age range in the field, or even personality stereotypes, to be broken down and aspirations to be nurtured from an early age.

This outreach experience allowed us to show how three local-to-the-area people have been able to develop careers as scientists with a range of previous experience, highlighting that science can be accessed by all, regardless of background: one scientist joined their PhD programme from a Master's degree, one from an undergraduate degree, and another who came back into education, later in life, from a completely different career. This is beneficial to the children, as science is not often presented as an attainable career path.

We also have a responsibility at the National Horizons Centre to showcase our world-class facility to the local community and the opportunities that it offers to the Tees Valley. Currently, the National Horizons Centre is playing a major role in developing the scientific skill capacity of the region to prepare scientists with the knowledge and skillset for the production of 60 million COVID-19 vaccines, through a bespoke training course.

Therefore, one of our motivations to participate in this programme was to open the lab doors of the NHC and allow local people to see inside, to instil career aspirations into potential scientists and to prove to local people that they can be employed locally in this field of work.

Providing educational scientific material to classrooms

Resources such as *Medicines from Microbes* provide a full support package of educational material and guidance to allow teachers to deliver a series of hands-on science lessons. With the industrial involvement, the activities can be easily adapted and developed around varying areas of expertise to emphasise the link between lessons and industry and to take place either in person or virtually.

The incorporation of the Q&A activity allowed the children to discuss, gain feedback on their work and ask any questions of professionals in the field. Personally, we were all happy to receive many questions covering topics ranging from our own work and what it's like being a scientist, to what the machine was behind us on the video call!

Overall, the aim of our session was to encourage the children to see science as interesting and accessible. We intended to provide an insightful and memorable experience for all, showing the importance of the scientific topics and how these can be utilised in a research laboratory.

National Horizons Centre

We all work at the National Horizons Centre (NHC) in Darlington, which was established by Teesside University to address the growth needs of the bio-based industries that are set to transform the UK economy, including biologics, industrial biotechnology and biopharmaceuticals. It brings industry and academia together, to provide the sector with knowledge, skills, talent and facilities to support its development and growth.
www.nationalhorizonscentre.co.uk

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Lucy Butler, Maria O'Hanlon and **Dominic Gilchrist** are PhD students working at the National Horizons Centre, School of Health and Life Science, Darlington.
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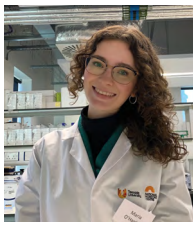
Biographies



'My name is Maria, and I am researching what causes Parkinson's disease, using fruit flies as a model organism. I thoroughly enjoyed the sessions with CIEC and the primary schools, not only because it was fantastic seeing the children being so engaged with science, but also because it was nice to talk to people about my own research too. I am very passionate about what I do, but it makes me even more excited when other people show an interest, so having children ask me about the brain and working with flies was really amazing. After our experience, I'd definitely encourage teachers and schools to get involved in this kind of activity.'

'My name is Lucy, and I am investigating how to overcome the antibiotic resistance crisis. I really enjoyed partaking in the 'Medicines from Microbes' sessions as it outlines my research area very well! It was brilliant to see the children engage with this real-life scientific research. It was also interesting to be questioned on specific details that we wouldn't normally focus on.'

'My name is Dom, and I am involved in the study of how pathogens and their hosts interact. I'm from Middlesbrough and came to science in my mid 30s, having always had an inquisitive mind. Having had many different careers including a car painter, bartender, pub manager and retail management, I decided to follow my passion and retrain as a scientist, joining Teesside University and completing my undergraduate degree in biological science before going on to studying my PhD at the NHC with Lucy and Maria. I really enjoyed taking part in the outreach with the primary schools, particularly the Q&A sessions, where the children asked us lots of questions about our own research and careers.'

Site-seeing to inspire primary children

Mackayla Millar explores the benefits of industry site visits to enrich the primary curriculum

Figure 1 Children enjoying a site visit

Educational visits are always a highlight of any school year, with museums, historical experiences and outdoor activity centres often winning in the popularity stakes, but have you ever considered a visit to a local manufacturing plant or science laboratory? You might feel that this would be a health and safety headache best avoided, or perhaps that a class full of excitable children may not be welcome in such an environment, but you might be pleasantly surprised on both counts. With guidance from the CIEC team, scientists, engineers, and technicians working at local industrial sites are often very keen to share their workplaces and passion for STEM careers with the next generation.

Safety first!

Risk assessments are a necessary part of any educational visit. They can be time-consuming and a real source of worry, especially when planning a visit to an industrial plant where there can be many perceived dangers. However, companies inviting children onto site will have undertaken rigorous risk assessments; your job is simply to assess the journey to and from the site as you would with any other visit. You may even be greeted in a classroom-style environment, which your class can use as a base, and find that protective equipment is provided for those all-important real-world experiences (see Figure 2).

A company with which CIEC work in the North East, Johnson Matthey, runs a great child-friendly activity that involves the children themselves in the risk management process. Children are supported to analyse potential hazards and the likelihood of them happening, drawing on examples that they can easily visualise, such as falling over in the playground compared to a piano falling from the sky! Wherever you visit, you can rest assured that companies will only take you to locations that are safe to visit, and you will be briefed on any rules to follow.

What will we see?

There are lots of different environments that you may encounter on a site visit. Production areas and factory floor tours are often included, where children can observe the busy working environment and see products at various stages of manufacture. You might see heavy machinery or robots in action, receive a demonstration of

Figure 2 Children wearing PPE during a visit to an industrial site

Key words: Industry Site visit STEM careers

Figure 3 Children getting hands-on with specialist equipment

specialist scientific equipment, or even be given a chance to operate tools, programme using Computer Aided Design (CAD), or carry out experiments under careful supervision. These types of hands-on experiences (see Figure 3) enable children to undertake a safe and simplified version of the work carried out by scientists, engineers and technical staff.

Control rooms are another possible element of a visit to industry (see Figure 4), presenting an opportunity to see the beating heart of a site with an impressive array of sensor technology under continuous monitoring, and communication devices relaying messages around the site or sometimes around the country. Companies may mock up a control scenario on computers for children to explore and find out what happens if, for example, a valve does not fully close, and an alarm sounds to signal that action must be taken. Science laboratories are also fascinating spaces to explore (see Figure 5) and present opportunities for children to use key investigative skills such as controlling variables, repeat testing and recording precise measurements.

Enriching the curriculum

Site visits can be an exciting addition to a broad and balanced curriculum and require some careful consideration to ensure that they build on your classroom learning experiences in a meaningful way. By doing a small amount of research to find out what a company does and what products they make, you can establish tangible links to the National Curriculum topics and 'working scientifically' objectives. The CIEC website has an extensive range of free resources, which pose real-world challenges set within an industrial context for children to solve, all of which sit within the scope of the National Curriculum (see Jane Winter's article on page 30 to find out more about CIEC's resources).

For schools in the North East, Humber and the East of England, these resources form the basis of our flagship Children Challenging Industry programme, which links classes of 9-11 year-olds to companies and STEM ambassadors in their local area. This exciting programme provides unique STEM learning experiences that make the world of local industry real and relevant to pupils' everyday lives.

Virtual site visits

So far, I have very much focused on the benefits of in-person visits to industrial sites and the excellent ways in which they support pupil engagement and provide insights into STEM careers. Children get to see first-hand the scale of industrial operations, which can range from the microscopic to the colossal and might otherwise prove to be incomprehensible (see Figure 6). However, in-person visits may not always be possible; coaches can be expensive, some sites are just not child-friendly, and some children may be unable to access an industrial site due to specialist physical or sensory needs. So what are your options?

Figure 4 Children visiting a control room

Figure 5 Children visiting a lab

Figure 6 Pupil taking in the incredible size and scale of an industrial site

In 2020, and for the first time in its 25-year history, the CCI programme went virtual, bringing the scientists and engineers direct to the classroom via online video conferencing platforms (see Figure 7). The coronavirus pandemic presented some very challenging hurdles to the usual format (classroom lessons followed by a visit to site), and so, with a great deal of creativity and co-operation from our wonderful industry partners, we have been able to provide virtual site visits to participating schools. Whilst there have been some drawbacks, there have also been many unexpected positives.

No physical visit meant that companies have been able to take an 'access all areas' approach and show children parts of their site that would not be suitable to visit in person. For companies who operate across multiple sites, it has been possible to introduce classes to lots of different people from across the business whom they otherwise would not have met. Less time spent walking around sites has meant more time for discussions around career pathways and the skills that someone might need to be successful in a STEM industry. And children have been finding out more about the different routes into employment and how hobbies such as baking and computer gaming could lead them into jobs as scientists and engineers (see Kate Sutton's article on page 6 for more about *careers education*). As well as live Q&A-style discussions, companies have been able to provide photographs and videos that show children the huge scale of their sites and the variety of jobs that their employees do day-to-day.

Although these examples are taken from my experiences delivering the virtual CCI programme this year, I hope that some of them inspire you to start conversations with the CIEC team or the industry ambassadors living and working in your local area. And, if the cost of coach travel was something that may have put you off an in-person visit of this nature in the past, this might be the solution for you!

Engaging with industry ambassadors on site

Whether visiting sites in person or remotely, you can interact with an array of personnel including scientists, engineers, technicians, and people who have risen through the ranks to managerial positions, all of whom can share details of their career pathways. However you choose to visit a site, give some thought in advance to areas that you would like your conversation with their ambassadors to go. Children's questions can lead down many avenues, so be prepared to step in with your own questions to steer the conversation in directions that are relevant to your class. Topics that I like to ensure are discussed include those relating to the diversity of employees, the role played by teamwork, and how important it is to be resilient and open to learning from your mistakes.

How can CIEC help?

If you have identified a local company with which you would like to collaborate, but they do not feel confident engaging with children, put them in touch with the team at CIEC, who have the knowledge and expertise to help them get started. To ensure that your interactions with industry ambassadors are meaningful and have the required impact, we can provide training to help companies to frame their practices, processes and products within the framework of the National Curriculum, and to support them to adapt their communication style to engage effectively with your class.

Have you had any great experiences of site visits? Why not share them in this journal to inspire others to embark on their own 'site-seeing' journey?

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Figure 7 Children speaking with a scientist during a CCI virtual site visit

Figure 8 CIEC advisory teacher training industry ambassadors

Not another questionnaire! Why is it important to measure the impact of educational programmes?

Agata A. Lambrechts explains how and why CIEC research and evaluations enhance the evidence base about good practice in science teaching and learning, and effective links with industry

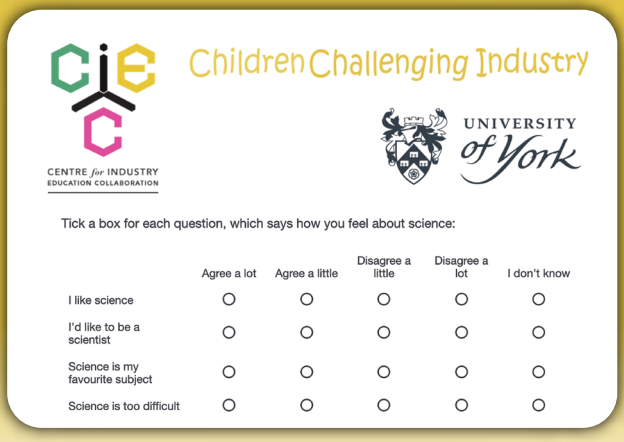

Figure 1 Snapshot of a CIEC questionnaire for children

The CIEC team has been running its flagship programme Children Challenging Industry (CCI) for 25 years. The programme provides young children (age 8-11) and their teachers with practical problem-solving classroom activities as well as access to science-based workplaces and professionals. Industrial partners benefit from the opportunity to raise awareness, in their local community, of their people and processes (what they do, how they do it, and who does it). Our team has carried out research and evaluation into the *impact* of our resources and programmes since the programme began in 1996, to ensure that CCI – and all our other programmes – are improved to meet the changing needs of both schools and companies. Furthermore, our research enhances the evidence base about good practice in building links between education and industry, which can be used to establish new programmes all over the world.

What are educational interventions?

