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JES

OUTDOOR LEARNING
Taking science outside

ENGAGING CHILDREN
Links with industry

ASSOCIATION FOR SCIENCE EDUCATION

Primary Science Teaching Trust

Bridging the gap between research & practice

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See article on page 30

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About the journal

The *Journal of Emergent Science (JES)* is an 'open access' biannual e-journal designed to bridge the gap between research and practice, complementing the ASE's professional journal, *Primary Science*. *JES* was founded in 2011 by Jane Johnston and Sue Dale Tunnicliffe of the Emergent Science Network. The journal has since been transferred to ASE and is published in partnership with the Primary Science Teaching Trust (PSTT). *JES* focuses on research and the implications of research for practice and provision of science (including health, technology and engineering) for young children from birth to 11 years of age. *JES* welcomes contributions from its audience of early years practitioners, primary school teachers, teacher educators and researchers.

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Contents

Editorial

Sarah Earle

Welcome to the new look *Journal of Emergent Science!* In line with the ASE's other journals, *JES* has had a bit of a facelift. The new sleek style does not mark a change in content: we still aim to publish open-access research for, and by, our audience of early years practitioners, primary school teachers, teacher educators and researchers.

In the first article, ***Havva Gorkem Altunbas and Joy Parvin*** provide a review of research arising from the Children Challenging Industry (CCI) programme, which has been working with primary schools for nearly 30 years. Exploration of pre- and post-programme questionnaires provides insight into the children's interest in science and STEM careers after linking with local companies. The third article also explores innovative ways to work with scientists, as ***Jamila Hussain and Vince Wilson*** provide a practitioner perspective on setting up an out of school science club for local families.

Emma Whewell and Helen Tiplady take us outdoors with their pre-service primary teachers, with a participatory action research project aimed at building the skills and confidence needed to teach science outside. With training that provided both the opportunity to reflect on challenges such as risk assessment or behaviour concerns, together with the experience of learning outdoors, the project supported the pre-service teachers to experience science in a way that they could see themselves implementing in their future practice.

The final contribution is a test case for our new article type. In adding a 'collective article' to our list of *JES* options, the aim is to support more practitioner voices to be heard. A range of short (200-300 words) contributions are brought together to consider how a particular topic is enacted in different contexts. In this issue, ***Julie Horsburgh, Rachael Newham, Danielle MacLeod, Darren McTurk, Graeme Robertson, Jayne Ross and Sarah Earle*** describe stories of primary science practice from classes where children are a mix of ages. The unique nature of mixed-age classes means that each teacher's description of their context can demonstrate a different way of making it all work for the children in that class.

In this issue, we have four different article types to celebrate:

- Research Review: summary of an established project or a review of current research in the field;
- Original Research: both small-scale research and larger projects welcome;
- Practitioner Perspective: considering application of research from the viewpoint of the practitioner; and
- Collective Article: bringing together a range of perspectives from multiple authors.

Contributions for any of these article types are welcome for the next issues. Please find submission deadlines below, or get in touch to discuss ideas: s.earle@bathspa.ac.uk

Issue	Submission to editor	Review and updating	Publication
JES 29	By 5th September 2025	September/October	November 2025
JES 30	By 30th January 2026	February/March	April 2026

Professor Sarah Earle, Professor of Primary Science Education, Bath Spa University, UK.

Bridging the gap: Inspiring primary school children through the Children Challenging Industry programme

Havva Gorkem Altunbas and Joy Parvin

Abstract

The Children Challenging Industry (CCI) programme, created by the Centre for Industry Education Collaboration (CIEC) at the University of York, has been helping primary school children explore the world of science and industry since 1996. This article looks at how the programme has impacted children's attitudes towards science and industry, encouraging interest in STEM (science, technology, engineering and mathematics) careers. By connecting classroom learning to real-world experiences, the programme gives children hands-on opportunities, such as site visits to local companies and activities with STEM professionals (CCI ambassadors), to see how science works in everyday life.

This article provides an overview of the findings from the paper *Children Challenging Industry: Improving Young Pupils' Engagement with Science through Links with Industry,* published in the *International Journal of Science Education*. The study involves 508 pupils aged 9-11 from schools in the North East and East of England regions. Drawing on data collected during the 2019–2020[1] academic year (Bórquez-Sánchez *et al*, 2024), the study emphasises the importance of introducing children to science and industry at an early age. Through questionnaires completed before and after the programme, the findings show that children gained confidence in science, developed a greater interest in STEM careers, and enjoyed learning through hands-on activities and visits to local companies. Interacting with real scientists and engineers helped children to understand how science works in everyday life, sparking curiosity and breaking down stereotypes about who can work in STEM. By fostering connections with industry, CCI shows how schools and companies can work together to inspire the next generation of scientists and engineers. Practical recommendations for teachers and programme organisers are also shared.

Keywords

Attitudes towards science, industry collaboration, hands-on learning, science capital

Introduction

Since 1996, the Children Challenging Industry (CCI) programme, led by the Centre for Industry Education Collaboration (CIEC) at the University of York, has been bringing science to life for primary school children. By linking classroom learning with real-world industry, the initiative helps children to see how science is relevant to their

[1]For the most recent and comprehensive evaluation of the CCI programme's impact on science education, please refer to the evaluation reports available at https://www.york.ac.uk/ciec/research/

everyday lives and opens their eyes to potential careers in science, technology, engineering and mathematics (STEM). Through activities such as site visits to local companies, hands-on activities, and sessions with CCI ambassadors, children are given opportunities to experience the roles of scientists and engineers first-hand. Teachers also benefit from the programme, gaining practical strategies to enhance their science teaching and make the subject more engaging for their pupils. This article provides an overview of the findings from the paper *Children Challenging Industry: Improving Young Pupils' Engagement with Science through Links with Industry*, published in the *International Journal of Science Education*. The data presented were collected during the 2019–2020 academic year (Bórquez-Sánchez *et al,* 2024). By reflecting on these outcomes, the article aims to highlight the significance of such initiatives in inspiring children and addressing the skills gap in STEM fields.

Theoretical context

Understanding pupils' engagement with science requires considering multiple factors beyond their academic performance or conceptual knowledge. Attitudes towards science and awareness of STEM careers play a crucial role in shaping future aspirations (Archer *et al,* 2015; Osborne *et al,* 2003). Engaging children in science during their early years is crucial for shaping their attitudes, interests and aspirations. Research shows that children often form their perceptions of subjects such as science and potential career paths well before secondary school and, without positive experiences, many may view science as intimidating, irrelevant, or 'not for them' (Archer *et al,* 2010; Sheldrake & Mujtaba, 2020).

"Inspiring children to see the relevance of science in their lives helps to build 'science capital', a combination of knowledge, attitudes and connections that make science accessible and relatable."

Building science capital and positive attitudes towards science

Inspiring children to see the relevance of science in their lives helps to build 'science capital', a combination of knowledge, attitudes and connections that make science accessible and relatable (Archer *et al,* 2015). This is particularly important for children who may not have exposure to science-based careers through their family or community. CCI aims to address this by making science tangible, exciting and tied to real-world applications. Moreover, introducing children to the variety of roles within STEM industries, from engineers and chemists to environmental scientists, can challenge stereotypes and broaden their understanding of what careers in science can look like (Vossen *et al,* 2023). For instance, seeing scientists and engineers who reflect diverse genders, ethnicities and backgrounds can help children to envision themselves in similar roles, breaking down barriers of perception (Archer & DeWitt, 2016). Beyond career aspirations, developing a positive attitude towards science equips children with the skills and confidence to engage with scientific issues as informed citizens (Osborne *et al,* 2003).

Gender differences in science engagement remain a significant issue. Research shows that girls often develop less confidence in their scientific abilities due to implicit gender stereotypes, parental and teacher expectations, and the perception that some science subjects such as physics are more suited to boys (DeWitt & Archer, 2015); Makarova *et al,* 2019). Many children, from a young age, associate scientists with men and view science careers as challenging, or even risky (Scholes & Stahl, 2022). These attitudes can shape subject choices and career aspirations, leading fewer girls to pursue STEM-related fields (Denessen *et al,* 2015). However, hands-on learning experiences, exposure to role models and making science relevant to everyday life can encourage more girls to pursue STEM (Archer & DeWitt, 2016; Forbes & McCloughan, 2010; Oon *et al,* 2020).

In an increasingly complex world, understanding topics such as sustainability, technology and innovation is vital for making informed decisions. Early inspiration lays the foundation for lifelong curiosity and critical thinking, qualities that benefit individuals and society alike (Sheldrake *et al,* 2024). CCI takes a proactive approach to sparking this interest, ensuring that children not only learn science but also see its value and relevance in the world around them.

Children Challenging Industry programme

CCI is a science education programme designed for primary school children and teachers, in collaboration with STEM companies. It focuses on engaging 9-11 year-olds through hands-on, real-world problem-solving activities while offering professional development for teachers. The programme connects schools with local science-based manufacturing companies through site visits or by bringing industry professionals into the classroom. A dedicated advisory teacher provides support, training and classroom activities for both teachers and industry volunteers. By incorporating industrial contexts, the programme enriches pupils' understanding of scientific practices and subject knowledge aligned with the English National Curriculum. Its primary goal is to enhance pupils' attitudes, motivation and enjoyment of science while introducing them to the work of scientists and engineers. Through hands-on science activities, site visits to STEM companies, and interactions with STEM professionals from industry (CCI ambassadors), CCI helps children to see science in action, making it more tangible, relatable and inspiring. By meeting scientists and engineers from diverse backgrounds, students can challenge stereotypes about who can work in STEM, broadening their career aspirations (Archer & DeWitt, 2016). The CCI programme provides practical tools for teachers and experiences that help students to see science as something that they can belong to and succeed in.

Each school-industry partnership creates a specific blend of classroom activities and site visits. For instance, children may work on challenges from the CIEC publication *Water for Industry*[2], such as selecting materials for pipelines, filtering river water, or cooling large tanks of hot liquids (see Image 1). An example of a subsequent site visit may be one where children meet engineers, scientists and technical apprentices, and observe heat exchangers, sensors and filtration systems (see Image 2).

▼**Image 1** *Water for Industry* classroom activity.

▼**Image 2** Site visit following the *Water for Industry* classroom activities.

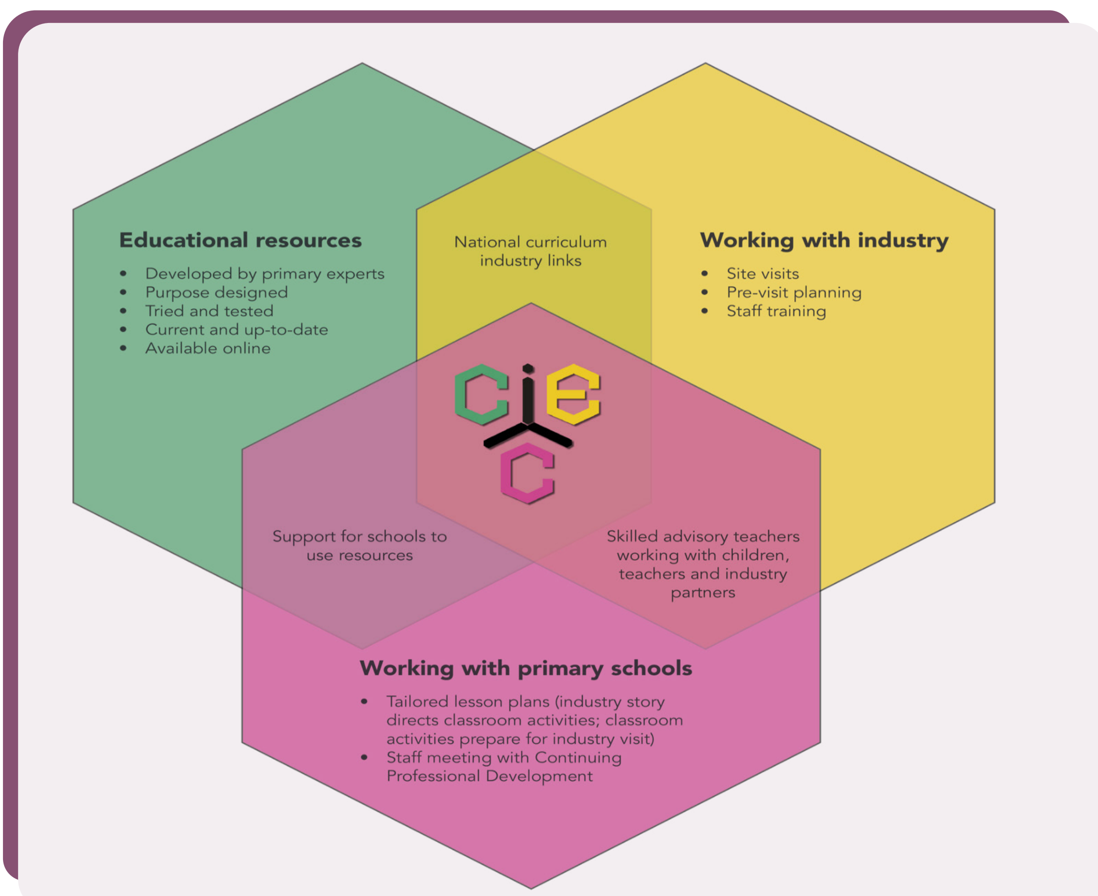
[2]Further details on Water for Industry activities can be found at https://www.york.as.uk./ciec/resources/primary/water-for-industry

This combination of activities is carefully designed by the advisory teacher, who visits the company's site in advance to determine accessible opportunities for children. Selected activities are shared with each company's CCI ambassadors as part of their training, ensuring a meaningful connection between the classroom and the workplace.

