JES

The Journal of Emergent Science

Issue 26 January 2024

ASSOCIATION FOR SCIENCE EDUCATION

Primary Science Teaching Trust

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Editor:
Sarah Earle
s.earle@bathspa.ac.uk

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

Cover Photo:
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Publisher:
Association for Science Education (ASE) College Lane, Hatfield, Herts, AL10 9AA, UK

ISSN: 2046-4754

The Journal of Emergent Science (JES) is published by ASE in partnership with the Primary Science Teaching Trust (PSTT).

It is free to access for all.

ASSOCIATION FOR SCIENCE EDUCATION

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Editorial

Sarah Earle

The Education Endowment Foundation (EEF) has recently produced a guidance report detailing six recommendations for improving primary science (Luxton & Pritchard, 2023). This guidance draws upon a systematic review of approaches where studies included a counterfactual (control) group (Bennett *et al*, 2023), together with teacher focus groups, a stakeholder guidance panel and other EEF guidance reports.

Their six recommendations for primary science practice are:

- Develop pupils' scientific vocabulary;
- Encourage pupils to explain their thinking, whether verbally or in written form;
- Guide pupils to work scientifically;
- Relate new learning to relevant, real-world contexts;
- Use assessment to support learning and responsive teaching; and
- Strengthen science teaching through effective professional development as part of an implementation process.

(Luxton & Pritchard, 2023, p.4)

The six recommendations could feel like a tall order for many primary and early years settings, which also have all the other subjects vying for attention. However, many of the instructions could support practice across the curriculum and may link to other initiatives in school. It would also be important for practitioners and science leads to consider where practice is already strong in their setting and perhaps select just one area on which to focus for future development. This is further discussed in the latest EEF podcast (EEF, 2024).

Articles in this issue of *JES* link to a number of these recommendations, with each including a strong overlap with one in particular. In line with EEF recommendation three, the first two articles are based around the theme of guiding enquiry and working scientifically. **Mohd Syafiq Aiman Mat Noor** provides guidance for enquiry with close consideration of materials, using cups as an everyday stimulus with children in Malaysia. Next, **Christine Preston** explores how her work as a practitioner in kindergarten and in support of teachers in Australia has led to the development of the Sci-5 programme, including a structure for supporting 5 year-olds with their emergent science learning.

In their research review, **Rebecca Donnelly** and **Helen Bridle** explore outdoor learning in the early years, considering how 'forest nursery' can provide an environment where stereotypical gender norms can be less prevalent. Forest nursery places learning in a real world context (EEF recommendation four), but this article also raises questions about challenging the *status quo*, making it important to consider how real-world links can support inclusion and the building of science capital (Nag Chowdhuri *et al*, 2021).

The final two articles share a climate theme. **Lewis Morgan** and **Sophie Nelson** explore how children can become 'climate ambassadors', working with their teachers to develop understanding of climate change, climate justice and sustainability. Whilst **Lucy Wood, Heather King** and **Melissa Glackin** share an evaluation of a pilot climate change project where schools worked collaboratively with external partners to co-design sustainable products and solutions to support the future climate. Both articles place practitioners and children in an active role, applying their knowledge to real-world contexts, in line with the EEF's fourth recommendation.

Parallels can be made between each article and at least one of the EEF guidelines, with this issue particularly focused on recommendations three and four. *JES* encourages authors to get in touch with the Editor at the e-mail below, to provide different viewpoints and explore other aspects of primary and early years science education practices.

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Dr. Sarah Earle is Editor of the *Journal of Emergent Science* and Reader in Education at Bath Spa University.
E-mail: s.earle@bathspa.ac.uk
Twitter: @PriSciEarle

‘Which cup is the best?’: Encouraging children to act like scientists when investigating the properties of materials

Mohd Syafiq Aiman Mat Noor

Abstract

This paper describes an enquiry-based science teaching sequence that was designed to teach about the properties of materials, and implemented with primary school children (aged 9 to 10 years) in Malaysia. The sequence consisted of three activities: ‘Naming the cups’, ‘Defining the properties of the cups’, and ‘Grading the cups’. The first activity aimed to develop children’s scientific literacy by encouraging them to observe and classify cups based on the materials that they were made of. The second activity aimed to develop children’s critical thinking skills, by enabling them to engage in processes such as grouping and classifying, analysing, visualising and synthesising information. The third activity aimed to challenge children’s understanding of the scientific method. The evaluation of the implementation revealed that the enquiry-based science teaching sequence was successful in enhancing the scientific literacy and critical thinking skills of the children. The teacher’s facilitation of open discussion among the children, coupled with opportunities to correct their misconceptions, contributed greatly to the success of the sequence.