An educational intervention is a programme or set of steps designed to help children during their educational journey, for example, to raise low levels of literacy, to improve attainment in maths or, as with our work, to raise interest in and engagement with science and increase knowledge about industry and STEM careers.

School interventions are usually specific in the length of time they take – from a single activity to several days, weeks or even months. The idea is that children receive the intervention as participants in an activity or sequence of activities, with the assumption being that the intervention will have a desired set of effects. To ascribe impact of an intervention in school, however, can be tricky; without a systematic evaluation, it is not possible to claim that the intervention caused the desired outcomes.

What are educational intervention evaluations and why are they important?

Educational intervention evaluations are systematic appraisals of the effectiveness of specific interventions. They answer the all-important questions of *what works, in what contexts* and *with which groups* in education. Frequent and rigorous evaluations that collect information from different sources are essential, so that any mistakes can be corrected, and alterations can be made to reflect changing needs of children, schools and other stakeholders.

Key words: Research ■ Evaluation ■ Impact ■ Interventions

Evaluations save teachers time in the long run by sharing with them which particular interventions have a real impact on their pupils.

Teachers can then put their time and effort into the most effective activities. Evaluations also help the senior management of a school to see the value in their staff and in children participating in the programmes. Evaluations of programmes like ours help to raise the profile of primary science, share the achievements of children and teachers – with the results featuring positively in Ofsted reports. Finally, they help us to show the funders the value of their continued support, which is vital to schools being able to access the programme at an 85% subsidised cost.

What makes a good evaluation?

Educational interventions can be tested and evaluated in different ways. This can include 'true experiments' carried out as part of randomised control trials, in which pupils, classrooms or schools are randomly assigned to receive an intervention or be part of a control group. Such experiments are often regarded as the ideal model of establishing whether an intervention 'works' (see Styles & Torgerson, 2018, for more information). Sometimes, however, it is not possible to randomise pupils, classrooms or schools. Alternatives include quasi-experimental evaluations (where an intervention is delivered without the random assignment of participants to conditions or orders of conditions), and simpler comparisons between pre- and post-intervention, calculating the correlation between participation in an intervention and outcomes. This quasi-experimental approach was chosen as the most suitable to evaluate the effectiveness of the CCI programme. Although such studies cannot fully rule out a variety of other explanations for change in outcomes, careful analyses of systematically collected data can go far in increasing our understanding of whether an educational intervention works and in what contexts.

It is important for evaluation reports presenting statistical data to clearly indicate which differences are statistically significant at conventional levels – generally the .05 level. Those findings show that there is only a 5% chance that the difference reported could have occurred purely by chance if the intervention's true effect is zero (for more information, see Tenny & Abdelgawad, 2020). Ideally, evaluations should also report the effect size (Coe, 2002), that is, the magnitude of the difference between pre- and post-intervention (Bakker *et al*, 2019). To allow for such reporting, which provides greater confidence that outcomes are due to the intervention and not chance, evaluations need to have relatively large sample sizes. Importantly, effect size should be reported for all measured outcomes, because, with large sample sizes, positive and statistically significant effects can sometimes be found due to chance.

The CCI programme – an educational intervention

The CCI programme is a multi-component intervention, involving delivery of two half-days of classroom-based science activities led by our specialist CIEC advisory teachers, sandwiched with a session taught by the children's usual teacher using CIEC science equipment and lesson plans. Every year, the vast majority of children (typically over 90%) go on a field trip to a local partner industry site, whilst some benefit from a visit by an industry ambassador. Teachers and the industrial volunteers involved in the visits are trained and supported throughout the programme by our advisory team. The fundamental principle of the CCI programme is that students learn about science through practical problem-solving activities set in real-life contexts. Crucially, the industry visit is tailored to follow on closely from the classroom activities and varies greatly between sites.

How does CIEC evaluate the CCI programme?

The evaluation of CCI aims to investigate the impact of the CCI programme on pupils and their teachers, in terms of their knowledge, views and enjoyment of science in school, and their understanding of the links with industry. The methodology used to evaluate the programme, like the programme itself, has evolved since 1996. Early on, interviews with teachers and focus groups with children were held to ask open-ended questions based on three areas:

- What are children's views of science and of industry?
- What are primary teachers' views of science and of industry?
- Does the use of industry-focused science lessons alter these teachers' or children's views?

The answers to these questions have helped us to develop questionnaires that consist of more closed questions based on level of agreement with statements. Two questionnaires are administered to pupils and teachers – one before the programme, and one after all the elements of the programme have been completed. In recent years, this has been done online. Our analysis is largely quantitative; however, we

Figure 2 CIEC presents some headline data in user-friendly infographics

Strengths of the CCI evaluation

- CCI evaluations report both statistical significance and, more recently, the effect size.
- Our sample sizes are relatively large, as every year hundreds of children participate in our programmes and complete both pre- and post-programme questionnaires.
- The quantitative findings are corroborated through analysis of qualitative comments made by children, as well as their teachers.
- We implement our CCI 'intervention' across a number of 'sites' (that is, different schools in various geographical regions), in typical school settings, with one of three CCI lessons delivered by children's regular teachers, and with schools being partnered with one of our industry partners.
- The evaluations are published on our website with open access, and use easily understandable, real-world terminology and language alongside the statistical data (for example, a 20% increase in number of children who agree with the statement 'There are many women scientists and engineers'), to ensure that our readers, who range from teachers to industry partners, can judge the importance of our findings.
- We consider the effect of our programme on subgroups of pupils – boys and girls, children in different parts of the country and in different year groups, alongside the effect on the overall population in our programmes, but treat any differences with caution.

continue to ask open-ended questions to get more in-depth, rich data from both children and their teachers.

Why are our evaluations important?

As noted above, at CIEC we believe that it is important to regularly evaluate our programmes. The findings help us to improve our training materials and teaching resources and allow us to ensure that our programmes continue to have a positive effect on children, fulfil the needs of teachers and meet the expectations of our industrial partners. This is particularly imperative when we start working with new schools and new companies and, more recently, in a new part of the country – we need to ensure that our programme works just as well in new contexts.

However, the value of our evaluations and research goes beyond that – to date, the evidence base on the effect of interventions in primary-age children and their teachers has been lacking, with only a handful of studies that explore industry links with this age group in the UK or globally. This is despite the well-known issue of STEM (Science, Technology, Engineering and Mathematics) skills shortage in the general population, as well as in the workforce (see, for example, EU Skills Panorama, 2014) and despite prior research evidencing that leaving focused interventions related to science and STEM careers until students start secondary school may be *'too little, too late'* (Archer *et al*, 2013, p.25). We believe that engaging students whilst in primary school opens their eyes to local opportunities and instils confidence in their own abilities to partake in the STEM pipeline, and thus may prove to be the most effective and efficient route to achieving the desired level of STEM skills across the population. We acknowledge that we have only a limited knowledge of the possible longer-term impact of the CCI programme, such as sustained engagement in science learning and attainment, choice of STEM subjects at secondary school and beyond, and choice of STEM-related careers. What we know thus far is based on anecdotal data – we know of STEM professionals in industry who were inspired to follow this route thanks to CCI; and we know of 15-17 year-olds who went to companies that they had visited with us to ask for (and get) work experience opportunities. Nevertheless, our evaluations and research based on the same data enhance the evidence base about good practice in building links between education and industry, which can be used to establish new programmes in the UK and beyond.

Figure 3 In-depth research reports present the detailed methods and analysis used in CIEC evaluations

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A whole school approach to developing Science Capital

Clare Docking suggests ways to develop Science Capital throughout your school

Figure 1 Role badges – used to raise science career awareness

Science Capital and primary science

An understanding of the theory of Science Capital is a great asset for primary teachers who are considering how to raise the aspirations of their pupils in regard to science and science careers. Research into young people's (age 10-14) science and career aspirations initially took place in the sphere of secondary education through the ASPIRES project (2013). One of the conclusions of the project was that primary teachers need to take the first important steps towards addressing the inequalities that lead to certain groups of young people entering a science career post-16. Research shows that, although many children find science enjoyable at school, this is not followed through with a desire to work in the world of science and that, arguably, if we have not captured a child's interest in science by age 11, it may be too late to alter their perceptions of science careers. However, research carried out by the Centre for Industry Education Collaboration (CIEC, 2020a), based at the University of York, supports the idea that we can change the attitudes of young children of primary age who struggle to see the relevance of classroom science to their own lives and the world around them. In this article, I will explore some ways that children's Science Capital can be raised using CIEC approaches, resources and CPD.

The theory of Science Capital

Firstly, what is 'Science Capital'? Briefly, Science Capital is a lens through which to consider why and how some young people participate in and engage with science-related experiences, whilst others do not. Teachers know that children come to school with vastly different levels of understanding of and engagement with science. As Archer's team of researchers describes, a young person's Science Capital is a '*hold-all or bag*' containing what you know – your scientific literacy and related knowledge; *how you think* – your attitudes to science, ways of thinking; *what you do* – science-related activities and behaviours; and *who you know* – science-related social contacts and networks (Archer *et al*, 2018).

This research shows that children with lower levels of Science Capital are less likely to aspire towards a scientific career, alongside other factors such as gender and ethnicity. A survey by the *Enterprising Science* project carried out in 2014 in England found that children who have high Science Capital tend to come from advantaged homes and be white or Asian males; their family members may well have science-based careers or know people that have. Over 25% of children surveyed had low Science Capital, and tended to be female and come from disadvantaged backgrounds.

In response to the challenge of how to develop Science Capital in primary schools, the CIEC team developed and rolled out, in three English regions, continuing professional development (CPD) for primary teachers: *A Whole School Approach to Developing Science Capital*. This CPD aims to help and support all the staff in a school to further their journey, whether they are at the beginning or partway towards enriching the children's Science Capital. Participating schools work towards a CIEC CPD completion certificate, which

Key words: Science Capital ■ Personalised learning ■ STEM careers

acknowledges the progress made in developing Science Capital throughout the school.

The CPD is intended for the whole staff and begins with an audit of current practice. The CPD is online, live, interactive and collaborative, and available to all schools across the country and delivered at a time to suit the school (frequently a twilight session). During the CPD, the school team takes stock of their science teaching that has a Science Capital focus – not necessarily always to change what is taught, but to 'tweak' the way it is planned and taught. Reflection time allows in-depth discussion and planning can take place. Once a school starts to focus on the different dimensions of Science Capital, they can begin to see where the gaps are in their provision and start developing an action plan.

We are delighted that, in recent years, all teachers attending our CPD sessions have rated our CPD as either excellent (80%) or good (20%). In the words of one Science Leader following the Science Capital CPD: '*Thank you for the session today. I found it incredibly useful. The audit was a fantastic way to identify what we do well and the gaps which we have*' (Andrew Martin, Cowick Primary School).

Find out what children know and build on it

At CIEC we personalise learning in a variety of ways. Through our CPD, we encourage teachers to group children in small teams of four and, to develop Science Capital, we give teams a 'company name'. All children are included and can collaborate, so discussion flows. Each child is given responsibility for a job or role within the group or 'team' and wears a badge to identify this (see Figure 1). For example, the 'Communications Officer' is responsible for eliciting the group's ideas and responses and reporting back to the rest of the class. This collaborative approach helps all children to get involved and enables questioning and discussion.

Used at the beginning of the year, surveys can highlight your class's experiences and knowledge, and children can be asked what science-related interests they have and whether any of their family and family friends work in science-related jobs. With this information to hand, it is then possible to make links between a unit of work or topic and the children's experiences at home. For example, a child whose parent is a horticulturalist may know about cultivating plants and can be encouraged to share this with the class. Surveys, as part of a homework task, can also be used to encourage discussion about science at home, therefore helping the development of Science Capital in the home. One such example can be found as an introductory activity in the CIEC publication *Sustainable Stories and Solutions for our Planet* (CIEC, 2019), which offers children the opportunity to survey their families and friends to gather their thoughts and ideas about sustainability.