The CCI programme's structure (Figure 1) includes elements highlighted as effective practices for engaging schoolchildren in promoting industry, as noted in the *Chemistry Council Sector Deal Report 2019* (Society of Chemical Industry, 2019). It also aligns with the Royal Society's vision for science education, advocating for stronger links between professional organisations and school education (The Royal Society, 2018). To this end, the programme offers tailored teacher training, specialised materials and professional site visits. CCI ambassadors involved in the programme aim to positively shape pupils' perceptions of science, echoing research by Forbes and Skamp (2013) that highlights the role of scientists in influencing children's attitudes towards science.

Figure 1 illustrates the structure of the CCI programme, showcasing its three key components: educational resources, industry collaboration, and primary school engagement. It highlights how these elements combine to connect the National Curriculum with real-world STEM applications, supported by CCI advisory teachers and CCI ambassadors. The overlapping sections emphasise the programme's integrated approach to enhancing science education for children.

▼ **Figure 1** CCI framework: Summary of key elements and influences on curriculum-linked teaching for effective learning in science (Bórquez-Sánchez *et al*, 2024).



Methodology

Research questions
The aim of this paper is to investigate the impact of the CCI programme and its components on children's attitudes towards science and industry. Specifically, the research questions are:

1. What is the impact of the CCI programme and its components on pupils' attitudes towards science?
2. What is the impact of the CCI programme and its components on pupils' attitudes towards, and knowledge of, industry, including about STEM careers in industry?
3. Are there gender differences in pupils' responses to the programme?

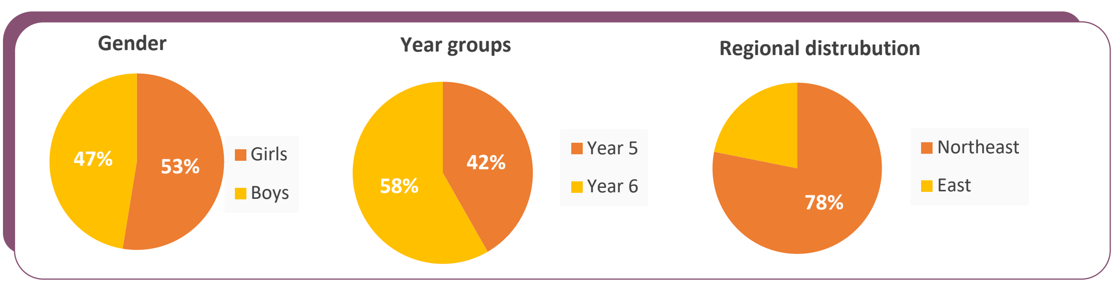
Recruitment and data collection
This study focused on 23 schools in the North-East (NE) and East of England (EE) during the 2019-2020 academic year. Schools were selected based on:

- Their level of participation in the programme since 1996; and
- Their representation of diverse socio-demographic characteristics, including children from various ethnic and socio-economic backgrounds, particularly those from disadvantaged areas.

Ethical approval was obtained, and parents were given the opportunity to opt out. Children completed online pre- and post-intervention questionnaires during school hours. Only responses from children who participated in both surveys were included in the analysis. The COVID-19 pandemic disrupted data collection from mid-March 2020, leading to refinements in programme delivery and evaluation methods. These adjustments have implications for the analysis and comparison of data.

Participant demographics
A total of 508 children from Years 5 and 6, aged 9-11, participated in the study. The gender distribution included 267 girls (52.6%) and 241 boys (47.4%). In terms of year groups, 212 participants (41.7%) were in Year 5, while 296 (58.3%) were in Year 6. Regarding regional distribution, the majority of participants, 397 children (78.1%), were from the North East (NE), with the remaining 111 (21.9%) from the East of England (EE) (Figure 2).

Figure 2 Demographic breakdown of the participants: gender, year group, and regional distribution.



Response rates varied across questions, as not all participants answered every item.

Instrument design
The questionnaire items were developed over many years, initially inspired by semi-structured interview schedules used in focus group interviews conducted between 1996 and 1999. The responses from these interviews were carefully categorised, forming the foundation for the questionnaire items. Over time, various researchers contributed to and refined these items, creating a robust tool with which to assess primary school pupils' attitudes towards science

and industry. Care was taken to avoid ambiguity and culturally inappropriate phrasing, as well as to use clear, age-appropriate language.

The design of the questionnaire was informed by multiple sources, ensuring that it aligned with established frameworks for measuring attitudes toward science, such as the science capital dimension from the ASPIRES project by Archer *et al* (2013).

Additionally, items were inspired by the ROSE project (Sjøberg & Schreiner, 2010), the Attitudes to Science and School Science project (Bennett & Hogarth, 2009), PISA attitude measures (OECD, 2016), and prior CCI reports dating back to 1996. To further refine the questionnaire and minimise bias, the structure followed Pell and Jarvis's (2001) guidelines for investigating primary school children's views on science, ensuring that Likert-scale items were developmentally appropriate for pupils aged 9-11.

The questionnaires included Likert-scale items and were refined through factor analysis to ensure reliability. The pre-programme questionnaire (20 items) measured pupils' attitudes and engagement with science and industry, while the post-programme questionnaire (26 items) included reflections on their programme experiences.

Data analysis

Quantitative responses were analysed using statistical software, focusing on changes in attitudes before and after the programme:

- Likert-scale items were scored and reverse-coded when necessary.
- Reliability of the questionnaires was assessed using Cronbach's alpha.
- T-tests and one-way ANOVAs examined changes and differences by participant characteristics.

Qualitative data from open-ended questions were analysed to identify recurring themes, providing insights into pupils' lived experiences and local social realities.

Results

This section summarises the quantitative and qualitative data collected from children who completed both the pre- and post-intervention questionnaires. The analysis focuses on understanding children's attitudes towards science and industry, examining how the CCI programme interventions influenced these attitudes and their perceptions of STEM careers. The findings provide insights into the effectiveness of the programme in promoting interest and engagement in science-related fields.

"The findings provide insights into the effectiveness of the programme in promoting interest and engagement in science-related fields."

Quantitative results

This section presents the quantitative findings from the study, examining how the CCI programme influenced pupils' attitudes towards science and industry. It explores changes in pupils' engagement, confidence and career aspirations.

Attitudes towards science

To evaluate how the CCI programme influenced pupils' attitudes towards science, we used a carefully designed 'Attitudes to Science' scale. A total of 453 pupils who completed both pre- and post-programme questionnaires were included in the analysis.

Our findings showed that the CCI programme had a positive impact on pupils' perceptions of science. There was a significant improvement in their overall attitudes towards science after participating in the programme. For instance, many pupils expressed a stronger interest in science as a subject, with notable increases in the number who identified science as their favourite subject, or saw themselves pursuing a career as a scientist. Additionally, pupils' confidence in their ability to engage with science improved, as fewer described science as being too difficult or overly focused on writing tasks.

Individual questionnaire items provided further insights into these changes. Statements such as *'Science is my favourite subject'* and *'I'd like to be a scientist'* saw the greatest increases in positive responses, with the former rising by 11.5 percentage points and the latter by 8.6 percentage points (Figure 3). Conversely, negative statements, such as *'We do too much writing in science'*, showed a decrease in agreement, reflecting a shift towards more positive attitudes overall (Figure 4).

Figure 3 Attitudes to science and science learning: statements representing positive concepts.

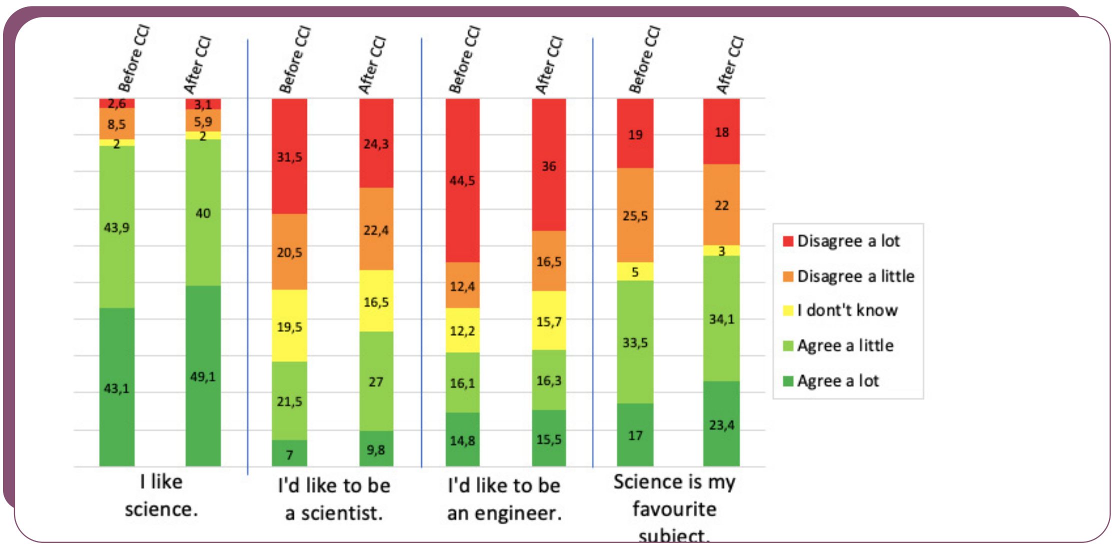
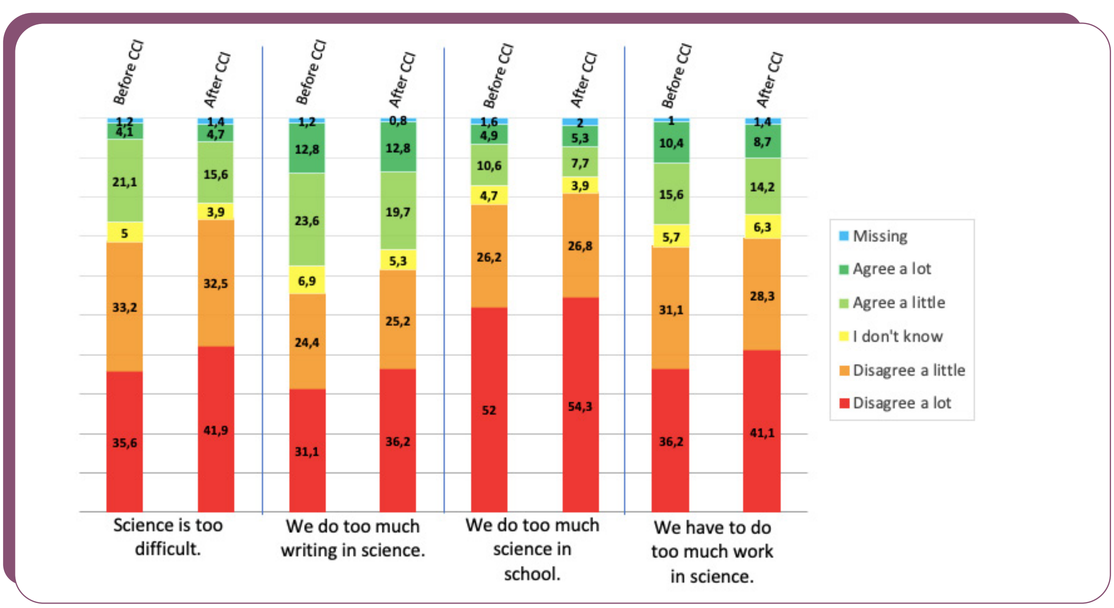


Figure 4 Attitudes to science and science learning: statements representing negative concepts.



These results suggest that the CCI programme helped pupils to not only enjoy science more but also perceive it as more accessible and engaging. Figure 4 shows how children's attitudes towards science changed before and after taking part in the CCI programme.