Keywords: Enquiry-based science teaching, properties of materials, teaching sequence, primary science

Introduction

The aim of this study was to assess the impact of a university- and industry-led STEM Academy model of multi-level partnership working on teacher and pupil confidence in and attitudes to STEM.

Enquiry-based science teaching is a strategy that encourages children to think, act and be like scientists (Hollingsworth & Vandermaas-Peeler, 2017). By building on children’s natural curiosity and engaging them in authentic science practices, this approach aims to foster in children a deep understanding of the world around them (Kuhn, 1993). Through hands-on opportunities to explore and seek answers to important questions, children are able to develop critical thinking skills and learn how to draw conclusions based on evidence (Deboer, 2006). Additionally, enquiry-based science teaching encourages children to share their new knowledge through various means, including informal class discussions and more formal presentations (Duran & Duran, 2004). This approach to primary school science education is designed to inspire a lifelong love of learning and curiosity about the natural world (Kamarudin *et al*, 2022).

Despite its benefits, enquiry-based science teaching requires significant teacher preparation and a shift from traditional teaching methods, demanding more time and resources for the implementation of hands-on activities (Baroudi *et al*, 2021). The delivery method also poses challenges in diverse classrooms, where children’s varying abilities must be accommodated, necessitating differentiated instruction (Bresser & Fargason, 2023). For teachers, there is a tension between the breadth of the curriculum content, which needs to be covered in its entirety, and the depth required to implement enquiry-based teaching (Abd-El-Khalick *et al*, 2004).

Moreover, assessing student learning through this approach can be difficult, as standard tests may not fully capture the skills developed (Mat Noor, 2021). These challenges highlight the need for strategic planning and resource allocation to effectively implement enquiry-based teaching.

Addressing children's misconceptions about the properties of materials

Research has shown that enquiry-based science teaching methods are effective in helping to address children's misconceptions about the properties of materials, and in enabling them to develop a deeper understanding of this subject matter (Hernández *et al,* 2015). Enquiry-based science teaching encourages children to act like scientists and to investigate the properties of different materials through hands-on investigations and activities (Inan & Inan, 2015). This approach allows children to discover new information through observation and experimentation, rather than simply being told what to believe (Harris, 2012). In addition, Barbara (2007, 2014) argues that in enquiry-based teaching, unlike other science practices, children grapple with sense-making, and the teacher's role varies from directive to collaborative depending on the level of enquiry, thus shaping the depth of children's cognitive engagement.

One study conducted by Acher *et al* (2007) found that, when enquiry-based science teaching methods were used to teach children about the properties of materials, they were able to overcome their misconceptions and achieve a deeper understanding of the subject. Children engaged in small group activities, manipulating different materials though the construction of models to understand these manipulations. This work also involved children communicating their ideas with peers through whole-classroom discussions. The study also found that children who were taught through enquiry-based science teaching were more engaged and motivated to learn about the properties of materials. Another study conducted by Wendell and Lee (2010) found that enquiry-based science teaching was effective in addressing children's misconceptions about materials science. In the study, children worked in pairs to complete a model house investigation using LEGO to deepen their understanding of the design problem's requirements or constraints. As they generated and implemented solutions to the design problem, they increased their understanding of materials science. The study found that, when children were able to conduct hands-on investigations to observe, compare and manipulate different materials, they were able to overcome their misconceptions and understand the concept more thoroughly.

To summarise, enquiry-based science teaching is effective in addressing children's misconceptions about the properties of materials (Hernández *et al,* 2015). Enquiry-based teaching differs from traditional practical science investigations in its emphasis on the process of questioning, exploring and analysing, rather than merely following a set of instructions (Constantinou *et al,* 2018). This approach is characterised by its focus on children-led questioning and exploration, where children are encouraged to formulate their own questions, hypotheses, and methods for investigation (MacDonald *et al,* 2020). Throughout this process, teachers encourage children to act like scientists and investigate the properties of different materials through hands-on investigations and activities (Hollingsworth & Vandermaas-Peeler, 2017). This approach allows children to discover new information through observation and experimentation and helps them to develop a deeper understanding of the subject matter (Muhamad Dah & Mat Noor, 2021).

Properties of materials in the primary science curriculum

In most of the primary science curricula, the properties of materials topic is usually covered as part of the broader area of materials science (Schibeci & Hickey, 2000). The main focus is on helping children to understand the physical and chemical properties of different materials and how those properties affect their suitability for different uses. At primary level, children are introduced to the basic properties of materials, such as their shape, size, texture, weight, colour and flexibility. They are also taught how to observe, compare and classify different materials based on their properties such as density, conductivity and melting point. Hands-on activities such as sorting, matching and experimenting with different materials are often used to help children to understand these concepts.