The media play a prominent role in children's lives today and most are aware of science stories hitting the news headlines. A portion of our children's knowledge and understanding comes through their engagement with TV news or *YouTube* science documentaries watched at home. Highlighting newsworthy science discoveries alongside everyday scientific observations helps to broaden children's engagement with science and avoid science discussion being restricted to a defined slot and topic each week. Mars exploration is very topical in 2021 and is explored in depth in CIEC's resource *Is There Anyone Out There?* (CIEC, 2018) and another, *Potatoes to Plastics* (CIEC, 2021), explains how we can create a useful bio-plastic product from waste potato peel and explores the current topic of single use plastics.

Seeing the relevance of science by starting with the familiar

To develop Science Capital, it is important to start with what is familiar to children. CIEC resources engage children in fun scientific investigations using everyday materials that children are familiar with, and with processes

Figure 2 Children follow a 'science recipe' to make a bar of soap

that they know from home. Here is one example: the *What's in a bar of soap?* activity from *Kitchen Concoctions* (CIEC, 2017) invites children to share their understanding of the properties and uses of soap. Children are then challenged to follow a recipe and use scientific processes to measure and mix ingredients to make a bar of soap. They investigate properties such as the viscosity of liquids used in everyday life.

As language can be a barrier to learning for less advantaged children, it is important to use familiar vocabulary and, through our CPD, we focus on simplifying vocabulary that is used in science industries to ensure that it is user-friendly and aligns with the vocabulary used in the science curriculum, e.g. *ingredients* rather than *chemicals* and *recipe* rather than *formula*. Using language that children are familiar with means that they all have the verbal tools to analyse and discuss their science learning.

The transferability of science knowledge is a key element of Science Capital. Children need to see how science concepts translate into familiar practical uses and everyday products to understand their relevance. CIEC resources link industry stories about the people and processes in local companies to the children's classroom investigations. This enables the children to see practical, everyday uses for the science that they are learning. For example, the children may investigate the best food and temperature for growing the microorganism yeast and then learn about a biotech company that manufactures machines that are used to grow the microorganisms used for medicines.

Knowing people in science-related roles

Some children grow up in an environment in which they know people – family or friends – with science-related jobs. Whilst we need to value all occupations, teachers can widen children's experience of scientific careers by inviting a broad range of adults working in science-related jobs into school. It is worthwhile investigating your local area to find out what kind of science is taking place in local companies and businesses in order to explore possible connections between their work and the science curriculum.

Ambassadors from a local company could visit your classroom to work with children in small groups on an activity linking their job to the science that the children are learning. They could also discuss their careers with the young people through question-and-answer sessions in the classroom. Our latest resource, *Potatoes to Plastics* (CIEC, 2021), written by Jane Winter (see article in this issue on page 30), provides ready-made ambassador interviews translated into news articles, thus introducing STEM careers in a cross-curricular way – an idea that could be adapted and used as a way of exploring the careers of your own ambassadors.

Broadening the definition of a science-related job beyond the stereotypical nurse or doctor helps the children to see the vast amount of career options available. CIEC's *Career Cards* (CIEC, 2020b) provides an example from one company of STEM careers open to children, whilst also challenging stereotypes and questioning gendered attitudes around expected career choices for girls and boys. These cards and the accompanying PowerPoint presentation could be adapted to build your own resource showing the profiles of the ambassadors who visit your school.

Figure 3 Yeast growth investigation in the context of making medicines

Engaging parents and family science skills

Engaging parents in your class's science learning is extremely useful, as we know that family is one of the most important influences on their child's interests and career aspirations. Making opportunities for family engagement in homework can be challenging, but is successful when equipment is easily obtained, no special expertise is needed, careful step-by-step instructions are given and there is room for exploration and questioning. Collaborative homework such as *IndusTRY AT HOME* (CIEC, 2020c) uses everyday household items to carry out fun practical investigations at home. They are designed so that children can do them with just a little help from parents, carers or older siblings. Children can then share the results when back at school, via photos, notes or drawings. Teachers can share these resources easily via the school website or newsletter.

Creating a school action plan for whole school development of science capital

The strategies above can all be included in an action plan for a whole school approach to developing Science Capital. Once you have audited your provision across the school, you can decide on which areas of Science Capital to focus. In order to do this, consider which types of activities you need to engage in, which strategies or approaches you would like to adopt, and plan how each year group will participate. Keep a record of your achievements and celebrate how far you have come on your journey as a school, through sharing new science experiences and learning in sharing assemblies, through a whole school science event or keeping video diaries.

Figure 4 A virtual meeting with an ambassador

CIEC's research shows that personalising learning, using products and processes that are familiar to young people and introducing them to a range of scientists and engineers, has a positive impact on whether children consider that science and a future science career may be for them. As primary teachers, we can make a real difference to children's aspirations through tweaking our practice and consciously making choices to develop Science Capital through the primary science curriculum. We hope that CIEC can help you wherever you are on your journey!

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Sustainable stories and solutions for our planet

Figure 1 John Mackenzie (Regulatory Affairs Manager) and Simon Grant (Technical Director) from Thomas Swan and Co. Ltd. exploring practical activities for primary children at CIEC's sustainability workshop

Nicky Waller describes how primary children can learn how to help to look after our planet and explores how industry is playing its part in the bigger picture of sustainability

If you are familiar with CIEC's website, or have read Jane Winter's article on page 30, you will know that we provide a whole host of information regarding how we work with both industry and schools. Our school resources consist of downloadable materials for teachers and interactive areas for children to access with teacher guidance. For teachers of the 4-11 age range, these resources promote hands-on practical enquiry, problem-solving, teamwork and discussions, and are set in real industrial contexts.

The themes of these publications are regularly evaluated to ensure that they are meeting the needs of the school curriculum and the changing demands on our industry partners. In 2018, CIEC worked closely with Thomas Swan and Co. Ltd. in County Durham to see the creation, development and delivery of a new tailor-made resource, highlighting the issues and impacts of sustainability for primary-aged children.

'The future holds many challenges for young people and our current model of development is placing an increasing burden on the planet. In order to secure the future of children all over the world, we need to make a decisive move towards sustainable development' (Department for Children, Schools and Families, 2008, p.2).

A definition of sustainability

Given that young children will become the next generation of adults, it is important that they are educated about sustainability issues so that they can take positive action to help preserve their future in a changing world. There are many definitions of sustainability and it is important to reach a shared agreement of what sustainability actually means, so that it can be conveyed and understood by children.

One of the most frequently used definitions is taken from *Our Common Future*, also known as *The Brundtland Report* (1987): *'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* (Brundtland, 1987, p.37).

In simpler terms, sustainable development means meeting the needs of all people now, without having a negative impact on the needs of people living in the future.

Sustainable Stories

In order to develop a sequence of activities for classroom use that link purposefully to real-life scenarios from the world of STEM and industry, a one-day workshop was held with representatives from companies and organisations with a strong reputation for sustainability: Thomas Swan, Croda, Quorn, Johnson Matthey, University of York's Green Chemistry Centre of Excellence, York Environmental Sustainability Institute, Ineos and the British Plastics Federation (see Figure 1).

From this workshop, case studies were developed into industry-related practical and discussion activities pertaining to four main themes:

- The motives behind sustainability: how we see the planet for future generations versus how much we value material possessions of our own;

Key words: Sustainability ■ Problem-solving ■ Industrial storylines

- The product life cycle: looking at manufacturing different products and the various aspects and impacts of sustainability;
- Understanding the impact of our own behaviour in actively bringing about change and developing sustainability; and
- Exploring a range of careers associated with sustainability and their place in STEM industry.

The pilot phase

Activities generated during the workshop were written into a pilot resource, which was shared with case study companies for comment and collaboration. In addition to this, 32 primary schools from Teesside, Lincolnshire and Hertfordshire attended a twilight CPD session and were invited to trial the activities and provide feedback as part of the pilot study.

The objectives covered in the publication are most relevant to the Year 5 science Programme of Study (National Curriculum for England), with all the activities covering statutory enquiry skills taught in the Upper Key Stage 2 (age 9-11) programme of study whereby children are required to work scientifically. All respondents said that the resource provided enough information for teachers with a limited scientific background to use the material and also that they would recommend the publication to other primary teachers.

The final publication

After all feedback had been taken into consideration and final amendments made, *Sustainable Stories and Solutions for Our Planet* was published and uploaded to CIEC's suite of teacher resources, with special thanks to Thomas Swan for their time, energy and funding.

This final version contains two generic introductory activities to develop children's awareness and understanding of sustainability, and five case studies developed into classroom activities with accompanying PowerPoint presentations related to their industrial and scientific focus.

The publication is aimed at children aged 9-11 years, although all the activities can be adapted to suit a range of ages.

Figure 2 CIEC's sustainability publication

The two introductory activities encourage children to consider their own motives behind sustainability, as well as to develop an awareness of vocabulary linked to current environmental issues. A glossary provides a comprehensive list of all key vocabulary introduced and children can reflect upon the learning that is taking place.

The five main activities introduce children to challenges within the context of sustainability. These include the sustainability of common materials such as metal, plastic and fabrics and also the sustainability of food and energy sources.

The investigative approach provides opportunities for children to explore the varied roles of scientists and engineers in practical ways, allowing the development of key skills including discussion and problem solving.

A presentation accompanies each main activity, and contains opportunities for higher order thinking, further discussion and research. Each presentation extends the sustainability message to focus on a wider environmental issue, including:

Activity 1	Introduction to sustainability
Activity 2	Vehicle emissions and air pollution
Activity 3	Single-use plastics and the importance of recycling
Activity 4	The environmental impact of washing and replacing items of clothing
Activity 5	Alternative diets and an awareness of our carbon footprint
Activity 6	Our use of fossil fuels and the development of renewable sources of energy


SUMMARY OF ACTIVITIES

THEME	SUMMARY OF ACTIVITIES	APPROXIMATE TIME TAKEN
1a Preparatory survey	A survey is carried out by each child to ascertain their thoughts about sustainability as well as their understanding of the impact of their own behaviour in actively bringing about change. Children are encouraged to question family members and compile an overview of current attitudes towards sustainability.	30 mins (+ 30 mins discussion)
1b Environmental vocabulary	Children are challenged to create a 'big-book' style environmental dictionary which will help others in their school to learn about important environmental issues. They suggest definitions for a list of words provided and then refer to the glossary and return to the task to make amendments as they learn more about environmental issues in subsequent activities.	30 minutes (+ 15 mins after each activity)
2 Sustainable materials: which metal?	Children investigate how metals can corrode when exposed to substances in the environment and that rusting is one type of corrosion. They are introduced to the properties and uses of precious metals and consider how one company uses these to reduce the amount of dangerous gases emitted by high numbers of vehicles on our roads today.	2–3 hours (+ ongoing observations)
3 Sustainable materials: which plastic?	Children are challenged to identify and name unknown plastics by observing what happens when samples are placed in different liquids and when a force is applied. They learn about the impact that plastics can have on the environment and why it is important to recycle plastic items. They consider how one company supports a recycling scheme to reduce the amount of U-PVC that is usually used once and sent to landfill sites.	1–2 hours
4 Sustainable methods of cleaning: which washing product?	Groups of children plan and carry out their own fair test to investigate how effective different commercial washing products are at removing stains from fabric. They will consider how one company has developed an ingredient for a new washing product which washes clothes more effectively than ever so that we do not have to wash or replace them more than we need to.	2–3 hours
5 Sustainable sources of food: how can we grow oyster mushrooms?	Children consider the benefits of following a more sustainable diet as an alternative to obtaining meat from animals as a source of protein. They are challenged to grow a crop of oyster mushrooms as a sustainable food source before learning about one company's solution to producing protein-rich food in a sustainable way.	1–2 hours (+ ongoing observations)
6 Sustainable sources of energy: which plant material?	Children consider the need for renewable energy and how this can be less harmful to the environment than burning fossil fuels. They are challenged to carry out two investigations for a fictitious company in order to find a sustainable plant-based source of fuel. They learn about a real company's solution to producing energy for electricity from natural, sustainable sources such as plants.	1–2 hours

Figure 3 Summary of activities

The presentations have been created to help children to develop a deeper understanding of our impact on the planet and to encourage them to weigh up different opinions and evidence for themselves: '*Empowering young people to take responsibility for their own future is not only desirable:*

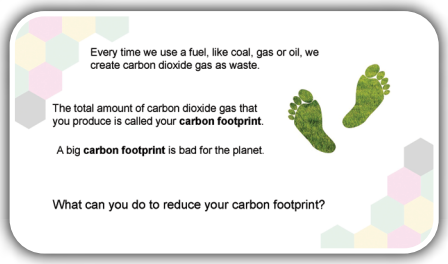

Figure 4 An example slide from accompanying presentation: ***Which washing product?***, which encourages children to explore sustainable methods of cleaning

it is a crucial feature of their education' (Porritt *et al*, 2009, p.6).