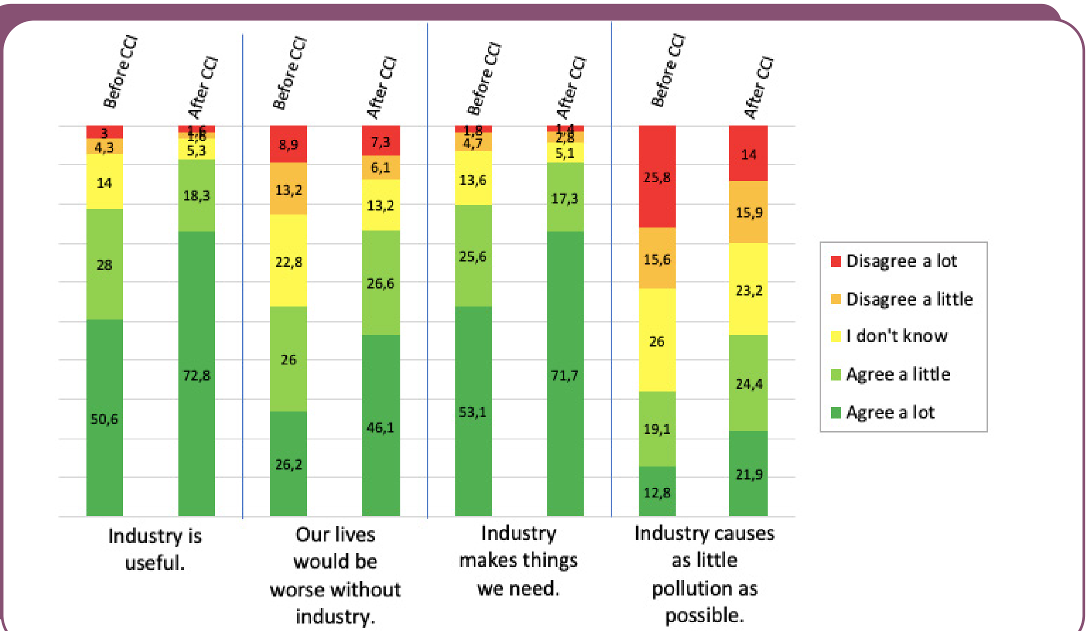
After the programme, fewer children felt that 'science is too difficult', or that 'we do too much writing in science', which suggests that the activities helped to make science feel more approachable and engaging. There were also slight improvements in how children viewed the amount of science and work that they had to do, showing that the programme might have made science feel less overwhelming and more enjoyable overall.

Attitudes towards industry

In addition to examining pupils' views on science, the programme also explored their attitudes towards industry. An 'Attitudes to Industry' scale was used, focusing on pupils' perceptions of the role of industry in their lives, its benefits and challenges, and the contributions of scientists and engineers.

The findings show that the CCI programme significantly increased pupils' awareness of the relevance of industry and its potential as a career pathway. After participating, more pupils recognised the importance of industry in their everyday lives, with responses to the statement '*Industry is useful*' increasing by 33.5 percentage points (Figure 5).

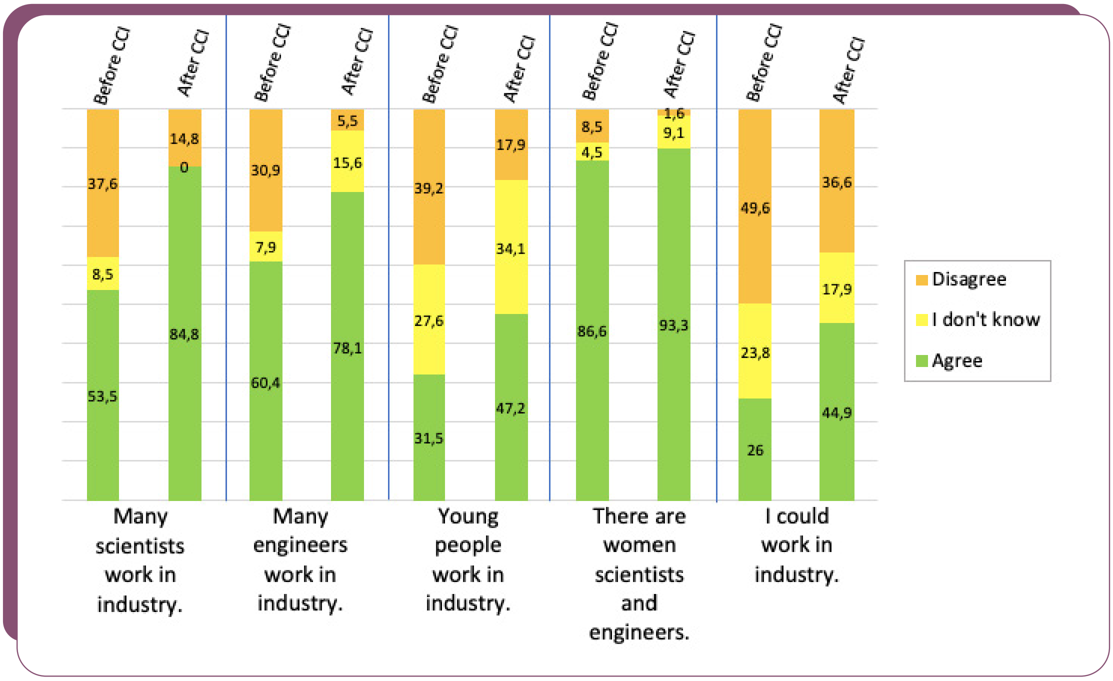
Figure 5 Attitudes towards and learning about industry (5-point Likert-scale items): statements representing positive concepts.



Similarly, the statement '*I could work in industry in the future*' saw an 18.9 percentage point rise in agreement. These changes highlight how the programme broadened pupils' understanding of industry's role and its connection to science and engineering (Figure 6).

The data also showed a significant improvement in pupils' knowledge of careers in industry. For example, agreement with '*Many scientists work in industry*' rose by 31.3 percentage points, reflecting the programme's effectiveness in exposing pupils to real-world STEM roles. The inclusion of diverse role models, such as younger professionals and women in engineering and science, appeared to challenge traditional stereotypes. This was evident in the increased agreement with statements such as '*There are women scientists and engineers working in industry*', which saw a moderate increase (Figure 6).

Figure 6 Attitudes and knowledge about the [careers in] industry (3-point Likert-scale items, before and after CCI).



Gender differences

The impact of the programme varied across different groups. Both boys and girls benefited from the intervention, but boys showed greater improvement in recognising the presence and contributions of women in STEM careers. This helped to narrow the initial gender gap in perceptions of diversity in industry. This finding is significant because it directly challenges the stereotype that STEM careers are primarily for men. While girls already had relatively high agreement with statements about women's roles in science and engineering, boys demonstrated a much larger increase in their recognition of female contributions post-programme. By exposing all pupils to diverse role models and real-life examples of women working in STEM, the programme helped to reshape boys' perceptions, making them more aware of the inclusive nature of science and engineering.

Regional differences were also observed. Pupils in the East of England, who had less exposure to industry before the programme, showed the largest improvements. For example, their agreement with *'Many engineers work in industry'* increased sharply compared to pupils in the North-East, who had a higher baseline awareness of industry. This suggests that the CCI programme is particularly impactful in regions with less prior exposure to STEM opportunities.

Qualitative results: Understanding pupils' experiences

This section explores the qualitative data collected from pupils' open-ended responses about their experiences with the CCI programme. A total of 948 comments were analysed to understand what pupils enjoyed most and least, providing deeper insights into how the programme influenced their attitudes to and knowledge of science, industry and STEM careers.

Influence of the CCI programme on pupils' attitudes and knowledge

The CCI programme had a profound impact on pupils' attitudes towards science and industry. Many pupils described their enjoyment of science both before and after participating in the programme, though some acknowledged that it had not always been engaging or easy. Positive comments about enjoying science at school or home before the programme made up 72% of responses, while 9% noted that science could occasionally feel challenging or less engaging.

The qualitative responses highlight how the programme further improved pupils' enthusiasm for science. For instance, pupils expressed a newfound excitement about conducting experiments and learning through practical activities:

> *'I think science is interesting and fun as it makes me intrigued to know more'* (Girl, EE).
> *'We don't do much writing in science, but I honestly would like to do more science experiments and write about it'* (Boy, NE).

What pupils enjoyed most

The hands-on nature of the CCI programme was a key factor in its success. Pupils frequently mentioned the activities (57%) and the visits to or interactions with industry partners (28%) as the most enjoyable aspects. Many pupils recalled specific activities or experiences that left a lasting impression:

> *'I enjoyed creating hydrogel because the progress was good, and I LOVED putting my hands in the bowl!'* (Boy, NE).
> *'I enjoyed going to the industry and seeing all of the machines, robots, and learning what [the company] do'* (Girl, EE).

Overall, 69% of pupils chose to mention learning something specific from these experiences, demonstrating the programme's ability to make science and industry tangible and relatable.

Learning about science and industry

The programme introduced many pupils to the concept of industry, which was unfamiliar to them beforehand. Pupils gained a clearer understanding of STEM careers and the roles of scientists and engineers. For some, the programme confirmed their existing interests, while for others, it sparked new aspirations:

> *'I most enjoyed getting to learn what all the different scientists' roles were and how they all impact [...] our lives today'* (Girl, EE).
> *'I loved visiting [the industry] because it really caught my attention and I really, really want to be a scientist when I am older'* (Girl, NE).

The programme helped many pupils to see the relevance of science and industry to their lives, even if they did not intend to pursue STEM careers. However, for a few (6%, or 24 pupils), some activities were described as 'hard' or 'confusing', suggesting areas where additional support or clarity might enhance the experience.

The qualitative findings underscore the importance of hands-on, practical learning in engaging pupils with science and industry. Activities, industry visits, and direct interaction with CCI ambassadors made abstract concepts more concrete and exciting. For many pupils, the CCI programme expanded their understanding of science and introduced new possibilities for their futures, even if they did not see themselves pursuing a STEM career. The combination of active participation and exposure to CCI ambassadors allowed pupils to make stronger connections between classroom learning and real-world science and reinforced their confidence and ability to engage with scientific concepts.

These insights suggest that integrating practical activities and industry partnerships into the curriculum can improve both engagement and learning outcomes. By providing opportunities for pupils to apply knowledge in meaningful ways, such approaches help to make science more accessible and enjoyable for a wide range of learners. Teachers and programme organisers should continue to offer clear guidance and structured support during activities to ensure that all pupils, regardless of background or confidence level, can benefit fully from these experiences.

"The programme introduced many pupils to the concept of industry."

General discussion and implications

Engaging pupils in STEM education at an early age is a key strategy to enhance their confidence, skills and interest in science, technology, engineering and mathematics. Research shows that early exposure to STEM can lead to a greater likelihood of pursuing related careers, help reduce inequalities, and improve overall attitudes towards science within society (Archer *et al,* 2013; Maltese & Tai, 2011). However, enjoyment alone is not enough to sustain engagement or lead to deeper learning. While hands-on activities and industry visits can make science more exciting and relatable, research has shown that these experiences must also be structured to promote conceptual understanding and long-term retention (Abrahams & Sharpe, 2010). Simply making science 'fun' does not necessarily translate into lasting knowledge gains or career aspirations (Archer *et al,* 2010; Fernandez *et al,* 2023). Instead, practical experiences should be purposefully designed to reinforce key scientific concepts and critical thinking skills, ensuring that pupils not only enjoy STEM but also develop a strong foundation for future learning (Fernandez *et al,* 2023).

"The presence of female engineers and scientists during visits and classroom activities played a crucial role in showing pupils that STEM professions are viable options for everyone, regardless of gender."

In line with these findings, our study highlights the positive impact of the CCI programme on primary school-aged pupils, particularly in helping them to understand how science and technology are used in real-world settings. While existing STEM-industry collaborations often target secondary school pupils, this programme demonstrates the value of focusing on younger children. By involving teachers, schools and local companies, the programme fosters an appreciation for the practical applications of science, linking it to careers and industries within pupils' communities. The study's results align with Demirhan and Şahin (2021), who found that pupils benefit most from hands-on learning and real-world problem-solving in science education. This approach resonates with Wolcott's (1991) idea that learning should be viewed as acquiring culture, connecting children to the practices and knowledge of the scientific and industrial communities around them.

Gender differences in science interest and engagement are well-documented (Toma *et al,* 2019; Weinburgh, 2000). In this study, both boys and girls demonstrated improved understanding and attitudes towards STEM careers, particularly regarding the presence of women in science and engineering. While the changes were greater for boys, the programme helped to challenge traditional gender stereotypes by exposing all pupils to diverse role models in STEM. The presence of female engineers and scientists during visits and classroom activities played a crucial role in showing pupils that STEM professions are viable options for everyone, regardless of gender. This aligns with Jerrim and Schoon's (2014) assertion that encountering diverse role models can influence pupils' career aspirations.

Theoretical and practical implications

The findings of this study point out the importance of integrating real-world contexts into STEM education, both for those who may pursue STEM careers and for those who will benefit from understanding science's societal implications in other fields.

The CCI programme serves as a model for building pupils' science capital, a relatively recent concept that encompasses science-related knowledge, resources and attitudes (Archer *et al*, 2015). By providing classroom activities, teacher training and collaborations with local companies, the programme enables children, particularly girls, to see science in action and consider careers that they may not have previously imagined.

This approach aligns with previous research by Forbes and Skamp (2013), which emphasises the positive influence of scientists and engineers on children's attitudes towards science. The programme also addresses a gap in science-industry initiatives at the primary level, delivering resources and activities fully aligned with the curriculum. Teachers are supported through training, pedagogical resources and industrial partnerships, ensuring that science topics are effectively introduced and taught.

Practical recommendations for teachers

1. **Integrating real-world applications**: Teachers can endeavour to link science lessons with practical, real-world examples to make science concepts more relatable. Visits to industrial sites and interactions with STEM professionals can inspire pupils and provide them with tangible career pathways.