In general, the properties of materials topic in the primary science curriculum focuses on helping children to: understand the basic properties of materials; observe, compare and classify different materials based on their properties; learn how properties of materials can be used to identify and classify materials; and be able to identify how properties affect suitability for different uses.

The properties of materials is an important topic in primary science education, and is included in both the Standards-Based Curriculum for Malaysian Primary School Science (MOE, 2018) (see Table 1) and the National Curriculum in England: Science Programmes of Study (DfE, 2015) (see Table 2). According to the Ministry of Education Malaysia (MOE, 2018), the properties topic should be taught to Year 4 children, who are aged between 9 and 10 years. Similarly, in England, the Department of Education (DfE, 2015) states that the topic should be taught to Key Stage 2 (Year 5) children, who are aged between 9 and 10 years. Understanding the properties of materials is essential for primary children, as they need to be able to understand the characteristics of different materials and how they can be used (Mat Noor, 2022b). This knowledge is useful for their everyday lives and can help them to make informed decisions when choosing materials for various tasks.

Table 1. The Standards-Based Curriculum for Malaysian Primary School Science, Year 4 (MOE, 2018).

Content Standard	Learning Standard
8.2 Properties of Materials	8.2.1 Describe the properties of materials by conducting an activity. 8.2.2 Create objects by applying knowledge of the properties of materials. 8.2.3 Reason about the selection of the type of material used in the created objects. 8.2.4 Explain observations about the properties of substances through sketches, information and communication technology (ICT), writing or discussion.

Table 2. The National Curriculum in England: Science Programmes of Study (DfE, 2015).

Year 5 Programme of Study	
Properties and Changes of Materials	Pupils should be taught to: • Compare and group together everyday materials on the basis of their properties, including their hardness, solubility, transparency, conductivity (electrical and thermal), and response to magnets. • Know that some materials will dissolve in liquid to form a solution, and describe how to recover a substance from a solution. • Use knowledge of solids, liquids and gases to decide how mixtures might be separated, including through filtering, sieving and evaporating. • Give reasons, based on evidence from comparative and fair tests, for the particular uses of everyday materials, including metals, wood and plastic. • Demonstrate that dissolving, mixing and changes of state are reversible changes. • Explain that some changes result in the formation of new materials, and that these kinds of change are not usually reversible, including changes associated with burning and the action of acid on bicarbonate of soda.

The context

The author implemented the lesson on investigating the properties of materials as part of their doctoral dissertation (see Mat Noor, 2022a). The lesson was implemented in Malaysia, and the participants consisted of 35 Year 4 children (ages 9-10) at a high-performing school in Kelantan, Malaysia. The lesson plan, which spanned a duration of approximately three weeks, was divided into three distinct activities, one for each week. The development of the lesson was thoroughly reviewed by five experts in the field of science education, including university academics and specialist subject leaders. The lesson, while specifically designed for Malaysian children, is adaptable and can be applied when working with children of the same age worldwide. The lesson sequence, implemented in a single lesson period (60 to 90 minutes), not only presents the basic activities involved in the lesson, but also seeks to integrate them with scientific enquiry (Deboer, 2006).

The development of learning objectives and learning outcomes

The author made the decision to develop the learning objectives and learning outcomes of the lesson by using the 'Structure of the Observed Learning Outcome (SOLO)' model (Biggs & Collis, 1982). This decision was based on the realisation that the stages of the SOLO model were compatible with the enquiry-based science teaching goals that he sought to implement. Hattie (2012) has described SOLO as a *'powerful model'* for setting learning intentions and accessing learning objectives and learning outcomes (p.54). By using the SOLO model in many of his works (e.g. see Hattie, 2012), Hattie has demonstrated how the model could be used in evaluating learning intentions and success criteria. Therefore, this body of scholarly literature inspired me to use this approach.

The SOLO model includes five levels of understanding: pre-structural, uni-structural, multi-structural, relational, and extended abstract (Biggs *et al*, 2022). These levels represent a progression from a lack of understanding to a deep understanding of a concept. In the current lesson, the decision was made to focus on the latter three levels – multi-structural, relational and extended abstract – as they were deemed more appropriate for the abilities of 10 year-old children. Using these levels, learning objectives and outcomes were carefully crafted, which are presented in Table 3.

Table 3. Utilisation of the SOLO model in the construction of learning objectives and learning outcomes.

SOLO	Learning Objectives	Learning Outcomes – at the end of the lesson children will be able to:
Multi-structural (Use two or more discrete and separate pieces of information contained in the stem.)	Recognise that cups are made up of different materials.	Name the material that each cup is made from.
Relational (Use two or more pieces of information, each directly related to an integrated understanding of the information in the stem.)	Know that the cups made from different materials have different properties.	Explain that the properties of cups are based on what materials they are made of.
Extended abstract (Use an abstract general principle or hypothesis that can be derived from, or suggested by, the information in the stem.)	Understand what properties make the material/cup the best for drinking.	Discuss which material/cup is the best for drinking based on their properties.