Real examples from the classroom: Introductory activities

Anna Ronsano, class teacher at Whinney Banks Primary School in Middlesbrough, completed the introductory activities with children in her Year 5 class (age 9-10). First of all, they carried out the survey (Activity 1a) to reveal their thoughts about sustainability as well as their understanding of the impact of their own behaviour in actively bringing about change. She encouraged all children to question family members too and they compiled a class database of current attitudes towards sustainability.

In the second introductory activity (1b), the children created a 'big-book' style environmental dictionary with the intention of helping others in their school learn about important environmental issues. The children discussed their ideas for definitions of the words provided and then referred to the glossary to make any improvements to their suggestions.

Ms. Ronsano's feedback about these activities was extremely positive: *'The environmental vocabulary activity was a great way to learn about sustainability as it promoted good conversations and questioning with the children'.* She also commented on how much the children had particularly liked the creative way of recording the vocabulary. An example of one child's work can be seen in Figure 5.

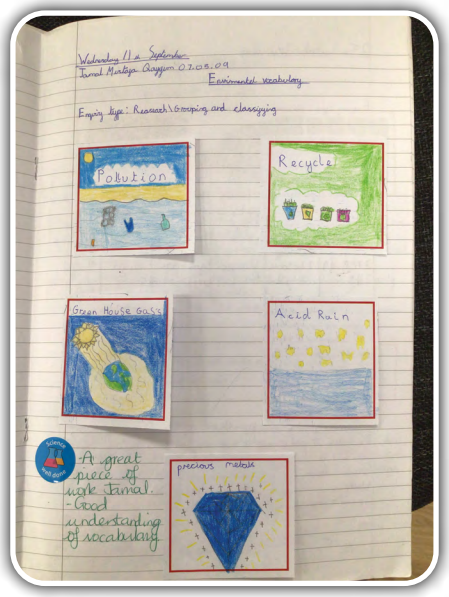

Figure 5 Example of children's work for the environmental dictionary

Real examples from the classroom: Which metal?

Jeanette Harrison, Year 6 (age 10-11) teacher from Breckon Hill Primary School in Middlesbrough, carried out Activity 2: *Which metal?* with her enthusiastic class. The children investigated how metals can corrode when exposed to substances in the environment and then developed their own questions about rusting. They also looked at environmental vocabulary from the introductory activities and linked this to the learning.

Working in small groups, the children used steel wool pads to compare a control pad with one dampened with water, one with saltwater and one with a mixture of water and mild white vinegar (acid). Children examined the pads at regular intervals over the period of a week and took photographs and measurements of changes over time, including observations of how the colour of the liquids changed in each container.

The sustainable story from industry extended the children's learning to precious metals and how they are unique in many ways – they are relatively non-reactive, so they will not rust or explode when exposed to different substances or high temperatures. The children were keen to hear about how scientists at Johnson Matthey use precious metals to help our environment, by reducing the amount of dangerous gases emitted by high numbers of vehicles on our roads today.

Figure 6 Rusting investigation results

Figure 7 Odd One Out activity

Mrs Harrison reported that *'The children found this really exciting, they were amazed to see how quickly changes appeared in the metals. They then used their knowledge of this to carry out the "odd one out" activity using evidence from their investigation'.*

She also told us that *'I love the resources, and the children gained a lot from the activities. I think most of this was due to it being such a current topic and something that they could relate to – hence we have used them again this year, and as part of British Science Week, with resounding success'.*

Examples from the classroom: Which plastic?

Children attending the school science club at Bader Primary, Thornaby, carried out this activity with the science subject leader, Charlotte Ferens. They were challenged to identify and name unknown plastics by observing what happens when samples are placed in different liquids and when a force is applied.

The sustainable story for this activity enabled the children to learn about the

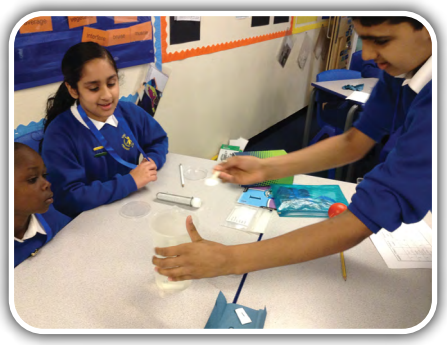

Figure 8 Identifying plastics activity

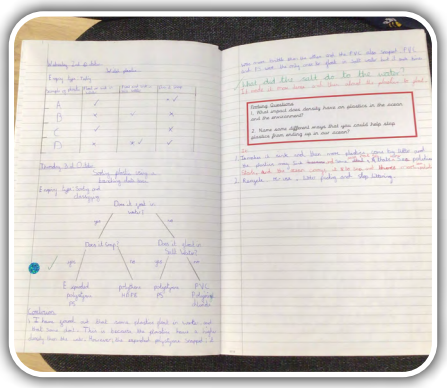

Figure 9 Example of children's work using a key

impact that plastics can have on the environment and why it is important to recycle plastic items. They then found out about the scientists at Ineos and how the company supports an innovative recycling scheme to reduce the amount of U-PVC that is usually used once and sent to landfill sites.

Ms. Ferens reported that *'The children loved this activity! They were so surprised with the results and have since used their knowledge of density and the ocean to look at plastics in the ocean more closely. An expert group of children in our science club also carried out their own research about the effect of salt in the sea on plastic.'*

Examples from the classroom: Sustainable sources of food

Ms. Ferens also used the mushroom-growing kit that she received at CIEC's regional teacher CPD session with children attending science club. They considered the benefits of following a more sustainable diet as an alternative to obtaining meat from animals as a source of protein, before attempting to grow a crop of oyster mushrooms as a sustainable food source.

Figure 10 Children growing mushrooms as a sustainable source of food

The sustainable story from Quorn introduced the children to one company's solution to producing protein-rich food in a sustainable way. Due to the success of these activities, the Year 5 and 6 curriculum at Bader Primary School now embeds sustainability as a theme for summer term science activities, using the *Sustainable Stories and Solutions to Our Planet* resource from CIEC.

The importance of learning about sustainability

In more recent years, many primary schools have recognised the growing importance of educating young children about sustainability and the world around them. As part of the local to global element of a curious curriculum, primary schools are signing up to help deliver on the United Nations 17 Sustainable Development Goals. This involves planning for opportunities to link enquiry themes with bigger global issues in order to allow learners to explore the ideas, concepts, issues and reality regarding sustainable development.

The 'global goals' apply to everyone in the world and cover issues such as equality, hunger, energy, clean water and sanitation, biodiversity, climate change, economic growth, sustainable cities and responsible consumption, as well as strategies such as education and justice.

Every school now has the opportunity to cover a range of the goals through its teaching and wider activities. By linking learning in the classroom to real-life problems and scenarios, children can hear positive stories of scientists working towards solutions to global issues and this can help allay developing anxieties

Figure 11 United Nations Sustainable Development Goals

that some children may have about the world that they are inheriting.

Using *Sustainable Stories and Solutions for Our Planet* as a teaching resource provides a wealth of ideas for how to do this in the primary classroom and supports teachers in bringing young children and external agencies, such as local industry, together.

Returning again to feedback provided by teachers in CIEC's pilot sustainability study, when asked: 'Do you think the children gained a better understanding of sustainability having the industry story for a context?', there was a resounding 'yes' from all respondents, with many positive comments including:

'The children enjoyed the activities and it gave them a greater insight into industry'

'The learning had a true purpose and put their actions into context'

'The sustainability resource is filled with enjoyable, real-life learning'.

Sustainable Stories and Solutions for our Planet can be freely downloaded from the CIEC website at www.ciec.org.uk

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What is BEST for primary science?

Nicky Waller explains the BEST approach to teaching and assessing science, with details of how this is being piloted successfully in primary schools

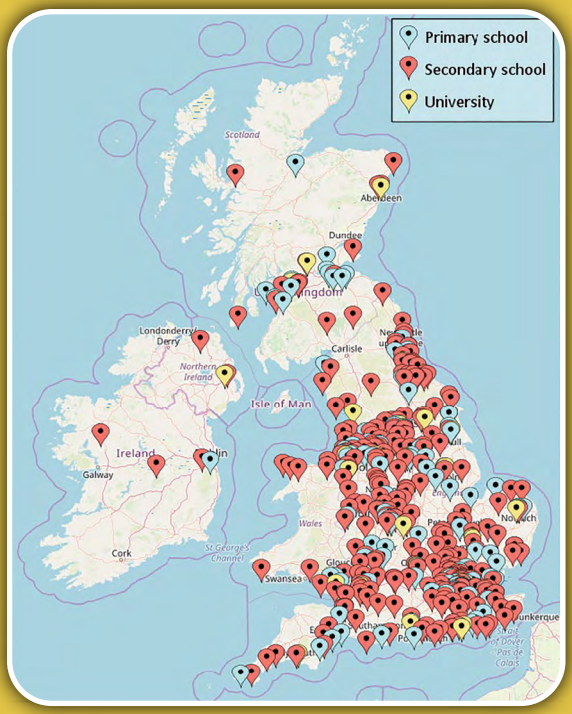

Figure 1 One quarter of all downloads of secondary BEST resources are by primary schools

A little background

Best Evidence Science Teaching (BEST) is a large online collection of resources developed for effective teaching of difficult ideas in science, currently for use in secondary schools. The unique selling point of BEST is that it enables teachers to draw on the best research evidence when teaching a wide range of topics in the science curriculum. The comprehensive suite of resources is intended to help students to make progress in understanding key concepts in science education and support teachers in developing evidence-based practice.

The secondary BEST resources have been developed by the University of York Science Education Group (UYSEG) and funded by the Salters' Institute, a charitable body that works to support science education. The initial funding was for four years (2015-2019) to develop resources for the 11-14 age range. The very positive reception given to BEST by teachers and others involved in science education resulted in the Salters' Institute agreeing to fund (i) the extension of BEST to cover the 14-16 age range, and (ii) a small-scale pilot for BEST materials for the 9-11 age range, to be conducted by the Centre for Industry Education Collaboration (CIEC) in collaboration with UYSEG.

Teachers' views of BEST

All the current BEST resources are free and open access, and are hosted online by STEM Learning at www.BestEvidenceScienceTeaching.org. Key indicators of levels of uptake are the figures on page views and downloads of the resources from STEM Learning's website. Several months after the launch of BEST, the figures were described as 'significant successes' by Yvonne Baker, the Chief Executive of STEM Learning.

One notable feature of the data is that around 25% of the downloads are by primary schools, indicating a level of interest in primary-focused BEST resources.

CIEC conducted the pilot in collaboration with UYSEG during the 2020-21 academic year, with the aim of uncovering whether or not there is a genuine interest from primary teachers to develop BEST resources for the primary school age range.

BEST for primary?

In October 2019, CIEC carried out a feasibility study to analyse the potential reach of the 'BEST approach' to support science teaching and learning in the primary school. A full scrutiny of existing BEST resources explored whether the structure of BEST lends itself to the primary age range. Suggestions were also made regarding which elements of BEST might need adapting to suit the age 9-11 phase in the initial instance, but also whether there is potential to use and adapt the same structure for younger primary-aged children and their teachers.

Based upon the positive outcomes of the feasibility study, the Salters' Institute agreed funding for the Primary Pilot Study with primary teachers from around the country to further establish the potential interest and impact of BEST on primary science.