2. **Providing diverse role models**: Exposure to diverse professionals in STEM, particularly women and younger role models, helps to challenge stereotypes and encourage inclusivity in science and engineering careers. Teachers can use resources such as:
   a. Primary Science Teaching Trust's (PSTT) *A Scientist Just Like Me (ASJLM)* to introduce pupils to diverse real-world scientists in an engaging and relatable way (https://pstt.org.uk/unique-resources/a-scientist-just-like-me/).
   b. nuSTEM's scientists' resources, which showcase a variety of STEM careers with downloadable classroom activities (https://nustem.uk/resources/).
   c. Career cards, designed by CIEC to be used alongside a PowerPoint presentation with 9-11 year-olds to raise their awareness of the range of STEM careers open to them, career opportunities available in industry and the advantages of studying STEM subjects when they are older (https://www.york.ac.uk/ciec/resources/primary/career-cards/).

3. **Enhancing curriculum resources**: Programmes such as CCI should focus on developing high-quality, curriculum-aligned resources that are designed for classroom use. These resources should complement experiential learning activities, such as school trips and investigations. CIEC provides free, research-informed STEM teaching resources, which can be accessed online at https://www.york.ac.uk/ciec/resources/.

4. **Supporting teacher training**: Continuous professional development for teachers is essential to ensure that they feel confident in delivering STEM lessons that incorporate industry contexts. Training should include practical strategies for engaging pupils in hands-on activities and integrating STEM careers into the curriculum.

> **"This study contributes to the limited evidence on STEM programmes for primary-aged pupils."**

Contribution to STEM education

This study contributes to the limited evidence on STEM programmes for primary-aged pupils. The findings demonstrate that programmes like CCI not only enhance classroom interactions but also provide valuable training and resources for teachers. These initiatives are particularly effective in fostering positive attitudes towards STEM careers and equipping pupils with the skills and confidence to consider future opportunities in science, technology and engineering. By addressing both theoretical and practical challenges, the CCI programme offers a blueprint for engaging younger learners in STEM, ultimately helping to build a more inclusive and scientifically literate society.

Limitations and future directions

The limitations identified in this study fall into two main areas. Firstly, the participating schools represent a self-selected group from those offered the programme, which may mean that the full diversity of ethnic groups and socio-economic backgrounds in the region is not fully captured. This could have influenced the analysis by overlooking groups that might require additional support, or by not accounting for certain external factors. Secondly, the study did not include follow-up with science teachers after their participation in the CCI programme. As a result, it was not possible to gather evidence on how the full set of resources influenced their classroom practices in the long term, making it harder to assess sustained changes in teaching methods.

To address these limitations, we are currently working on several ongoing studies aimed at exploring these aspects further. For instance, efforts are being made to involve a more diverse range of schools to ensure better representation of different ethnic groups and socio-economic backgrounds. We are also conducting follow-up studies with teachers who participated in the CCI programme to examine how they integrate the resources into their teaching practices over time. These longitudinal studies aim to capture the long-term impact of the programme, including changes in teaching strategies and the effects on pupils' engagement and learning outcomes.

Conclusions

This article presents a summary of the findings from the study *Children Challenging Industry: Improving Young Pupils' Engagement with Science through Links with Industry*, published in the *International Journal of Science Education*. The data, collected during the 2019–2020 academic year (Bórquez-Sánchez *et al*, 2024), highlight the programme's impact on young pupils' engagement with science and industry.

This study concludes that the CCI programme has a positive impact on pupils' attitudes towards science and industry. Participants reported increased engagement and knowledge, particularly in areas where they previously had limited exposure. The hands-on activities and connections with CCI ambassadors helped to demystify STEM careers and foster a sense of curiosity and possibility among pupils.

The programme also provided primary teachers with new approaches to teaching science, supported by advisory teachers. These approaches encouraged innovative classroom interactions and linked industry-relevant activities with the curriculum.

Our findings suggest that the interconnected design of the CCI programme, integrating classroom-based learning, teacher training and industry partnerships, can serve as a model for developing future science-industry collaborations. By addressing the identified limitations, such programmes have the potential to generate even more consistently positive outcomes for pupils, ultimately enhancing their attitudes and aspirations towards STEM.

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Original Research

Taking science outside: Supporting primary teacher trainees' skills in effective outdoor learning and teaching

Emma Whewell and Helen Tiplady

Abstract

Outdoor learning offers a wide range of benefits for children, from enhancing their physical and mental health, to enhancing creativity, to improving their social skills and sense of place (Whewell & Allan, 2023). However, many primary trainee teachers feel hesitant about teaching science outside the classroom due to concerns about safety, limited resources and the challenges of planning for outdoor learning.

This participatory action research (PAR) project was a partnership between the University of Northampton and Teach Outdoors Ltd., an industry partner supporting this research endeavour. Teach Outdoors Ltd. aims to provide schools and educators with the training and support that they need in order to ensure that all children can reap the benefits of the outdoor environment. Together we sought to address these concerns by helping primary Initial Teacher Education (ITE) students to build the confidence and skills needed to make outdoor learning a natural part of their science teaching.

The programme combined practical workshops and online training, followed by the students leading an outdoor learning session during school placements. The training provided participants with the tools that they needed to navigate challenges, such as risk assessments and managing behaviour in outdoor settings. By exploring creative ways in which to use outdoor spaces, the training empowered students to see the unique opportunities that these environments offer to engage and inspire learners.

After completing the training, participants reported feeling more prepared and enthusiastic about taking their science teaching outdoors. They also experienced how outdoor learning helps children to develop essential skills such as problem-solving, resilience and creativity. By incorporating outdoor learning into teacher training, this project demonstrated how we can prepare future educators to create meaningful, memorable learning experiences that go beyond the classroom walls and focus upon eco-centric educational experiences.

Keywords
Outdoor learning, confidence, participatory action research (PAR), initial teacher education, early childhood studies, experiential learning, science education

Introduction

Outdoor learning offers significant benefits for children, including improvements in physical development (BERA/TACTYC, 2014; Fjørtoft, 2004), creativity, physical and mental wellbeing (Knight, 2011; Sutterby & Frost, 2006), and language development (Richardson, 2014; Richardson & Murray, 2016). Despite this, many educators lack confidence in teaching outside the classroom due to concerns about safety, resource availability and planning (Barrable *et al*, 2022). This project aimed to address these barriers by providing education students with a training programme designed to build their knowledge, skills (disciplinary and pedagogical) and, ultimately, confidence in utilising outdoor spaces effectively.

This project introduced 17 primary ITE students to practical strategies for outdoor learning. These were designed with the students by Teach Outdoors Ltd. The training was designed using data from pre- and post-training surveys and focus groups with the participants. The goal was to empower future teachers to integrate outdoor learning into their professional practice and create enriching, real-world learning experiences for children. This paper focuses upon the teaching of science outdoors as part of a larger project that offered training and experience in a range of primary curriculum areas.

Context and challenges

The science National Curriculum for primary school-aged children in England encourages teachers to ensure that their provision *'allows children to experience and observe phenomena, looking more closely at the natural and humanly-constructed world around them'* (DfE, 2013, p.5) and that *'most of the learning about science should be done through the use of first-hand practical experiences'* (p.5).

Outdoor learning in science offers an opportunity to move beyond the transactional delivery of curriculum content and engage children in transformative, experiential learning. Specifically, in primary schools in England, children should be taught substantive and disciplinary knowledge (Ofsted, 2021) throughout their learning, for example using their local environment throughout the year to observe and name a variety of plants, trees and animals in their locality. They should engage in activities that allow them to understand habitats and changes over time in plants and animals, encouraging 'working scientifically' in their thoughts, questions and exploration of their local environment.

In England, outdoor learning is not consistently integrated into the curriculum, particularly beyond early years education (Leather, 2018). Many schools struggle with limited outdoor space, resources and tight timetabling schedules that further restrict opportunities for outdoor learning (Davy, 2016). Additionally, educators may lack the training and confidence needed to address logistical and safety concerns, manage behaviour, and align outdoor learning with curriculum goals (Gill, 2010).

This project's training programme addressed these challenges by equipping ITE students with practical tools, pedagogies and strategies to plan, lead and evaluate outdoor learning activities. It emphasised the importance of overcoming barriers and highlighted the potential of outdoor learning to enhance student subject knowledge (DfE, 2013), engagement and wellbeing (Waite & Pratt, 2017).

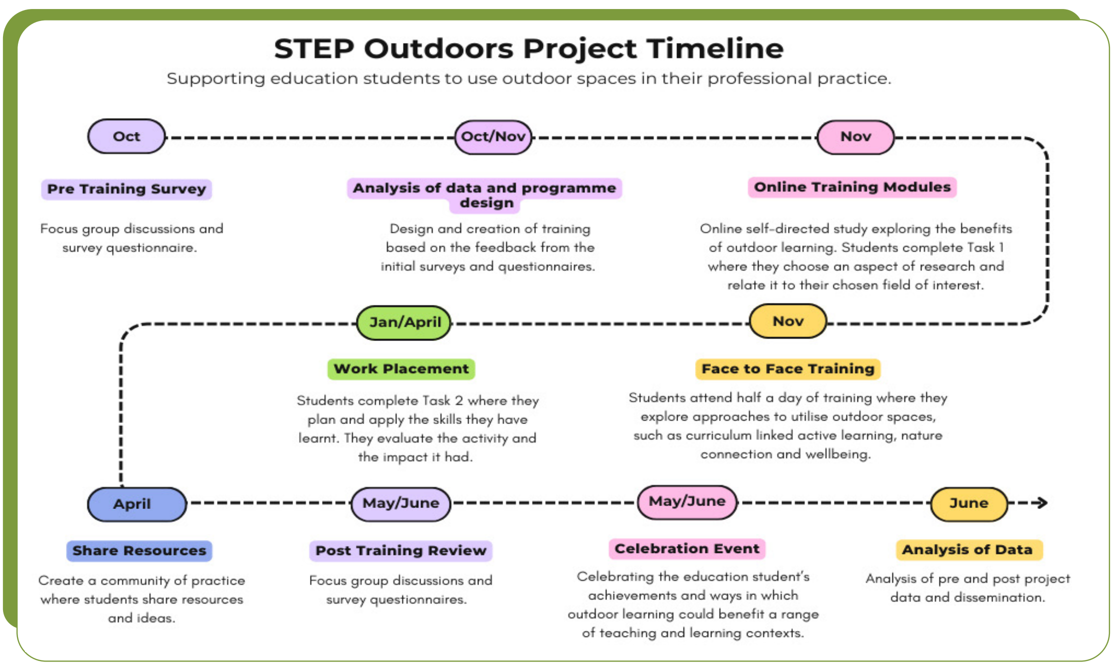
Training approach

The project adopted a participatory action research (PAR) approach, engaging 17 ITE second-year students as active participants in designing and refining the training programme (Robson, 2024). The 17 students responded to a call for volunteers from the second year of the BA Primary Education degree programme. The second years have compulsory placements in the summer term, which aligned well with the project timeline. PAR prioritises collaboration, in this case between the project team and the ITE students. This methodology removes power relationships and values all participants' input in any research, with the aim of improving practice through iterative feedback and mutual learning (Kindon *et al*, 2010). PAR studies of this type use self-reported data, and this has challenges based on an individual's prior experiences and contexts. Although not widely generalisable, they provide suitable and helpful data for a study of this type.

The training included:

- An initial focus group to identify participants' concerns and prior experiences with outdoor learning (Figure 1);
- A blended training course featuring online modules and hands-on practical workshops led by Teach Outdoors Ltd.; and
- Opportunities for students to implement their training during school placements, followed by reflective focus groups to evaluate their experiences and offer suggestions for the next iteration of the training programme.

Figure 1 Timeline and design of the project.



Pre-training findings (survey and focus group)

The focus group and survey included questions relating to general outdoor learning principles and then specific questions related to the primary education subjects, mathematics, English and science. Initially, we asked the trainees to rate their general confidence in outdoor learning. Tables 1 and 2 demonstrate that participants indicated a general lack of confidence in taking teaching and learning outside and the planning required to do so.

Table 1 How confident are you to take teaching and learning activities outdoors generally?