Key words: Formative assessment ■ Diagnostic questions ■ Children's misconceptions ■ Research evidence

BEST Primary Pilot Study: Phase 1

The pilot study began in April 2020, with twenty teachers recruited from primary schools in Yorkshire and the North East of England, who were given the opportunity to help shape the development of BEST primary resources from the outset.

Ten of these schools were allocated to Phase 1 of the pilot and asked to feed back on a selection of draft primary BEST activities that had been adapted from existing 11-14 resources to complement the following Year 5 (age 9-10) topics in the English National Curriculum for Science:

Science topic/area	Content at the upper primary level
Living things and their habitats	The diagnostic questions link with popular biology topics in which children learn how to identify and compare simple features of living things, and sort these into groups based on common observable characteristics.
Properties and changes of materials	The diagnostic questions link with popular chemistry topics in which children learn about properties and uses of everyday materials.
Earth and space	The diagnostic questions link with popular physics topics in which children learn about the Earth, space and our place in the universe.

Each activity contains comprehensive teacher notes aimed at supporting primary teachers to run the activities with children aged 9-11 years.

All teachers in Phase 1 attended virtual feedback meetings whereby they shared their thoughts on how useful and useable the resources would be for them, how well they thought they might work with their classes, and ways in which the activities might be improved for a primary audience. Feedback was extremely positive, with primary teachers reporting that the diagnostic questions provided ample opportunities to encourage discussion in the classroom, as well as being excellent 'ice-breaker' activities to aid with pre-assessment at the start of a key scientific concept.

Quotes from primary teachers in Phase 1 of the pilot study include:

'I think all of the resources are really useful and would be easy to use in the classroom. The resources all encourage open-ended discussions that allow for assessment of children's prior knowledge, but also encourage the use of scientific vocabulary to justify their opinions, which I think is extremely valuable'

'It is great that the misconceptions are identified and this is good for teachers that are not sure themselves'

'In my class I believe the resources would work well. The children love discussions and adding to each other's ideas. I think this would give the class a good opportunity to begin challenging one another's views in a mature way'.

Figure 3 Children justifying their ideas in different corners of the classroom

BEST Primary Pilot Study: Phase 2

All twenty schools participated in Phase 2 of the pilot study, from April to July 2021. Teachers received updated versions of the draft resources, amended and adapted to make them more suitable for use in primary schools in light of responses provided at the feedback meetings.

In addition to this, several primary schools from Stoke-on-Trent also became involved in Phase 2 of the primary pilot study, with the aim of using the draft resources as the starting point for a city-wide diagnostics support package. Headteachers in Stoke had been searching for a consistent suite of tools for use in all schools to better support transfer from Years 6 to 7 (age 10-12) and believed BEST to be the only researched and thorough tool to recommend.

For each activity, pilot schools received a Word document comprising a pupil activity sheet and teacher notes, plus a PowerPoint presentation for use on screen in the classroom. All teachers were asked to try the activities in class and then provide their thoughts through an online questionnaire or more in-depth interview. Five of the twenty schools agreed to the observation of a science lesson in which the resources were being used.

Getting to grips with diagnostic questions

Diagnostic questions are at the heart of BEST and are intended to help teachers collect evidence of what

Figure 2 Year 5 child responding to diagnostic question: Is it a bird?

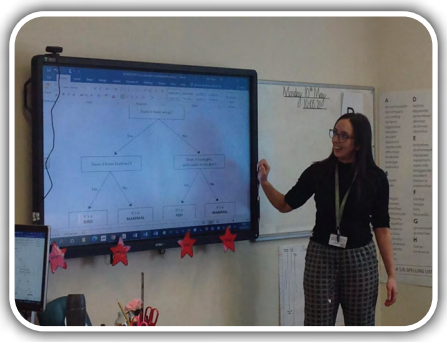

Figure 4 Teacher introducing a classification key

the children in their class are thinking, including:

- what they currently understand; and
- any preconceptions and misunderstandings they may have.

The diagnostic questions are designed to target particular preconceptions and misunderstandings that have been reported in the research literature as being common in children of this age.

They are intended to function as formative assessment items: the evidence they provide about what children are thinking can help teachers to decide what to do next in terms of focusing and sequencing their teaching.

It's up to individual primary teachers how to make best use of the diagnostic questions. For example:

- you might choose to use them at the start of a lesson, or partway through, or at the end – whatever you feel will give you the best information about what the children are thinking; and/or
- you could ask children to respond in different ways, for example by voting on the answers using mini-whiteboards or by moving to different corners of the room, or by simply recording their answer on the activity sheet.

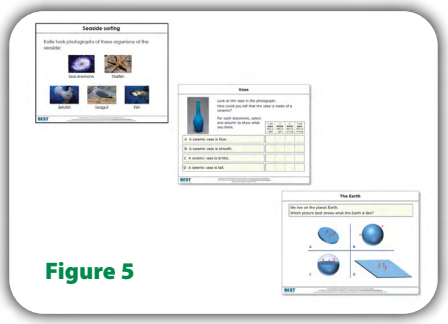

Figure 5

Uncovering children's misconceptions

The recent Ofsted review of factors that influence the quality of science education in schools in England (Ofsted, 2021) explores the literature relating to high-quality school science curriculums, assessment, pedagogy and systems. The research states that *'There is a clear relationship between young children's general science knowledge and their later science achievement. If gaps in pupils' knowledge are not addressed early on, evidence suggests that these will continue into secondary school and beyond'* (Morgan *et al,* 2016, pps.18-35).

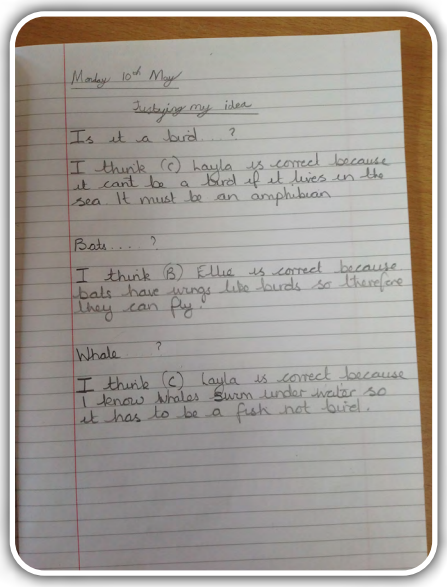

Figure 6 Revealing common misconceptions at upper primary

Throughout the review, there is an importance placed on pupils taking a *'metacognitive perspective'* by needing to not only know why a scientific idea is correct, but also why their misconception (prior knowledge) is scientifically wrong. Ofsted suggests that *'The curriculum should anticipate where pupils are likely to hold misconceptions. These are explicitly addressed, and pupils learn how the misconception is different to the scientific idea'* (Ofsted, 2021).

During Phase 2 of the primary pilot study, teachers commented on how useful the BEST diagnostic questions had been in revealing a wide range of, often incorrect, scientific ideas that children bring with them to their lessons. Some examples of this type of highly revealing dialogue are included next:

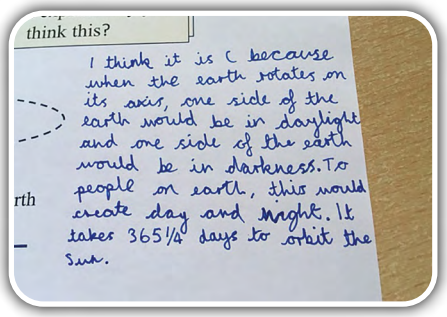

Figure 7 Opportunities for children to show existing knowledge and understanding

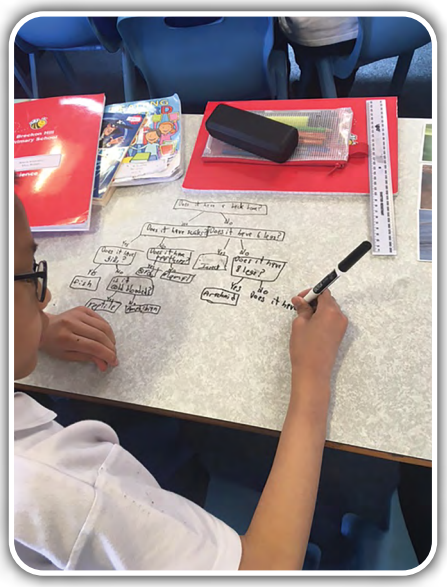

Figure 8 Diagnostic questions leading to response activities

Example 1

C1: A penguin can go on water and on land so is an amphibian.
T: That's right, it can, but why is it not an amphibian?
C2: Because a penguin doesn't go right under the water so that doesn't count.

Example 2

C1: Does a penguin actually have feathers?
T: If you haven't seen one, you wouldn't really know. They look quite smooth like smooth skin but [are] actually feathers clustered together to keep them warm in their environment.
C2: What if you had a bird and shaved all its feathers off? It wouldn't be a bird then.
T: That's because you have changed it but the bird does have feathers naturally.

Example 3

C1: The Moon will be facing one side of the Earth, which will be night.
T: What has the Moon got to do with it?
C1: When the Earth faces away from the Moon it will be day.

Progression toolkits: more work to be done for primary

The original resources in the BEST collection are not intended as stand-alone activities. Each one is part of a progression toolkit for a key concept taught in secondary school science.

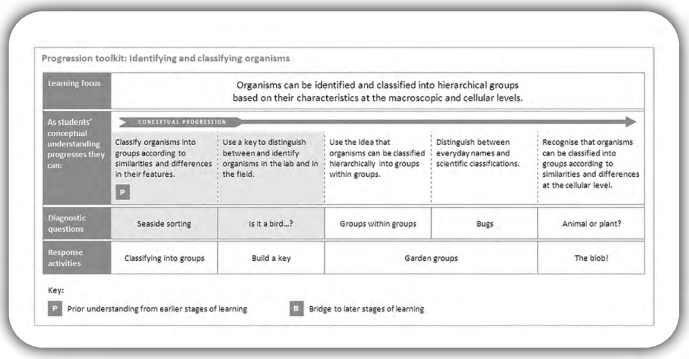

Figure 9 Example progression toolkit, age 11-14

The first two rows of the pathway describe what students should be able to do as their understanding of the key concept develops – this takes the form of observable learning outcomes to guide the teaching focus. An example from the 11-14 progression toolkit for the key concept *Identifying and classifying animals*, taken from a biology unit of work, is shown in Figure 9.

The P symbol shows that the first statement indicates prior understanding from earlier stages of learning. This would link back to what students have been learning at the primary school level and would be a good end point for a primary pathway.

The middle column in each progression pathway indicates the level of conceptual understanding that a student aged 11-14 might have, in order to be categorised as working at the 'expected standard' for this particular area of learning. Organising the pathway in this way enables teachers to make consistent judgements for students working towards or above the expected standard.

Although the development team at UYSEG and CIEC has not yet developed any progression toolkits or response activities for BEST Primary as part of the pilot study, they intend to do so if the pilot is taken forward into a full curriculum development project. Progression toolkits for the primary age range, like the secondary models, would need to be based on careful consideration of available research evidence on learning pathways, common student misunderstandings, and effective teaching approaches at the primary level.

Feedback so far

At the time of writing this article, feedback had been gathered from a small number of primary schools through lesson observation and detailed teacher interviews. The overall response from both children and teachers has been overwhelmingly positive, with the use of diagnostic questions revealing often unanticipated misconceptions and then moving the learning forward from useful, informative starting points. Some examples are given below:

Feedback from teachers

'I think the whole feel of the lesson was it's okay if it's wrong, then they were more open to trying it. I think sometimes when you do open it, they come up with better ideas than what I would think of.'

'I would have made a lot of assumptions about their knowledge and understanding of different animals without these activities.'

'I feel that I considered more of their knowledge in understanding where they need to go next, whereas I think if I'd probably done it without these resources, I just would have stuck a load of pictures of different animals and probably not even thought about the fact that, well do they know that a penguin doesn't have this or that characteristic?'

Feedback from children

'I enjoyed learning about animals in this different way.'

'I liked going into the different groups in different corners of the room to show what I understood and then explaining why I thought this to others in my class.'

'I liked the guessing parts, sharing our thoughts and listening to other people's ideas.'

What next for BEST Primary?

The final phase of the pilot study will be for CIEC and UYSEG to collate all feedback received from Phase 2 teachers and produce a summary report in Autumn 2021. If the feedback is as positive as we anticipate, we hope to expand the number of BEST resources aimed at the primary age phase and create a more extensive and established primary collection, including subject maps, progression toolkits and response activities.

Interested in getting involved?

CIEC would love to hear your thoughts on the expanded development of primary BEST and whether you would welcome the creation of a full complement of resources for Upper Key Stage 2 children, as well as a suite of diagnostic questions for younger children, eventually covering the full primary age phase.

We would also love to hear from primary teachers about which elements of the existing BEST resources you feel that you would value the most, such as subject maps, progression toolkits, diagnostic questions, response activities and teacher notes.

CIEC will be looking for primary schools and teachers from around the country to take part in further stages of this exciting pilot study. Please do get in touch if you are interested in signing up and getting involved.

For further information about exciting developments regarding BEST for primary schools, please contact: joy.parvin@york.ac.uk or nicola.waller@york.ac.uk

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Nicky Waller has been working as an advisory teacher for CIEC since 2004 and is passionate about building teachers' and children's confidence in all things primary science.
E-mail: nicola.waller@york.ac.uk

Take your science teaching to the next level: STEM volunteers in the classroom

Jane Winter describes the impact that STEM professionals could have in the primary classroom, and shares some tips for how to get started

Figure 1 Scientist at work: Meeting people from the world of work helps children to understand the relevance of science beyond the classroom

As you have chosen to read this, you are probably enthusiastic about teaching science and you probably teach above average science lessons in terms of children's engagement and progress. You are more likely than the 'teacher in the street' to have heard of Science Capital and to know that, as well as ensuring enjoyment and learning in science lessons, it is important to raise children's aspirations and to help them to understand that science is relevant to their lives both now and in the future. However, I wonder if you have dipped your toe into the wonderful world of inviting STEM professionals (volunteers from science-based industries, universities, etc.) into your classroom? Are you ready to push yourself out of your comfort zone to work with a stranger and welcome them into your classroom to give your science teaching a whole new dimension? The logistics of finding someone and then arranging a mutually convenient time can appear daunting, combined with fact-handing over control of some of the lesson. So, do the benefits make the effort worthwhile?

A little effort reaps huge rewards

Teachers who have taken the plunge report that working with STEM professionals leads to deeper engagement and more 'sticky' learning. Remember the proverb 'Tell me something and I will forget, show me something and I may remember, involve me and I will understand'? If you want children to *really* understand that science is done by 'normal' people and is something that they could aspire to, letting them meet and interact with real live scientists is unsurpassed. Moreover, if children see links between the science that they do in school and a real-life context, the experience becomes more meaningful and relevant to their lives. Children often learn more, and retain this learning for the long term.

Key words: STEM volunteer ■ STEM professional ■ Ambassador ■ Science capital

	Potatoes to Plastics **(without a STEM volunteer)**	***Potatoes to Plastics*** **(with a STEM volunteer)**
Links to Year 5 (age 9-10) curriculum	Yes	Yes
Cross-curricular introduction	Children read and write about STEM professionals in an English lesson.	As well as reading about STEM professionals, children meet and interview one before writing a report about them in an English lesson.
Introduction to main activities	Teacher tells children about how science can be used to find solutions to environmental problems. She gives the example of extracting starch from potato peel and gives children instructions to do this.	Children meet a scientist who shares some of the solutions to environmental problems that she and her colleagues have been working on. She tells them how to extract starch from potato peel and tells them that she will be coming back to show them what to do with it.
First activity	Class teacher supports children to extract starch from potato peel following instructions from CIEC publication.	Class teacher supports children to extract starch from potato peel following instructions left by the scientist.
Second activity	Class teacher supports children to turn potato starch into bio-plastic following instructions from CIEC publication. She heats the mixture for them in a saucepan on a cooker.	Class teacher and scientist work together to support children to turn potato starch into bio-plastic. The scientist brings in a magnetic hotplate, which she demonstrates to children before using it to heat their mixtures. During the activity she also answers children's questions about her job and shares anecdotes from her experience.
Final investigation	Children test their bio-plastic and send their findings to a fictitious company. (If the findings are sent to CIEC, the children will hear back from the 'company' who will thank them for their contribution to research and development.)	Children test their bio-plastic and send their findings to the scientist. She promises the children to pass on their findings to the Research and Development department of her company. In due course, the children hear back and are thanked for their useful contribution.

Figure 2 An example of a science activity with and without a STEM volunteer

A tale of two science lessons

Figure 2 uses CIEC's latest primary science publication, *Potatoes to Plastics*, to exemplify the differences between carrying out a set of science activities in the classroom both with and without the support of a local STEM volunteer. As we already know, lessons without

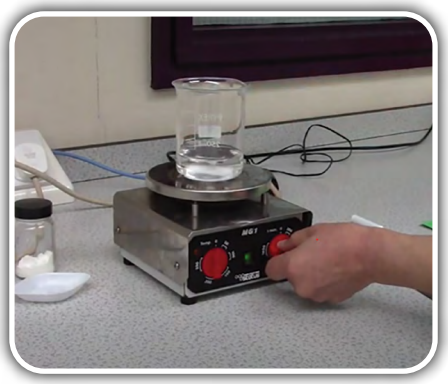

Figure 3 A STEM professional can bring specialist equipment into the classroom. Here, a magnetic hot plate is being used, which simultaneously heats and stirs the liquid

the input of STEM professionals can be engaging, effectively cover the science programme of study and support children to understand that science has an important role to play in their lives. This example links closely to the Year 5 'materials' strand of the curriculum and is also topical, as it shows how a waste product, potato peel, can be turned into a biodegradable alternative to a fossil fuel-based product. One might have thought that it would be hard to improve on this science experience in terms of engagement, learning and relevance.

However, Figure 2 demonstrates how the input of a STEM professional can take the learning experience to the next level, in many ways. Getting to meet a real-life scientist does more to dispel stereotypes than any other experience that you can give children in school. Furthermore, if that scientist tells children about how they use aspects of science familiar to the children in their work, the school curriculum becomes more meaningful to the children, raising Science Capital whilst increasing long term retention of learning. Teachers often tell us that when they are reviewing the year with children in July, it is the work with STEM volunteers that children recollect most enthusiastically, which leads to secure learning that can be built upon in subsequent years.

First: catch your scientist

The easiest place to try to locate a STEM professional can be within

It is second nature for teachers to use a variety of tools to help children learn. Teachers choose their vocabulary carefully, repeat instructions in a variety of ways and use non-verbal reinforcement to clarify meaning. This reduces the cognitive load for children as they grapple with fresh ideas and concepts. However, it is not possible to pass this experience on to visitors when we welcome them into our classrooms. I once attended an assembly run by an enthusiastic and well-meaning engineer from a local power plant. Sadly, even the teachers in the audience didn't understand most of what he said, let alone the Key Stage 1 (age 5-7) children sitting in the front row!

CIEC's 30+ years of experience providing training for scientists and engineers to work with primary school children can help. CIEC's team supports potential volunteers to develop the skills to enable them to communicate effectively and confidently in the classroom. CIEC's CPD team identifies activities that will make strong links between the primary science curriculum and the science that takes place in a particular workplace (see Figure 5). This service is often commissioned by companies who would like to develop the effectiveness of their schools' outreach team. CIEC can also support groups of schools that want to get the best possible results from inviting STEM professionals into their classrooms.

When volunteers have developed their role in partnership with CIEC, the impact on the children has been very high. STEM professionals also tell us how much more meaningful the interaction is for them, as a result of CIEC support. They feel more confident going into the classroom, as well as having the satisfaction that their more skilled approach is having a positive impact on children's lives. Moreover, collaboration with CIEC maximises the development of skills that they take back to the workplace – benefiting both themselves and their employers.

Figure 4 Lightening the load with CIEC

the school community. Send a letter to families and ask colleagues about relatives or friends who have STEM careers. This approach can lead to two different groups of people coming forward. Firstly, you may have offers from people who use the products of science at work. For example, hairdressers use a range of chemicals that would be harmful if the correct procedures were not followed. Motor mechanics need to manage the use of products in engines as well as understand the physical laws of motion. If you have volunteers in this group, try a cross-curricular English-focused activity. Groups of children interview these volunteers about their jobs and share written reports. The quality of children's work tends to be higher when children plan these interviews in advance, planning questions that they would like to ask and giving volunteers notice of the questions.

Children do benefit from meeting a range of people who use science in their jobs, as it helps them to understand the relevance of science to their lives and raises their Science Capital. However, the focus of this article is on a second group of volunteers. These are people who need STEM qualifications to do their jobs, including scientists and engineers. When asking for such volunteers, you may be surprised by the range of careers represented in your school's wider community. In my own experience, I have met a quality control specialist working in a food factory, a radiographer from a hospital, an environmental scientist working for the council and an agronomist who supports farmers to get the best yields from their crops. You cannot really have too many STEM volunteers as, ideally, every class in the school should get to work with at least one STEM professional every year – so don't turn anyone down!

Making use of contacts is a good first step towards developing the school's broad link with the STEM world of work. However, to find the exact scientist who you want to carry out a specific activity, contact a local organisation that employs STEM professionals, such as a science-based industry, a university or a military station. If you are lucky, you will find that the organisation that you have approached encourages their employees by allocating time each year to participate in schools' outreach. Companies wish to support their local community, whilst raising awareness of what the company does and the range

Real-life STEM application	CIEC publications	Link to the National Curriculum
Aeronautical Engineering	*Feel the Force*	Forces
Growing the microorganisms needed to make antibiotics	*Cough Syrup* *Medicines from Microbes*	Living things
Environmental Science	*Sustainability* or *Potatoes to Plastics*	Living things and their habitats
Agronomy	*Turf Trouble*	Plants
Power Plant Engineering	*Generating Electricity* http://www.ciec.org.uk/resources/generating-electricity.html	Electricity
Veterinary Science	*Medicines for Pets*	Materials

Figure 5 Bridging the gap between real-life applications and primary science

Figure 6 Two-way benefits: children learn from STEM professionals, and CIEC's volunteers value the experience and enrichment to their working lives

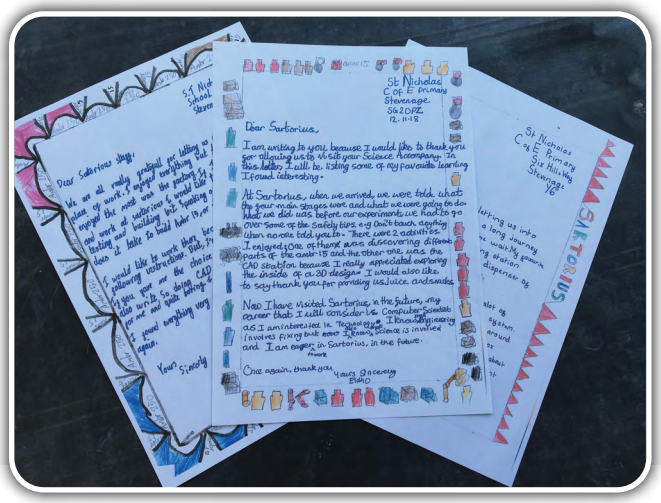

Figure 8 Thank you letters are often treasured by the STEM volunteers who receive them

of careers that they have available. There are also nationwide initiatives, such as STEM Ambassadors, which might lead to you locating the right person to visit your school.

With the advent of modern technologies, it is possible to arrange for children to have virtual contact with scientists who live further away. With geographical barriers removed, children can meet specialists who might not be present n your local area, and possibly for more than one meeting. The recent experience of the CIEC team has shown that working remotely with scientists is a positive experience for everyone concerned. However, we would always counsel that face-to-face meetings are preferable for that real 'wow factor' memorable learning, with remote meetings supplementing, rather than replacing, professionals' in-person visits to the classroom.

Following the visit, by way of thanking the STEM professional, children write letters, providing a real audience and purpose for this literacy task. These are often treasured by the recipients, and may well increase your chances of persuading your STEM professional to come back to your classroom the following year (Figure 8).