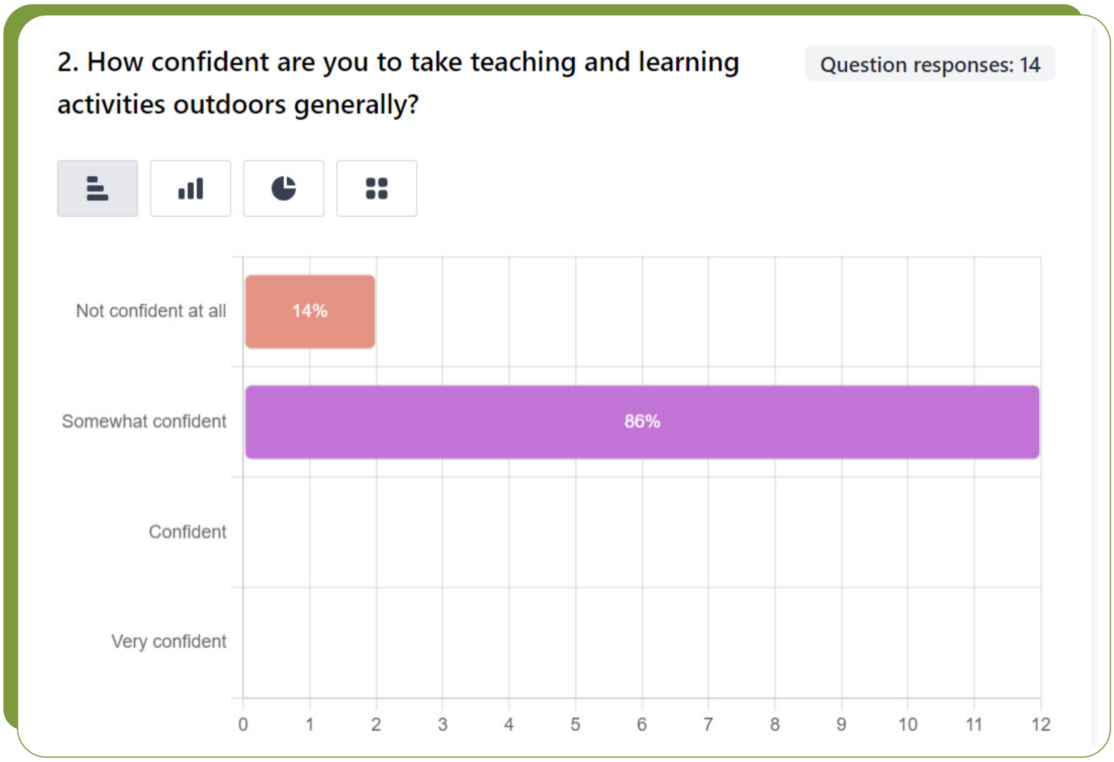
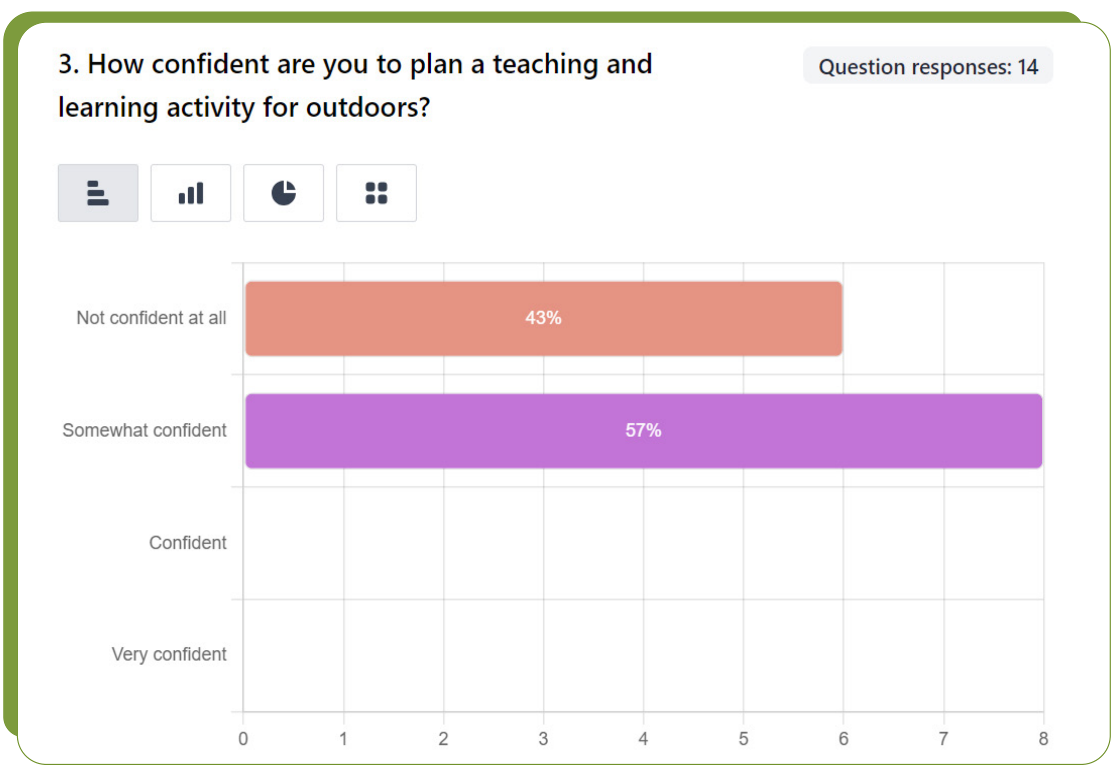
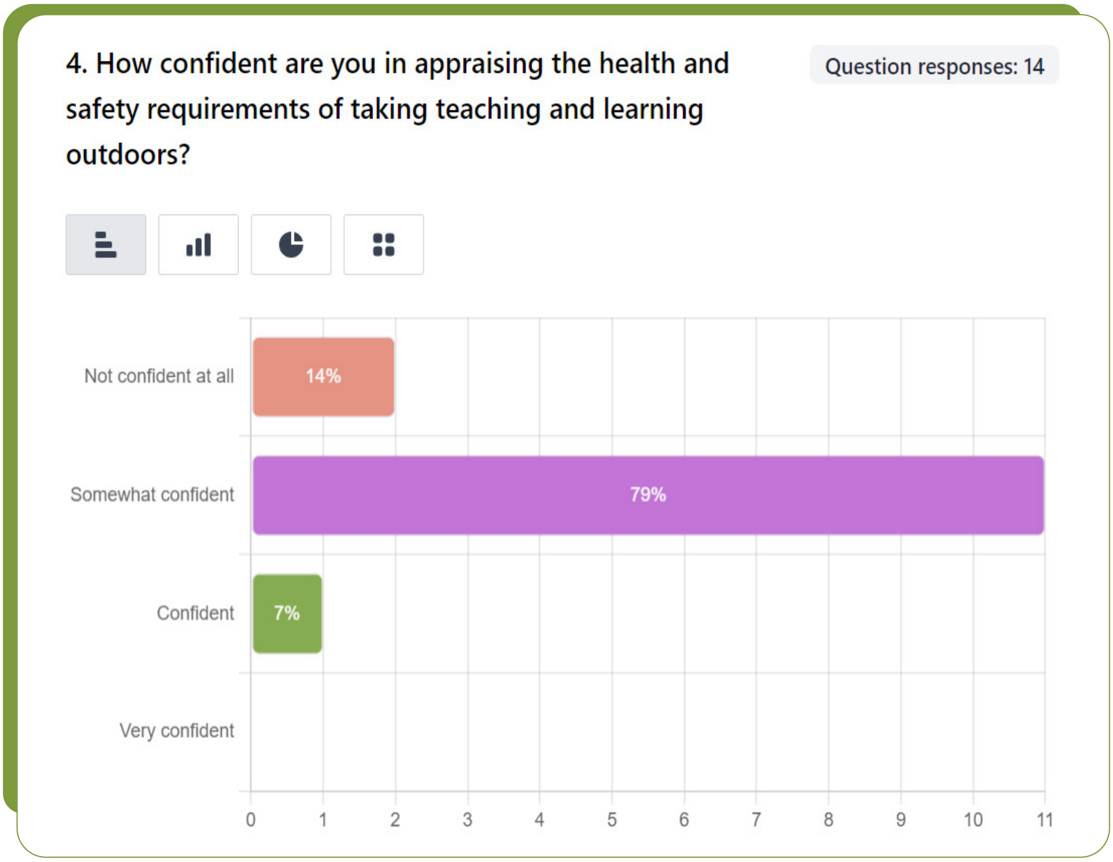


Table 2 How confident are you to plan a teaching and learning activity for outdoors?



Before training, students expressed concerns about leading outdoor activities, managing behaviour and ensuring safety (Barrable & Lakin, 2020).

Table 3 How confident are you in appraising the health and safety requirements of taking teaching and learning outdoors?



Participants were particularly apprehensive about balancing curriculum demands with the practicalities of outdoor learning (Table 3). For example, participants largely rated themselves as 'not at all confident' or 'somewhat confident' relating to the health and safety requirements of outdoor learning. Participants noted:

> *'How you deal with those kind of like loose cannons...'*
>
> *'I didn't actually say whether children could go, so when they went to do an activity, they all just spread like eagles.'*

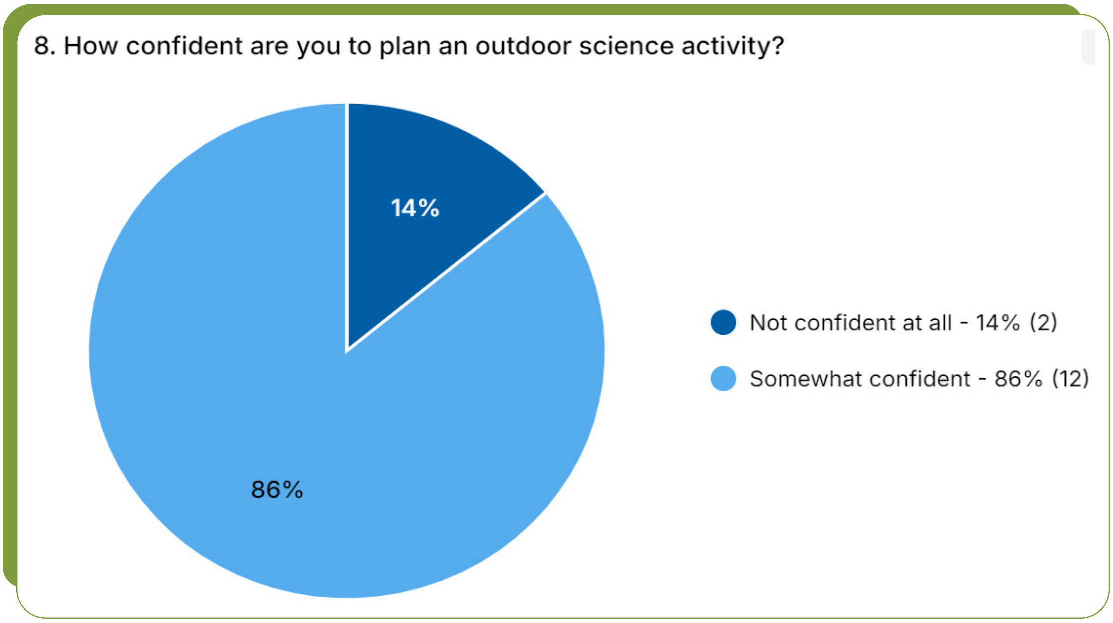
These concerns mirror findings in existing research, highlighting the perceived risks and challenges associated with outdoor learning (Catling & Willy, 2018).

When asked specifically about their experience of taking their science teaching outside, students described what they had observed in schools:

> *'Our second placement last year, we were learning about living things and their habitats and science. So we actually took the children outside to walk around the school grounds to find living things, and we found that it was more interactive for them rather than stating this is a living thing.'*
>
> *'I think my main concern would just be having the confidence to like be able to deliver like a session just completely by myself or like with teaching assistants.'*

They recognised the benefits and were keen to have a go but, when asked, identified a lack of confidence in planning for outdoor learning in science (Table 4).

Table 4 How confident are you to plan an outdoor science activity?



Bespoke training programme

Participants received guidance on addressing logistical challenges, managing safety (Beames *et al*, 2012), and integrating outdoor learning across subjects such as science, English and mathematics. They also explored ways to use the outdoor environment creatively and spontaneously. The training programme consisted of four units:

- **Unit 1**: Online self-directed study explored the benefits of outdoor learning. The participants chose an aspect of research and related this to their chosen field to explore how an outdoor environment could enrich and support their area of interest, for example, child development, nature awareness, or self-regulation.
- **Unit 2**: Face-to-face training – the participants explored approaches to utilising outdoor spaces, such as active learning, nature connection and wellbeing.
- **Unit 3**: Participants applied the skills that they had learned through demonstrating a practical example of how they used the outdoor space and then evaluated the activity.
- **Unit 4**: Evaluation of the activity. Participants shared their outdoor activities and photos on a Padlet. They also summarised their key learning from the project.

Example training activities

The face-to-face training included activities specific to science teaching and working scientifically.

Figure 2 ChatterPix Kids.

Using the application ChatterPix Kids (Figure 2) *(ChatterPix Kids can make anything talk. Take a photo, draw a line to make a mouth, and record your voice),* participants tried a Year 1 (age 5-6 years) activity: identify and name a variety of common wild and garden plants, including deciduous and evergreen trees. The participants choose a living thing and talk in the first person, describing key features, their habitat, or their survival needs.

Figure 3 A 3D food web.

Figure 4 Exploration of 'living, dead, never been alive'.

Using an activity from Learning through Landscapes (ltl.org.uk/outdoor-learning-training), the participants explored a Year 4 (age 8-9 years) activity based on the National Curriculum requirement that children should construct and interpret a variety of food chains, identifying producers, predators and prey, alongside recognising that environments can change, which can sometimes pose dangers to habitats. Participants used string and name tags to build a 3D representation of a food web and explore the challenges of pesticides and over-farming (see Figure 3).

Using an activity from TeachOutdoors (teachoutdoors.co.uk), participants engaged in a Year 2 (age 6-7 years) activity: explore and compare the differences between things that are living, dead and things that have never been alive. By collecting items from the grounds, they categorised them into 'living', 'dead', 'never been alive'. The participants then engaged in exploratory talk about how they knew that they were living/dead/had never been alive (Figure 4).