Figure 7 Many activities link primary science with real-life applications

Cross-curricular support

The *Potatoes to Plastics* resource described above includes magazine-style articles written about some of the scientists working in the Chemistry Department at the University of York. These are designed to be used in an English lesson, with literacy-learning objectives. Another article written about an 11 year-old boy is intended to inspire children to write about themselves as future scientists. Both activities can support teachers to address the thorny issue of being expected to produce science writing to the same standard as writing in English lessons, as well as incidentally raising Science Capital. These activities are a useful supplement to working with STEM professionals in the classroom, but cannot replace the magic of this experience.

Now you have read about the opportunities that working with STEM professionals could open up for you and your class, what are you waiting for? I have no doubt that once you have dipped your toe in the water, you will never look back.

Jane Winter has been a Professional Development Leader with CIEC since 2014. She believes that a good science education starts from Early Years and loves supporting teachers throughout the primary age range to deliver inspiring science experiences.
E-mail: jane.winter@york.ac.uk

The Centre for Industry Education Collaboration – A Global View

In 2018-19, Dr. Guirong Wang, from Beijing University of Chemical Technology, spent a year with CIEC. This article explores the innovative work of CIEC from her viewpoint*

Guirong with children celebrating their Children Challenging Industry (CCI) success in Cambridge

Why did you choose to visit CIEC for a year?

I met Sir John Holman in November 2017 when he visited Beijing – he was attending an academic event as the President of the Royal Society of Chemistry. He told me about the world-class outreach work that CIEC has been doing for thirty years, explaining that they have combined the design of effective practical programmes with research and evaluation of impact. I did some further research and realised that there was nothing like this elsewhere in the world.

I have always been impressed with the outreach work done in the UK, which has the longest history in the world, going back to the Michael Faraday Christmas lecture of 1825! In recent years, the Chinese government has begun to recognise the importance of outreach both for primary and secondary school students and for the general public.

In 2016, my home university, Beijing University of Chemical Technology (BUCT), set up the BUCT Outreach Centre, both to promote the development of science outreach and to collaborate with other organisations. Working with my Beijing supervisor, Professor David G. Evans, over the past three years, we have taken part in many national and local science festivals, and organised demonstrations and hands-on experiments for students.

Our activities are very popular, but we wanted to evaluate the activities and do further research on outreach, and we needed some help. That's why I decided to come to the UK and spend a year with CIEC, where I am being co-supervised by Sir John Holman and CIEC's Director, Joy Parvin.

Can you tell us a little about the flagship Children Challenging Industry (CCI) programme that you have observed?

In the first a few months of my visit, I became familiar with the publications that have been developed and used in the CCI programme, and observed

*This is an updated version of an article first published in *ChemYork* in Spring 2019

Key words: International China Collaboration

different aspects, including the delivery of lessons in primary schools, science staff meetings for teachers and the training of scientists and engineers who work in industry to work effectively with primary school children. I also accompanied some classes on their site visits to science-related companies, which is clearly the highlight of the programme for many children. I realised that all these sessions are based on careful evaluation and research over many years, which ensures the effectiveness of this programme.

What do you think are the benefits for the children who take part in Children Challenging Industry?

In the CCI programme, children learn science in a real-life context, improving their motivation and enjoyment of science. When I took part in the classroom sessions and site visits, I could see the excitement on their faces. However, I think what's more important and will have a long-lasting influence on children is that the programme helps to develop their awareness of what they can do in the future and why they need to learn science: great career guidance for children of this age.

I have noticed that teachers benefit from the programme too. They receive training from CIEC specialist teachers at staff meetings and work alongside them delivering two lessons linking science from industry to the primary science curriculum. Teachers also accompany their classes on the site visit and interact with a variety of STEM ambassadors trained by CIEC. All this leads to teachers being a lot more confident in their own ability to deliver effective and relevant science lessons – this continues to benefit the children even after the CCI programme is finished.

How are the publications used in the Children Challenging Industry programme developed?

I was delighted to be able to observe the development of a new primary science publication, based on sustainability, which was co-ordinated by one of the CIEC team, Nicky Waller. The process began with a workshop contributed to by members of the CIEC team and members of the Department's Green Chemistry Centre of Excellence, with input from chemists and engineers working for Thomas Swan, Johnson Matthey, Quorn, Croda and Ineos. Nicky and Joy [Parvin] used the contributions at this event to draft an exciting new publication combining information about sustainability with engaging practical activities and links with the primary school curriculum.

How does the work of CIEC interface with other educational initiatives?

John and Joy have offered me many opportunities to learn about other organisations and projects in the UK that collaborate closely with CIEC. For example, I met the Primary Science Quality Mark (PSQM) Director, Jane Turner. CIEC has been involved with PSQM since its inception. During my visit, CIEC ran a pilot project with PSQM schools, funded by the Royal Society of Chemistry. This project aimed to use the expertise developed through CCI to support PSQM schools to have greater impact on the aspirations of primary children. It achieved this by brokering links between STEM ambassadors and teachers and training them to make the most of the collaboration.

What has impressed you most about CIEC?

People working in CIEC are really enthusiastic and passionate about what they are doing – they are very effective and collaborate with each other very well. The CCI programme has now been running for 25 years and has fostered many connections with primary schools and industries to benefit large numbers of children and teachers. Each session of the programme is designed very carefully and every detail considered to a very high standard. CIEC evaluate their programmes using questionnaires and interviews with children and teachers. This makes CCI very systematic, both practically and theoretically – this cannot be done without determination and persistence. That's the most impressive part about CIEC.

What have you taken back to China based on your experience with the team?

I have delivered some elements of the CCI programme since I returned to China. It is not exactly the same, because of differences in the culture, context and education systems. I am currently working with Nanjing Publishing Group and CIEC to begin our first major pilot of CCI in Nanjing! As the CIEC team has developed remote training opportunities for companies and schools during the pandemic, we hope to utilise this model. We hope to start with 5-6 primary schools and one company, after adapting two of CIEC's publications: *Water for Industry* and *Potatoes to Plastics*. I think that the link with industry is really important and special.

I have seen that companies in the UK become very involved in organising the children's visit. They take their social responsibility extremely seriously, and I believe that this will contribute significantly to the next generation. In China, some industries are also keen to help improve science education. I hope to start the pilot by working with one bio-plastics company and hope too that this experience will provide insight and guidance for other outreach programmes in China. I have been inspired by my work with CIEC and feel very lucky to work with them. I hope that we will establish more collaborations on science outreach in the future, which will benefit a lot more children, especially in China.

Dr. Guirong Wang is an associate professor in Chemistry and Outreach Co-ordinator at the Beijing University of Chemical Technology.
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One of the ways in which CIEC supports primary science education is by providing curriculum-linked resources for teachers and children to access. Resources can be searched by age group (5-7, 7-9, 9-11, or suitable for all), or by the three broad categories: science topic, types of enquiry and cross-curriculum.

The resources are designed to help teachers to make links between industry and teaching, providing opportunities to bring science to life for children and to enhance science capital. The range of resources varies, but most include children's activity sheets, teachers' notes and additional resources such as cartoons, PowerPoints or video clips.

Our team of reviewers (all Yorkshire PSQM hub leaders on this occasion!) have reviewed a selection of resources, but it is well worth spending time exploring the full range, which can all be found in the Support for Schools area of the CIEC website, ***ciec.org.uk.***

Sustainable Stories and Solutions for our Planet

Nicky Waller and Joy Parvin (funding from Thomas Swan)
CIEC
www.ciec.org.uk
Free to download

A science investigation pack for 9-11 year-olds containing practical and discussion activities: two introductory activities and five case studies

This new publication from CIEC highlights the issues and impacts of sustainability for Upper Key Stage 2 (age 9-11) children. It contains practical activities that drive discussion, including two introductory activities to develop children's awareness and understanding of sustainability and five case study activities from companies with a strong reputation in sustainability.

The resource includes an initial survey, safety guidance throughout and links to industry regarding sustainability. It is cross-curricular and has suggested extension tasks to ensure challenge for all.

Positives: It has really clear guidance for use throughout. It is highly relevant and much needed to support learning of sustainability issues at primary level – an important subject that our children need to learn about. The hands-on activities and engaging way that the vocabulary is shared will appeal to children and encourage their curiosity.

Allowing children to build on prior knowledge, the resources are clear, with vocabulary and objectives stated as well as a glossary to develop the understanding of students. Enquiry types, guidance on time needed, a planning template and other printable resources needed are also provided. It links well to the English National Curriculum, with a focus on Year 5 (age 9-10). Independent thought, science skills and key transferable skills including discussion and collaboration are all engaged. It introduces vital issues and positive/realistic answers to sustainability issues. Developing independence is a key positive regarding these resources. Teacher notes and hints are very useful and the PowerPoint presentation that accompanies it is concise, informative and thought-provoking.

A negative for all teachers is not always having enough time to address wider curriculum issues, although it is becoming increasingly apparent that this problem must be discussed and addressed with pupils as we move forward through the climate crisis.

A thought-provoking and engaging resource, which will really support educators to build links and knowledge amongst pupils through hands-on activities, also developing an understanding of key vocabulary and the importance of protecting our environment for future generations, including their own.

Kate Sutton CSciTeach
Teacher and Science/STEM/ Careers Lead, Burlington Junior School, Bridlington.
PSQM Hub Leader – Yorkshire Coast

Kitchen Concoctions

CIEC/Joy Parvin and Nicky Waller
CIEC, Department of Chemistry, University of York
www.ciec.org.uk
Free to download
ISBN: 1 85342 608 3

Science and technology activities for 7-11 year-olds: a 79 pp resource booklet in pdf format

Kitchen Concoctions is a set of nine lesson activities focusing on mixtures that can be found in most home kitchens and how their properties make them suitable for their uses. One great thing about all the

materials that are investigated is that they are ones that will be really familiar to children, such as mince pies, squirty cream and soap, which will help them to see how their science learning relates to their own lives and may even lead to conversations at home about what they have learned.

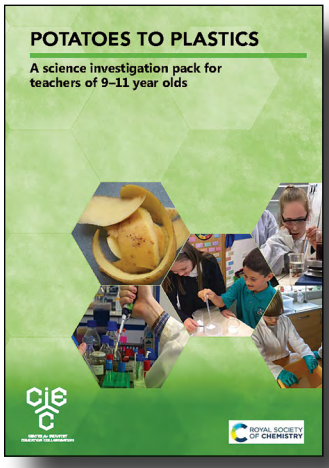
Each activity includes a brief summary that gives an overview of the activity, the learning objectives for the session and resources needed, which is then followed by a detailed explanation of how to carry out the activity. The lessons can be delivered in the sequence presented or teachers could easily pick and choose which they would like to carry out in their classrooms. Although lesson objectives are included, these could be improved by explicitly linking to the National Curriculum, but teachers who are familiar with this will be able to deduce these links themselves from the given objectives *(NB: upcoming improvements to the CIEC website from September 2021 will address this issue – Ed.)*. One key feature of the lessons are the direct links to how the science covered in each activity links to industry, which will really help teachers to explain why the processes they are carrying out are useful in the wider world and help to develop science capital. You can really tell that these have been written by those with teaching experience, as they include useful practical tips such as where to order some of the less common materials. Also really useful are the suggestions for open-ended questions to ask at different points in the session, which will really inspire rich discussion.

Kathryn Horan
Teacher and independent consultant, Pudsey Waterloo Primary School

Potatoes to Plastics

Jane Winter (Editor: Joy Parvin)
CIEC, Department of Chemistry, University of York
www.ciec.org.uk
Free to download

A 38 pp downloadable PDF activity booklet for 9-11 year-olds, incorporating all the paper resources needed to both undertake and support the activities within this investigation pack



This is a resource aimed at children aged 9-11. One of the prevailing foci is finding solutions to environmental issues, an area that many schools are researching with children of all ages. It works through a simple investigation to allow children to create a useful product from household waste. The beauty of this investigation is that the resources are easy to obtain and children will be familiar with them – potatoes! The investigation could be undertaken either in the classroom with groups of children or at home with parents and/or carers, as all the resources needed are readily available.