"Post-training surveys and focus groups revealed notable improvements in the confidence levels of the participants' understanding and use of learning outside the classroom for science."

Post-training findings

The students, having completed their outdoor learning sessions in a range of settings, reflected on their experiences. Post-training surveys and focus groups revealed notable improvements in the confidence levels of the participants' understanding and use of learning outside the classroom for science. Participants felt better equipped to plan and lead outdoor sessions, with one participant stating that *'It's [taking children outside to learn] easier than I thought it would be'.*

Participants reported that they noticed that outdoor learning enhanced children's engagement, collaboration and wellbeing:

> *'Seeing just how much enjoyment they get out of being outside. That's something that, when I was a child, I loved all my outdoor lessons. They're the ones I remember the most'.*

Mygind (2007) highlights the positive effects of outdoor learning on children's physical fitness and concentration. Participants also recognised the value of outdoor learning in fostering creativity, resilience and problem-solving skills in children (Wood & Haddon, 2021):

> *'After getting outside with the children I am more open-minded about the impact it has'.*

The training helped participants to recognise the value of experiential learning and the potential for spontaneous, meaningful teaching moments. For example:

> *'They [the children] were all collaborative in some way as well. So, it wasn't really like independent work. They also had their peers to kind of bounce off'.*

These reflections align with Vygotsky's (1962) social-constructivist framework, emphasising the role of active, context-based learning in cognitive development. While some challenges, such as limited outdoor space, remained, students learned to adapt creatively. For example:

> *'My school didn't have tons of outdoor space [but] it's easier than you think it is to do something outside'.*

Participants in urban settings utilised small playgrounds or nearby parks. They also developed strategies to address logistical concerns, such as planning for diverse needs and incorporating risk assessments into their practice (Catling & Willy, 2018).

Experiential learning emerged as a cornerstone of the training programme's success. By engaging in hands-on outdoor activities themselves, participants experienced first-hand the challenges and rewards of outdoor learning. This approach aligns with Ryan and Deci's (2008) self-determination theory, which emphasises the importance of autonomy, competence and relatedness in fostering intrinsic motivation and confidence.

Participants observed that children displayed higher levels of engagement and collaboration during outdoor lessons. They also noted improvements in behaviour, with one student commenting:

> *'I thought the children would be really overstimulated from it. And I didn't find that to be the case at all. In fact, they were quite chilled when they came back in'.*

These observations support findings by Whewell and Allan (2023), who argue that outdoor learning can positively impact both academic outcomes and emotional wellbeing and regulation strategies.

"Participants observed that children displayed higher levels of engagement and collaboration during outdoor lessons. They also noted improvements in behaviour..."

Recommendations

Recommendations from this small-scale study are three-fold: firstly, the importance of embedding science learning outside the classroom opportunities in ITE. This should encompass both procedural and substantive curriculum knowledge and practical application. This would support students to develop the skills and confidence needed to integrate outdoor learning into their science teaching during their school placements and Early Career Teacher years. This could include acknowledgement of behaviour management strategies to enhance logistical and safety considerations, including risk assessments, that are useful in the outdoors.

Secondly, we recommend that support whilst on school placement includes opportunities to practise outdoor learning, with guidance from experienced mentors and practitioners/mentors who have undertaken outdoor learning training. Placement schools could offer their outdoor spaces and resources to foster an environment where trainees can experiment and refine their approaches.

Finally, ITE can promote a transformational mindset that encourages trainees to view outdoor learning as an integral part of their pedagogical toolkit for science, highlighting its role in fostering creativity, resilience and working scientifically in children.

Conclusion

This project demonstrated that targeted training could transform ITE students' perspectives on outdoor learning, shifting their focus from their perceived logistical challenges to its transformative educational potential. PAR methodology embraces participants as researchers and allows shared knowledge creation and action; it is this that made this study unique and successful.

The importance of embedding outdoor learning into teacher training programmes addresses practical concerns and, through projects such as the one described in this article, we can empower students to build their confidence in taking their science teaching outside. By equipping future teachers with the confidence and skills to embrace outdoor learning, we can foster richer, more engaging educational experiences for children.

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The role of parents in promoting their children's interest in science through engagement with informal science learning

Parent and daughter at the 'plants under the microscope' session in July 2023.

Jamila Hussain and **Vince Wilson**

Abstract

This article explores an example of a family-oriented approach to science education. We consider the Saffron Science Club and the role of parental participation in enhancing the educational experience for both children and parents*. The Nottingham-based science club has been running since 2022 for families living in the locality, aiming to promote science to the community directly in an informal, out-of-school setting. Having set up the Club to support family engagement, we then evaluated and reflected on its impact. This article outlines both the establishment of the Club and our evaluation of it. By involving parents in the learning process, we wanted to see if this approach could lead to deeper-rooted connections within the community, creating a family feel in the engagement process, with the parents as active agents in promoting children's interest towards science learning. Informal dialogue with the families during the sessions informs our reflections on the process.

*Please note that the term 'parents' is interchangeable for parents/carers/ grandparents.

Keywords Informal science, parent participation, science engagement, science clubs

Introduction

Saffron Science Club began in the summer of 2022, running for one hour on a Saturday morning, once a month, in a library in the Meadows region of Nottingham. We chose the library as it serves as a vital community hub; the library is a Carnegie library, turned 100 years old in March 2025, and is well-loved by the local community. The library allows access to children attending three local primary schools and their families as an important after-school location for clubs and other library services. In Nottingham, one fifth of the population was income-deprived in 2019. Of the 316 local authorities in England, Nottingham is ranked as the 17th most income-deprived (Office for National Statistics, 2023). In terms of deprivation, approximately two thirds of residents in the Meadows region rent their homes. The Meadows residents have a lower level of formal qualifications compared to the national average, with approximately one third of residents having been born outside the UK (iLiveHere, 2021).

The Saffron Science Club's focus is to bring working scientists face-to-face with families, within an accessible, friendly local setting. Over the past few years, we have created a rolling programme. The Club runs monthly on the third Saturday at 11.00am until noon. We can cater for approximately ten children and their families.

We have found variation in engagement with the sessions during the year; for example, sometimes there are low numbers due to school holidays, celebrations of festivals, or a clash with another event running in the local area. There is some consistency in the attendance of the families, but there is also transition of the families moving to other areas of Nottingham, or to another country. Also, when the children move on to secondary school, they are reluctant to continue attending the sessions with their parents. We have high ambitions for the Club going forwards; for example, we aim to forge stronger links with the University of Nottingham's outreach programme to enable a visit to the University's campus. In addition, we also intend to reach out to the local initiative, City as Lab, to build stronger links with Nottingham City's 'Child Friendly City' initiative.

"The Saffron Science Club's focus is to bring working scientists face-to-face with families, within an accessible, friendly local setting. Over the past few years, we have created a rolling programme."

We have considered Bronfenbrenner's Ecological Systems Theory (1979) when attempting to understand the educational impact of their surroundings on a child. The mesosystem is one of the five environmental systems in this theory, and represents the interactions between different microsystems in an individual's life, for example, the relationship between a child's home and school environments. We wanted to see to what extent these interactions can influence the family's engagement with their child's learning of science. Bronfenbrenner's Theory (1979) highlights the importance of wider systems and connections within a community for the children's learning. It explains that learning is not isolated but is linked contextually, and this is impacted by learning through the community and environment. The Saffron Science Club's focus is on informal learning within the community and whether this could impact on learning within the home and the wider community.

Parents play a powerful role in their children's education and future aspirations (Joy *et al,* 2021). Our aim was to establish a science club in the heart of a diverse community. We wanted to bring science to the families in an easily accessible format, which added meaning to their everyday lives. One of the strongest aims was to link the learning to the National Curriculum (DfE, 2013). We wanted the children to be able to make contextual links between learning at the Club and their learning in school. Our Club distinguishes itself from others by strongly emphasising the linking of new learning with existing knowledge, with learning experiences designed to connect with the prior learning from the National Curriculum (the theory of constructivism will be discussed later in the article). We aim to make learning enjoyable and engaging, but it is crucial that it remains relevant to the children's existing knowledge and goes beyond isolated enrichment sessions. Our mission is deeply rooted in extending and building upon the children's current knowledge incrementally. We ensure that learning is connected to everyday life and the local community, with the aim of supporting the children to learn more and remember more by building knowledge into their long-term memory (Sweller, 2011).

The Sutton Trust (2021) has reported interesting findings on social disadvantage and links to social mobility within the higher education sector: *'Disadvantaged young people who didn't attend higher education were also much more likely to end up in the lowest income groups'.* Higher education is a key driver of social mobility in this country. Young people from less affluent backgrounds who attend university are more likely to move into higher income brackets (The Sutton Trust, 2021). As academics in higher education, we wanted to provide opportunities for both children and their parents with the session. We interacted with the families and encouraged everyone to join in with the activities.

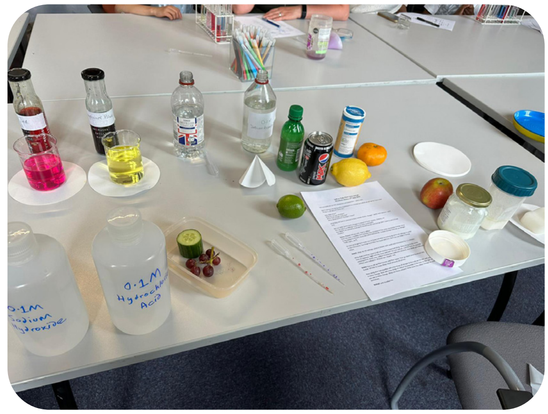
Our sessions made direct links to everyday life; e.g. the acid and alkali session linked to the colour of a rhododendron's petals, pink or blue, depending on the acidity of the soil. We looked at familiar plants and flowers under the microscope to make observational drawings and talk about the colours and textures seen at a magnified view.

Overview of last year's sessions

The Saffron Science Club 2024-2025		
20th Jan	Tim Self, Laura Kilpatrick, Robert Marcus	Food, bugs and things that glow
17th Feb	Dr Jamila Hussain	Vibrations and sound
16th Mar	Dr Mattea Finelli	How your brain works– making your own brain cells
20th Apr	Prof Reg Dennick	Potato electricity
18th May	Dr Vince Wilson	Electric circuits
15th June	Dr Vince Wilson	Electric circuits – resistors
20th July	Dr Michael Garle	Natural history/rocks
17th Aug	David McMahon, Tom Hartman	Pollinators and flowers Photographing specimens in jars. How good are my toys? The science of dinosaurs
21st Sept	Prof Reg Dennick	Chromatography
19th Oct	Tim Self	Microscopes/raspberry pi

All the contributors are working scientists, either employed at, or former employees of, the University of Nottingham. Jamila Hussain is an alumnus of the University of Nottingham, currently working as a Senior Lecturer at Bishop Grosseteste University.

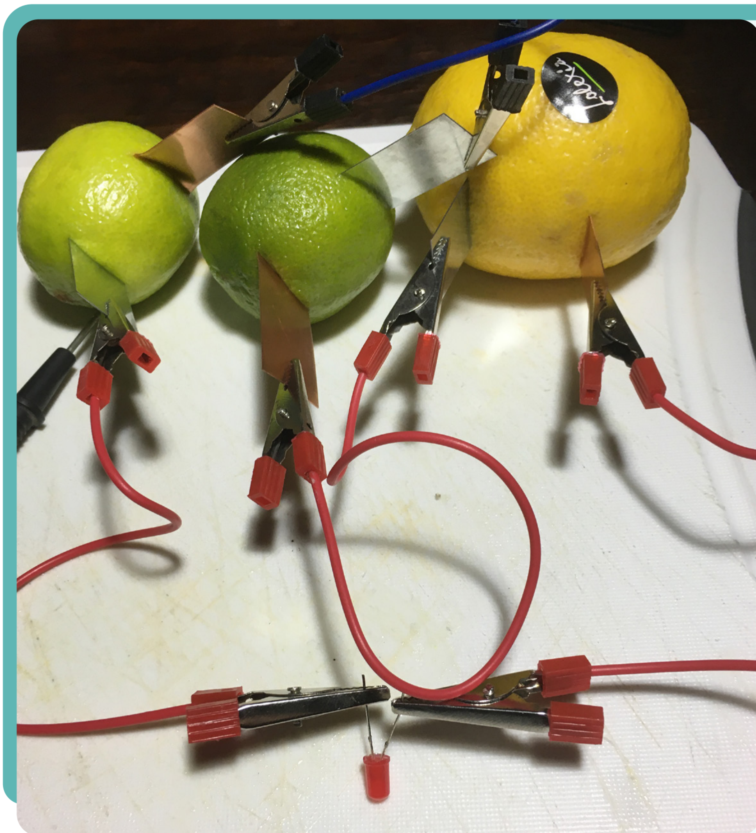
Professor Reg Dennick at the acid/alkali pH session, June 2023.



The library's room capacity was sufficient for up to ten children and their parents/carers. Children attended with parents, grandparents and other extended family members. We had children as young as two years attending, right up to age eleven years.

Looking at plants using confocal light microscopes loaned by The Royal Microscopic Society, October 2024.

Electricity from fruit, April 2024.