Key features in the activities:

- Promotes diversity within science: the scientists within the first activity are all people who a range of children could realistically aspire to be.
- A clear list of resources: the majority can be found easily either in the home or school; others can be easily sourced.
- There are several different types of enquiry types within the seven activities.
- Links to real-life problems and allows the learners to consider their own solutions after the step-by-step activities.
- A list of key scientific vocabulary.
- 'Questions for thinking' section at the end of each plan to aid the learners in using the aforementioned vocabulary.
- The children will have to be experienced in following instructions carefully to be able to make the plastic. If there are any problems in extracting the starch, this will have a knock-on effect on subsequent sessions.

The resources have clear links to the National Curriculum for Science for Year 5: properties and changes of materials; however, there are also some clear cross-curricular links to other STEM subjects. There are 7 activities within the booklet, the first three being English-based for 3 hours, and the latter science-based for between 4-7 hours. This would therefore take a good amount of time, but could not be completed in a day, as Activity 4 requires a 3-day waiting time before the next activity. This is worth using in either class or at a science club. It uses a real-world problem and allows the learners to provide a solution through science, whilst encouraging them to be 'real scientists'.

Liz Flintoft
Lecturer, McMillan School of Education @ Bradford College University Centre

IndusTRY at Home

CIEC
www.ciec.org.uk
Free to download

Why not IndusTRY AT HOME? A series of 13 downloadable science activities for children aged 7 years or older and their families to use at home

This is a series of free downloadable activities and investigations, for home use by children aged 7+, linked to industry and science in

the real world. The attractive layout, with engaging contexts, includes information to support home learning and experimentation with Working Scientifically skills embedded. Context titles include: *Investigating craters; Fun with foam; What's in a mince pie?; Pipeline shapes;* and *Fire extinguisher*. Children may need help from an adult to start before independent use. Children can invite their parents, additional adults, younger children or siblings to join them in additional challenges.

Key features in the activities:

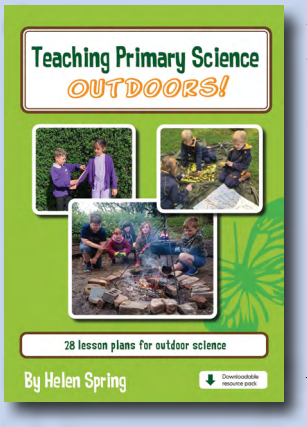
- Questions and challenges such as 'How can you solve the problem?' promote thinking and problem-solving.
- A list of resources, commonly found in the home, needed to carry out the activities.
- A word list of key vocabulary.
- 'Things to talk about' to encourage children to use and apply key science vocabulary.
- Video introductions from volunteer female engineers and science students share their job roles and set challenges for investigation (e.g. *Which Plastic?*).
- 'Watch out' warning symbols highlight any potential risks and safety measures.

If the activities are scaled up for a whole class, consideration will be needed for further risk assessment for whole-class use, including where supervision is needed. Timings may take longer in a whole-class context. There is a lot of information for pupils to process, which may need scaffolding for different learner needs. 'Things to talk about' would work well in 1-1 discussions with the teacher, other pupils or teaching assistants, or in whole-class reflection.

These resources are well worth investigating, for use at home, school, or science clubs! The range of activities and contexts linked to industry would be a great addition to different areas of the science curriculum, with the bonus of developing an interest in science and building science capital.

Mandy Hodgskinson CSciTeach
School Improvement Officer, East Riding of Yorkshire Council

New from Millgate Publishing!
Teaching Primary Science Outdoors



Author: Helen Spring
Age range: 5-11 years
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ISBN: 9780863574733
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Teaching Primary Science Outdoors is a book packed full of activities for teaching science in the outdoor environment. The lessons are designed to cover curriculum objectives and include ideas for assessment, as well as support and challenge suggestions. The lessons are suitable for most school grounds and the majority do not require resources that schools wouldn't normally have access to.

This book will inspire you to take your class outdoors, and provides some simple ideas for activities, as well as a few more ambitious outdoor science lesson ideas!

The 28 lessons each cover the following:

- Enquiry type – Which of the 5 types of enquiry is used in this lesson?
- Conceptual knowledge – Lesson objectives which support children's acquisition of knowledge.
- Working scientifically – Lesson objectives which support the development of scientific enquiry skills.
- Assessment – A description of what children meeting the objectives will be able to do.
- Resources needed – What equipment will need to be prepared in advance of the lesson?
- What to do – Ideas for how to structure the lesson.
- Assessment for learning – Formative assessment activities that can take place as part of the lesson; these can be used to inform future teaching.
- Science Capital – Suggested ideas for developing children's Science Capital as part of the lesson, or as an addition to the lesson.
- Support – Guidance for supporting children who are working below age-related expectations.
- Extension – Guidance for challenging more able children.
- Follow up – Suggested ideas for follow-up lessons.
- Key vocabulary

The book is supported by a comprehensive Pdf pack of resources and useful links.

Available from www.millgatehouse.co.uk

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The Association For Science Education is a family of teachers, trainees, technicians, consultants and academics united by a common goal: promoting excellence in science education.

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- Up to 8 user access at a heavily discounted rate*
- Subscriptions to sector-leading journals and magazines such as Primary Science and Education in Science
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- Up to 50% off in the ASE bookshop for all users
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* £130 per primary school for 8 named users or £90 for individual Primary Teacher memberships

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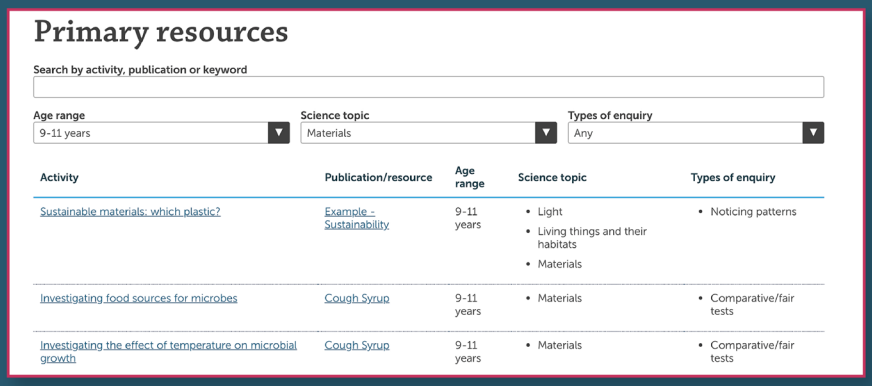
The Association for Science Education

Online free downloadable activities to:

- cover the National Curriculum for primary science and
- help build children's science capital

Search our new website to find just the activity for each term's science topics linked to real problems faced by scientists and engineers in industry!

Search via age range, science topic and keywords.



Primary resources

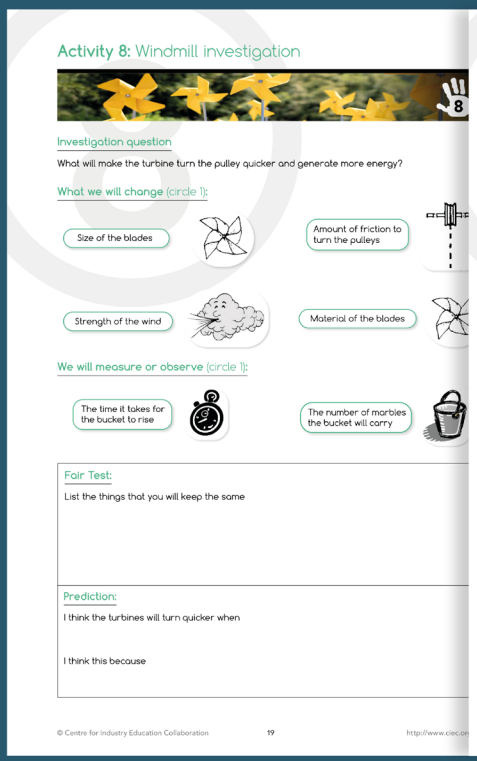
Search by activity, publication or keyword

Age range: 9-11 years | Science topic: Materials | Types of enquiry: Any

Activity	Publication/resource	Age range	Science topic	Types of enquiry
Sustainable materials: which plastic?	Example - Sustainability	9-11 years	• Light • Living things and their habitats • Materials	• Noticing patterns
Investigating food sources for microbes	Cough Syrup	9-11 years	• Materials	• Comparative/fair tests
Investigating the effect of temperature on microbial growth	Cough Syrup	9-11 years	• Materials	• Comparative/fair tests

Children's sheets support developing scientific knowledge and enquiry, from problem-solving to planning, recording and group or class discussions.

Teachers notes support real-life practical investigations and discussions to promote higher order thinking.



Activity 8: Windmill investigation

Investigation question

What will make the turbine turn the pulley quicker and generate more energy?

What we will change (circle 1):

Size of the blades | Amount of friction to turn the pulleys | Strength of the wind | Material of the blades

We will measure or observe (circle 1):

The time it takes for the bucket to rise | The number of marbles the bucket will carry

Fair Test:

List the things that you will keep the same

Prediction:

I think the turbines will turn quicker when

I think this because

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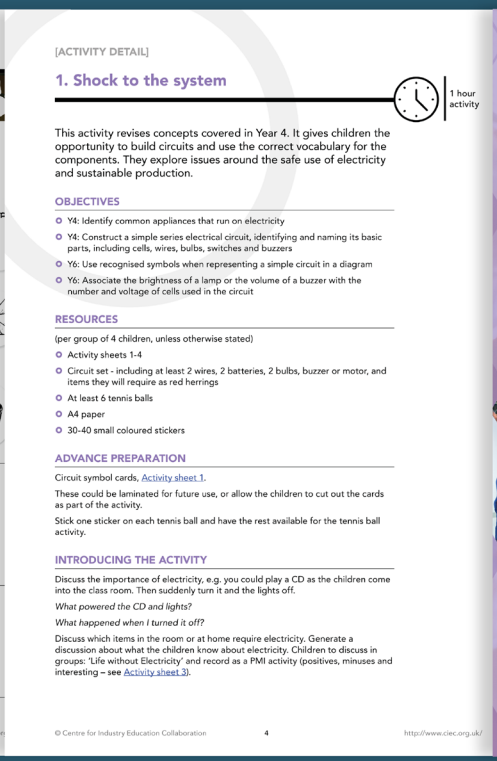

[ACTIVITY DETAIL]

1. Shock to the system

1 hour activity

This activity revises concepts covered in Year 4. It gives children the opportunity to build circuits and use the correct vocabulary for the components. They explore issues around the safe use of electricity and sustainable production.

OBJECTIVES

- Y4: Identify common appliances that run on electricity
- Y4: Construct a simple series electrical circuit, identifying and naming its basic parts, including cells, wires, bulbs, switches and buzzers
- Y6: Use recognised symbols when representing a simple circuit in a diagram
- Y6: Associate the brightness of a lamp or the volume of a buzzer with the number and voltage of cells used in the circuit

RESOURCES

(per group of 4 children, unless otherwise stated)

- Activity sheets 1-4
- Circuit set - including at least 2 wires, 2 batteries, 2 bulbs, buzzer or motor, and items they will require as red herrings
- At least 6 tennis balls
- A4 paper
- 30-40 small coloured stickers

ADVANCE PREPARATION

Circuit symbol cards, Activity sheet 1.

These could be laminated for future use, or allow the children to cut out the cards as part of the activity.

Stick one sticker on each tennis ball and have the rest available for the tennis ball activity.

INTRODUCING THE ACTIVITY

Discuss the importance of electricity, e.g. you could play a CD as the children come into the class room. Then suddenly turn it and the lights off.

What powered the CD and lights?

What happened when I turned it off?

Discuss which items in the room or at home require electricity. Generate a discussion about what the children know about electricity. Children to discuss in groups: 'Life without Electricity' and record as a PMI activity (positives, minuses and interesting – see Activity sheet 3).

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GENERATING ELECTRICITY

A science investigation pack for teachers of 7-9 year olds

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