We encouraged all attendees to join in with the hands-on learning (Montessori, 1964): for example, designing electrical circuits using fruit and making a model of a neural pathway with play dough.

Our pedagogical approach was to use children's prior knowledge to make connections to new learning (Vygotsky, 1972; Piaget, 1978; Bruner, 1960). We wanted the children to understand how they could link their existing understanding of the world with new learning, through step-by-step instructions and the introduction of new knowledge in accessible chunks, adding to their existing schemas (Piaget, 1952). By involving parents in the learning process, we wanted to see if this approach could lead to much deeper-rooted connections within the community, creating a family feel in the engagement process. We engaged with the parents and attempted to draw them into conversations and discussions about the science. We explored how the parents could act as active agents in promoting children's interest in science learning (Bruner, 1960; Halim *et al,* 2017). We wanted the parents to see themselves as *'the more knowledgeable other'* alongside the scientists who delivered the sessions (Vygotsky, 1978).

Methods

We now move to discussion of our research that emerged from the set-up of the Club.

The primary aim of our work was to explore the effectiveness of engaging parents alongside their children with science learning. Having set up the Club, we then wanted to determine whether this approach could make learning family-oriented, to see if parents could become co-creators in their children's journey of acquiring science knowledge.

Our research questions included:

1. Can a family-oriented approach to science education develop deeper connections within the community?
2. What role does parental participation play in enhancing the educational experience for both children and parents?

We obtained ethics approval through Bishop Grosseteste University to collect views and voices from the children and the families. We carried out the sessions with the intent of focusing on the parents as much as the children. This was an exploratory, investigative project, which gathered data through in-person, face-to-face interactions and observations with the parents and their children who engaged with the Saffron Science Club.

During the actual sessions, the scientist delivering the learning focused on the teaching and learning aspects of the science being introduced. The supporting academics observed, informally, the engagement with the activities and the interactions within the families and between the families and the scientists. Additional data were collated through questions posed directly to both children and the families about their views and perspectives of science education, after the sessions had finished.

Informal interviews were also conducted as conversations and informal dialogue throughout the sessions. Children were asked about their engagement with the sessions and aspects of the science activities that they found to be most interesting, and their future aspirations with respect to careers in science or STEM. The observations carried out in the sessions also involved taking photographs and note-taking, and incidental conversations about parents' own lived experiences of science learning.

There were insufficient data generated for thematic analysis or pattern identification from the very small numbers agreeing to participate in this study (n=7 for the children, n= 5 parents), so we have presented emerging themes and issues as findings. The sessions consisted of different families attending; on occasion, we had the same children and families attending different sessions.

"This was an exploratory, investigative project, which gathered data through in-person, face-to-face interactions and observations with the parents and their children who engaged with the Saffron Science Club."

Data from practice

Finding 1

Session feedback highlighted that parents who received their education outside the UK found that a holistic approach to understanding science formed the basis of their science education in school. One parent who has spent two years in the UK stated: *'In primary school, when studying plant growth, we also looked at the long-term benefits on the environment...as well as health benefits of eating plants. At secondary school, we learnt about a pollution-free environment...using electric cars...and looking at alternative fuel sources...rather than fossil fuels...'* (the quotes have been translated and/or paraphrased).

Finding 2

When parents who received their science education outside the UK reflected on their experiences of science whilst growing up, they reported that an immersive home experience, where science was embedded in daily life at home, provided context to formal learning. For example, two parents, born outside the UK, stated: *'Growing up, we kept animals such as goats, chickens, rabbits and dogs. We grew green chillies, mangoes, aubergines and pumpkins. We pickled cucumbers and carrots. We made our own yoghurts and jam'*. We discovered a sense of a wealth of incidental science knowledge linking home experiences to school education from the parents who were born outside the UK.

"Growing up, we kept animals such as goats, chickens, rabbits and dogs. We grew green chillies, mangoes, aubergines and pumpkins. We pickled cucumbers and carrots. We made our own yoghurts and jam."

Finding 3

UK-born parents discussed their views on science education as children and as adults. These parents reflected on their early life struggles with learning science as children at school. They went on to discuss how this early experience impacted on their confidence and views of science later in life as adults. For example, two parents stated that early life experiences had impacted negatively on their views of science today; they also stated that, because of their schooling experiences, they found relating to science hard as adults.

Finding 4

Discussions with the children highlighted their ambitions to have a career in science (teacher, doctor, dentist). There was no talk about other routes within science, such as a research scientist. Children are exposed to the roles of dentists and doctors from a young age, at home and in school, meaning that children are more easily able to identify with these roles as potential careers for themselves. One Year 6 (age 11) child stated: *'I would like to become a secondary school science teacher...because I have always wanted to do science stuff with children...big children in secondary school understand more...I would like to learn about the hard bits of science, e.g. how some animals became extinct, how long does it take for an astronaut to get to the moon...why do leaves come off trees?'* Another Year 6 child said: *'I would like to become a haematologist, talking to a doctor...would help me decide'*. Another Year 6 child: *'I would like to become a dentist...visiting people in their place of work would help me decide'*.

Finding 5

The children expressed various requests for what they would like to see more of in their science sessions. From the seven children, we had a range of answers: e.g. *'cooking/healthy food/food-tasting/making ice cream, melting chocolate, having visitors, making something fun, planting, building a bug hotel/building circuits, more outdoor learning, learn about germs, practical experiments of everything'*. These results reinforce Ofsted's (2021) findings of relevant practical experiments to reinforce children's learning. Johnston and Tunnicliffe (2014) also reported the importance of *'hands-on science-based activities providing "practical experience" of scientific phenomena'*. The fun element of a club setting was also highlighted by Burke *et al* (2021).

Finding 6

Reflecting on the Saffron Science Club sessions since the summer of 2022, we have observed parental interactions with the activities and with their children. Sometimes the parents have been hesitant to join in, then, towards the end of the session, they have found themselves in competition with their children, for example, making observational drawings from a microscope, or making a picture from fruit that lights up under UV light. It has been interesting to see the parents in the role of learners themselves; as reported by Watts (2000), *'both children and adults grew in enthusiasm, excitement and enjoyment…'*.

Finding 7

We also noted the powerful role that language plays in science communication, not only when introducing activities to the families, but also when asking them to follow clearly defined step-by-step instructions. We need to dedicate more time to the language aspect of science learning in the future; suffice to say, a large bank of scientific vocabulary would be clearly beneficial and supportive in producing more in-depth dialogue and discussion about our sessions. We know that language plays a definitive role in enabling children's acquisition of knowledge of the world at any stage of early development (Nelson, 1998).

Dr. Michael Garle and a 'Rocks' session, June 2024.

Discussion of findings

It is important to acknowledge that the families participating in our science club have made an active choice to attend, indicating a pre-existing interest in science. Consequently, our findings are representative of these engaged families and cannot be generalised to all families within the Meadows community. The data reflect a selective, purposeful sample of those who chose to participate, rather than the entire population of the area.

After running the science club sessions for over two years, we realised that, to engage the children and their parents in the learning process, we needed to maintain the informal learning atmosphere (DeVille, 2024). We engaged the families with purposeful science learning (Bevan *et al*, 2019; Ofsted, 2021). They related everyday objects to science, e.g. looking at broccoli and lettuce leaves at a magnified level, seeing the colours in felt tip pens, and using investigations to find out whether predictions were true or not. In the floating and sinking session, the children became researchers and developed their scientific literacy. Holbrook and Rannikmae (2009) highlighted important aspects that reflect Saffron Science Club's core values with family engagement, namely, enabling a positive attitude to science, recognising science's societal impact, e.g. development of the COVID vaccine, and the interdisciplinary nature of science within STEM and the creative arts (Aguilera & Ortiz-Revilla, 2021; Vincent-Lancrin *et al*, 2019).

Plants and Light session, July 2024.

We realised the importance of dialogue between the children and their parents (Alexander, 2008), and the value of continuing these conversations at home, with *'dyadic conversational turn-taking at home'* in addition to the importance of *'decontextualised language **leading**... to conversations that are longer and more sustained'* (Leech *et al*, 2021). Furthermore, these authors conclude that, when parents engage with their children in extended conversations during everyday opportunities, this leads to building strong language skills in early childhood. Language proficiency is particularly important in the early years for children's attainment; e.g. only 43% of those pupils who were recorded as being new to English achieved a good level of development at the end of Reception compared to 88% of those who were recorded as fluent in English (DfE, 2020). Parents who engage in more conversations with their children encourage the children's language skills development and related vocabulary and academic language abilities, moving from the social to more formal learning (Cummins, 1979, 2001). This is particularly crucial for children who are disadvantaged, or have been disadvantaged by the impact of the pandemic (Pascal *et al,* 2021).

Although we agree that hands-on practical activities that relate to the daily lives of the families support new science learning (Hainsworth, 2017), we also focused on the use of decontextualised scientific vocabulary in future sessions, for example, 'specimen' when referring to a petal on a microscope slide, 'light microscopy, magnification' and words such as 'chromatography' and 'infra-red/ultra-violet radiation'.

The findings regarding differences in children's responses based on their parents' views were ambiguous. Some children showed greater interest and engagement in the sessions when their parents were more interested, and *vice versa.* However, the alignment between children's and parents' views on science was inconsistent and not explicitly measured. This could be an area for future investigation, to determine if and how parental interest influences children's engagement.

In conclusion, our preliminary findings support the importance of working with parents to promote their children's interest in science activities. This may lead to enhanced interest in pursuing careers in STEM-related fields. Indeed, a study by Tiza *et al* (2021) concluded that that evoking participant interest and engagement is best practice to increase interest in STEM fields. The study also illustrated the importance of providing participants with freedom of choice, and making an activity playful also made the topic more accessible. This is the basis of Saffron Science Club's sessions. We hope that the holistic approach of family engagement instigates science conversations that are continued in the home and when the family visit places in their localities. We will pursue the use of scientific language in both contextual and decontextual pedagogies to promote the development of accurate scientific language. We will promote the importance of language for science (Hussain, 2021). We will spend the upcoming sessions exploring how children are influenced by extrinsic motivators (factors such as parental advocacy and educator praise), and wholly or partly intrinsic motivators, where they take the lead/initiative to direct an interest in a chosen area themselves for the motivation for and pride in what they have accomplished (Ryan & Deci, 2000).

Conclusion: Addressing research questions

Can a family-oriented approach to science education develop deeper connections within the community? Our findings suggest that engaging both children and parents in science education can promote stronger community ties. The family-oriented approach can encourage shared learning experiences and sustained conversations at home.

What role does parental participation play in enhancing the educational experience for both children and parents? Parental participation plays a crucial role in enhancing the educational experience by promoting active engagement and interest in science. When parents are involved, they can support and extend their children's learning, leading to improved language skills, scientific literacy and a positive attitude towards science. This collaborative approach also helps parents to become co-creators in their children's educational journey, making the learning process more meaningful and impactful.

Next steps

In the upcoming year, we will focus on children's science identity. We recognise that children from under-represented groups often lack visible role models within scientific fields; this is partly due to the current curriculum (DfE, 2013). We also acknowledge that there is a diminished identification with STEM disciplines as viable career pathways, other than medical routes (doctor/dentist). We will try to address this in forthcoming sessions. A focus on language is also an important consideration for us – we want *'to increase adult comfort and confidence with family science'*. We will aim to further promote parental conversations to increase children's scientific dialogue.

To support family science and serve the community, we need to tap into the rich resource of science capital that families have to offer by giving parents a platform for 'family science' fun. We will attempt to promote parents' confidence in their own ability to support emergent scientific thinking with their children, by giving them a sense of empowerment and recognition of themselves as contributors.

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Collective Article

Stories of practice in primary science from mixed-age classes

Julie Horsburgh, Rachael Newham, Danielle MacLeod, Darren McTurk, Graeme Robertson, Jayne Ross and Sarah Earle

Abstract
Grouping children into classes where their ages span more than a year is a common, yet under-researched, area of practice. In order to provide an insight into current practice in primary science, five teachers from Scotland and one teacher from England share examples from their schools. As a collaborative article, teachers are co-authors, with a visible voice within the text. The stories of practice share common themes, such as the opportunities for practical work in open-ended enquiries or challenges, which provide an accessible means of teaching science to mixed-age classes. Authors also note the difficulties of repeating content or deciding on the most appropriate grouping for children with different levels of maturity. The stories of practice largely take a positive stance, with authors sharing examples of how they have created successful primary science teaching experiences.

Keywords:
Mixed age, multigrade, composite, primary science, adaptive teaching

Introduction

A class where children of different ages are taught together may be called mixed-age (England), composite (Scotland) or multigrade (internationally). With an estimated 30% of children across the world experiencing multigrade teaching (Create, 2008), it is an area that has long been neglected in policy and research (Little, 2001; Boyd, 2020). How organisation of mixed-age classes impacts the application of teaching practices in primary science is the focus for this collective article.

The monograde class, where children are aged within a year of their peers, is seen as both the norm and the ideal (Little, 2001). However, in reality, mixed-age classes can be found in all areas, for example, where lack of funding for teachers in underserved areas leads to the formation of larger classes, or where smaller populations in rural areas result in a combination of ages to make a fuller class. Ronksley-Pavia *et al* (2019) note that some authors make a distinction between multigrade classes that are formed by necessity, often in rural or remote areas, and multi-age classes that are formed as a philosophical choice to create a ‘community of learners’, often in urban areas. The complexity of school formation in the UK means that urban mixed-age classes are not unusual, with fluctuations in birth rates and popularity of particular school types leading to a variety of different class combinations.

In some contexts, multigrade classes mean that the teacher splits their teaching time between groups of children of different ages, as each sub-group of ages follows their own grade-specific curriculum (Smit & Engeli, 2015). In practice, this could mean the teacher working with one year group at a time whilst the others work independently, or more of a carousel of activities for different age groups, with the teacher directing attention to those most in need of support. In other contexts, children are largely taught as a class, with pedagogical adaptations to support learners of different ages. A 'parallel curriculum' may be in place, where children follow the same theme or topic, but with objectives related to their year/grade, with workload implications for provision of multiple levels of work (Ronksley-Pavia *et al,* 2019).

There is a limited number of empirical studies considering mixed-age teaching of primary science. In some studies, the social interaction of mixed-age groups has been noted, for example, with older children supporting younger to positively impact their science learning (Kallery & Loupidou, 2016). Where peers become the 'more knowledgeable other' (Vygotsky, 1978) in collaborative group discussions, younger children learn both about science and about social interaction from the model of the older children. In Kallery and Loupidou's (2016) study, there was little discussion of what the older children gained from the exchange, perhaps raising questions about whether older children in the group were in need of their own 'more knowledgeable other'. Lindström and Lindahl (2011) found a negative effect on cognitive skills following a rapid expansion of mixed-age classes in Sweden. Other studies take place in a mixed-age setting, but do not explore this as a feature affecting pedagogy or learning (e.g. Kim, 2016), pointing back to the 'invisibility' of multigrade classes observed by Little (2001).

"With any lesson or class, you have to adapt to meet the learners' needs, adapt the vocabulary and the way we're introducing the concept to help them understand, so it's the same for composite classes."

The national curricula of England and Scotland are both laid out by age (DfE, 2013; Education Scotland, 2009), although there is a different amount of specificity within the guidance. For example, in Scotland the 'experiences and outcomes' are laid out in 'levels' that are spread across three years, with First Level covering Primary 2-4 (ages 5-8) and Second Level covering Primary 5-7 (ages 8-12). Whilst in England, objectives are laid out for each year group; although it is possible to teach these in different year groups in each Key Stage, in practice most schools adhere to the order provided.

Stories of practice

In order to explore how mixed-age primary science teaching and learning is enacted, this collective article shares the voices of six current primary school teachers. Five are from Scotland and one from England. Each section below details a different story of practice from a different school, to demonstrate the breadth of teaching and learning experiences across a range of settings. Key themes will be drawn together below.

School 1: Science challenges to support access

I work in the Roman Catholic school for the area, with up to 150 children, so there are often composite classes. With any lesson or class, you have to adapt to meet the learners' needs, adapt the vocabulary and the way we're introducing the concept to help them understand, so it's the same for composite classes. STEM is less of an issue than other subjects, because of the way that we approach it with challenges. I try to base it around a bigger project; for example, we did a carbon capture project, looking at the oil industry in the North Sea and climate change (including jogging on the spot wearing a jacket to model the layer of greenhouse gases!). Or, this term we're doing the Scottish landscape, looking at geology and rock formations, making salt dough maps. With STEM, it's easier to teach it as a whole class, because I see it as a level playing field – they're not held back by their spelling, etc. and they can all access the **science challenges**. Things like building a raft and waterproofing the materials so it wouldn't sink – there's lots of ways to design it. The Curriculum for Excellence gives us choice of which experiences we provide, so we can approach the same content in different ways to avoid repetition.

School 2: Practical science is not a barrier

I'm class teacher in a P5/6 (ages 8-10) class at the moment. I find that there is just a lot more differentiation in a composite class. There just needs to be a little more prompting, more scaffolding. But there is also the opportunity for their peers to lead too. It depends on the class. If the class is not too big a spread, then you can teach them as a whole class. I do the same input, but then there's a challenge by choice, so they pick the activity where they will succeed. For example, different kit for making electric circuits, or whether to do circuit drawings or diagrams with symbols. Sometimes they might pick one that's a bit tricky and then need help, but it's good for them to try, or, if it's too easy, then pick something harder. If there is a barrier, it's usually more of a literacy barrier, to write it down – there's **no science barrier** because they can all join in with the **practical** side of things, like making magnetic games or waterproof materials/floating linked to the Titanic topic. It's quite useful for the older ones to support the younger ones, but sometimes it's the other way as well, because the younger children are more OK with making mistakes and trialling things.

When you've got a composite class, you need to know your children really well, know what they'll find tricky, their barriers, to pre-empt that, so that they are not struggling with the science when it's their literacy that is the barrier. You adapt things, change the vocabulary, or the way you are describing things, whether it is a composite class or not.

School 3: Maturity is a key factor

I have worked in a really small rural school for the last 7 years, we've only got 34 children in total. We split them across two classes (because composite classes are capped at 25 in Scotland) and I have Primary 4-7 (ages 7-12) at the moment, but that changes every year depending on numbers. I've been doing a three-year rolling programme to cover the Second Level content, although it's a bit more complicated now that I have P4s as well (First Level). The three-year rolling programme works for curriculum coverage, because it means that there is no repetition of a topic in those three years, but it's the **maturity difference** that causes the most difficulties. I find it easier to do the same topic across the whole class, but the younger children might not be able to cope with the complexity of the content, so I need to do a lot of tweaking. In any class you can get a spread of needs, but it's the difference in maturity that makes composite classes different. The understanding and life experience of a young P4 (age 7-8) is so different to an older P7 (age 11-12). The age difference in the class is too big for pairing oldest with youngest, because the older ones tend to just take over and use the younger ones as 'runners', but **close-age pairs** work better. I don't have any other adult support teaching science, so a carousel-type set-up would not work, because you need to manage the behaviour and safety for practical science. I tend to do a whole class set-up, then sit with the younger ones to support them. Actually, sometimes the younger ones surprise you; for example, when we were making marble runs in the woods, it was the two youngest in the class who persevered to make a vertical one with string, sticks and moss (Figure 1).

> **"In any class you can get a spread of needs, but it's the difference in maturity that makes composite classes different."**

Figure 1 Woodland marble runs.

School 4: Open-ended science enquiries in groups

Like many schools, our school roll can change over the course of an academic session and from one session to the next. This can result in composite classes being needed at the start of a new session. From a learning and teaching point of view, composite classes present a unique and interesting opportunity when it comes to science teaching, as it does for all areas of the curriculum. Whether it is within First or Second Level, or whether it crosses over Levels, this can be a great opportunity as there are science curriculum outcomes that are available. Effective learning and teaching in any area is about the prior learning that the young people have, as well as their individual and collective needs. This is as relevant to science as it is to areas such as literacy and, indeed, they are intertwined with one another. Using **scientific enquiry approaches,** like the post-it planning, helps because it focuses on the discussion, the thinking and the science and is not as heavily focused on other factors such as the children writing it all down. **Open-ended science activities** are more accessible in different ways, so that helps to allow all young people to engage in the learning. Thinking about how to group the children in any situation will depend on the cohort, as each one is unique. You might have pupils confident in science from a younger year group that work very well with those in an older year group, which benefits all learners. If any class has been together for a while, then knowing who works well together may be already known and the same goes for a composite group. When it's a new arrangement, effective communication between professionals and getting to know the learners is key. Using approaches such as **co-operative learning**, peer mentoring or coaching situations is a really effective way to maximise the uniqueness of composite classes, much in the same way as if there are individual requirements within a class.

School 5: Diversity of ages sparks more discussion

In mixed-age classes, you **teach the children in front of you**, and the specific year group that they belong to doesn't significantly impact how I approach teaching science. In fact, I really enjoy teaching mixed year groups because of the broad range of abilities and experiences they bring. While every class naturally has some diversity, mixed-age classes tend to have fewer extreme outliers because of their greater variety, which I find creates more opportunities for flexible groupings in science. Other subjects can differ because their curricula vary but, in science, our two-year rolling programme works really well. The timing of topics isn't as critical; students build foundational knowledge in the Year 3/4 class (ages 7-9) and revisit those topics in Year 5/6 (ages 9-11), reinforcing and expanding their understanding.

While teaching mixed age classes can be more challenging, it pushes you as a teacher to **adapt your methods to fit the children's needs –** not by changing the objectives, but by tailoring how you deliver the content. With a diverse range of needs and life experiences in the room, their science capital becomes a real asset. I plan for the highest level of need, but find that this approach benefits everyone in the class. I do think there's a real beauty to mixed age classes – the way that children grow and support one another. In subjects like science, there's a **sparky kind of thinking** within the room. For example, if you pose a question from Explorify (weblink below) like *'What if you only ate chips?'* to Year 3/4, or *'What if we all looked the same?'* to Year 5/6, the responses that you get are just fabulous. The children inspire each other, throwing out ideas and building on them because of the **diversity in age** and perspectives. Older children often model more sophisticated approaches to problem-solving, which younger children observe and apply to accomplish tasks more effectively. This interaction, in turn, boosts the older children's independence, confidence and competence. It builds a family feel and social co-operation across school as well. You see it in moments like when they play together on the playground with peers from different year groups, strengthened by the bonds they've formed in class.

School 6: Multi-composite teachers are masters of juggling

I work across two small rural schools in the Scottish Borders. Our class combinations change every year. In enrolment week, we get to find out how many P1 (age 4-5) children will be joining in August, and then we have to work out how to split the school into three or four classes. There's a new policy that you can't split a year group with less than five in each class, together with the national policy that children under five can defer for a year, so there's a lot to consider before we even think about the teaching. For the curriculum, we bundle the experiences and outcomes together into topics and have created a **three-year rolling programme.** For example, this year our big topics are materials and the human body, and then next year we'll be doing more of the physics (sound, electricity). By spreading out the topics, it means that we avoid immediate repetition, so a child might do the human body in P2 (age 5-6) and then again in P5 (age 7-8) to build on it. This would be different ages for different children because of the cycle, but you've got scope to go into different levels of depth, by looking at the Benchmarks. For example, in electricity everybody's going to be building a really simple circuit and we're going to be learning some of the vocabulary around that. But you might then leave your First Level learners to go and explore, building a circuit and lighting up the Teddy Bear nose, or making a little quiz button. Then you would be taking your Second Level learners and look to extend them by adding things like switches and motors. I've differentiated it by my groups and then they can apply it in an end result like designing a lighthouse model or a light-up Christmas thing, where I'd be expecting the younger ones to make it light up and the older ones to use a switch or multiple battery sources, etc. So you can kind of teach the principles in the group and then you can give them a follow-up assessment that allows you to pick into that. For multi-composite classes, the teachers are masters at juggling, everything is groups and rotations, 10 minutes with the teacher and **structured carousels,** because the stretch in the class is too different for whole-class teaching. The little ones tend to start with play, but the older ones start with the learning and then you build in the play and enquiry. **Low floor, high ceiling tasks** are ideal, just needing a wee bit of differentiating.

"For multi-composite classes, the teachers are masters at juggling, everything is groups and rotations, 10 minutes with the teacher and structured carousels, because the stretch in the class is too different for whole-class teaching."

Discussion and conclusions

The stories of practice above demonstrate the diversity of ways in which mixed-age primary science is enacted in a small number of schools. The following common threads emerge:

- Primary science can be adapted for mixed-age classes because of the accessibility of practical work and the open nature of enquiries and challenges (e.g. Schools 1, 2 and 4).
- Mixed-age groups can be supportive of science learning, but groups may need to be constructed and scaffolded with level of maturity in mind (e.g. through the use of group roles), so that all children benefit (e.g. Schools 3 and 4).
- Consideration of adaptations for different ages or stages can be beneficial for all children in the class, with the teacher allocating different levels of support or independence dependent on need (e.g. Schools 3 and 4).
- Mixed-age groups can enhance the diversity of responses (e.g. Schools 3 and 5).
- Content for mixed-age classes can be more difficult to manage if flux in numbers leads to different combiations of composite classes each year, or if the mix of ages straddles a curriculum change (e.g. across Levels in Scotland and Key Stages in England) (e.g. Schools 3, 4 and 6).

As can be seen by the diverse range of stories of practice above, mixed-age primary science teaching is not a simple matter. However, science also provides an opportunity for mixed-age teaching, with options for learning that are more open-ended and exploratory (Tinkler, 2024). The flexibility and pedagogical experience needed for mixed-age teaching is noted both here and in the academic literature (e.g. Ronksley-Pavia *et al*, 2019). The teaching of primary science is affected by the diversity of ages, the curriculum and the unique individuals within the class. We end with a call for mixed-age classes to receive more interest, in both the development of resources and in policy, to support teachers to adapt their primary science teaching for the children 'in front of them'.

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- Include a reference list (examples below), set out in alphabetical order

Referencing examples:

Book

Russell, T. & McGuigan, L. (2016) Exploring science with young children. London: Sage.

Chapter in book

Johnston, J. (2012) 'Planning for research'. In Oversby, J. (Ed) ASE Guide to Research in Science Education. Hatfield: Association for Science Education.

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