The lesson plan focused on addressing two key areas of the curriculum standards: conceptual understanding of key scientific ideas related to the properties of materials, and enquiry-based science teaching. Through the use of the SOLO model, the activities were designed to target the multi-structural, relational, and extended abstract levels. The first activity aimed to identify and correct children's misconceptions about the materials used to make the cups, while the second activity encouraged children to explore and identify the properties of different materials. Finally, the third activity challenged children to make evidence-based decisions about which cup was the best for drinking purposes and to present their arguments.

The enquiry-based science teaching sequences

Activity 1 – 'Naming the cups' (multi-structural)

Children entered the science classroom and sat in the groups of six that they had chosen. They brought cups from home and shared them with their peers. The teacher also provided several types of cup as a reserve to ensure that each group had a diverse selection, with a similar number of cups (n=8) for each group (see Figure 1). The first activity was to name the materials that the cups were made from and to write these names on the sticky notes provided. Within their groups, the children discussed and named the cups based on their existing knowledge. The teacher facilitated the children's discussion, checked groups' answers and corrected any misconceptions identified. This process is crucial in enquiry-based teaching, as it encourages children to use their higher-order thinking skills. Volunteer groups were also given the opportunity to present their findings to the class and a whole-class discussion was facilitated. The groups made corrections to the labels if they discovered any errors. The teacher explained that the children were beginning to investigate the eight cups like scientists. In the subsequent activities, the children were encouraged to work like scientists, by engaging with a series of activities that led to various conclusions. Thus, children discovered that science is a tentative activity that relies on experimentation.

Figure 1. Eight different types of cups were prepared for groups of children to investigate.

Materials:
1. Polystyrene cup
2. Melamine cup
3. Porcelain cup
4. Ceramic cup
5. Plastic cup
6. Stainless steel cup
7. Glass cup
8. Paper cup

The integration of scientific enquiry

In this activity, the children were required to name a variety of cups. This activity aimed to develop the children's science literacy by encouraging them to observe and classify the cups based on the material that they were made from (Mat Noor, 2021). The children used their sense of touch to identify the material that the cups were made from and grouped them according to similarities or differences. They also used their past experiences to make inferences about the cups and to name them. This activity aimed to develop the following thinking skills in children: attributing, comparing and contrasting, grouping and classifying, generating ideas, and making inferences (Zimmerman, 2007).

Activity 2 – 'Defining the properties of the cups' (relational)

The teacher provided a sheet of white flipchart paper with a prepared table template to each group and instructed the children to discuss in their respective groups the properties of each cup in front of them. The children shared ideas and engaged in a discussion with their friends. The teacher also instructed each group to come up with at least five variables, and they were told that each variable must be testable through investigation. Each group completed the task by suggesting 'the properties of the cups' (see Figure 2) and writing them in the first column of the table, as shown in Table 4. The teacher then offered the groups the opportunity to volunteer to present the outcome of their discussion in front of the class. The children were encouraged to justify why they had chosen certain variables. It was important for the teacher at that time to accept children's views and facilitate the discussion openly. The teacher would intervene if anything was incorrect, asking the children to justify their chosen properties of materials and correct any misconceptions.

Table 4. Example of the 'properties of materials' in the first column of the table that the children were expected to come up with.

	Cup 1	Cup 2	Cup 3	Cup 4	Cup 5	Cup 6	Cup 7	Cup 8
Waterproof								
Light/Heavy								
Insulator								
Recyclable								
Reusable								
Durable								

Figure 2. In their respective groups, children discuss the properties of the cups' materials.

The integration of scientific enquiry

The children collaborated as a team to generate ideas and prepare arguments for their scientific investigation (Muhamad Dah *et al*, 2023). By doing so, the children engaged in argumentation, a crucial social process where they co-operatively aligned their intentions and interpretations through a verbal rationale, thereby enhancing their understanding of scientific content and processes (Evagorou *et al*, 2020). They used their senses of hearing, touch, smell and sight to observe and identify the properties of the cups provided. They controlled variables by naming the manipulated variable and the different properties of the cups. They used a prepared template (table) to communicate their findings and explain their chosen variables. Through this activity, the children were able to practise the processes of grouping and classifying, analysing, visualising and synthesising information.

Activity 3 – 'Grading the cups' (extended abstract)

The groups carried out practical activities based on the chosen properties of materials (see Figure 3) and scored the cups that were the most practical to drink from on a scale of one to three, with one being the lowest and three being the highest (see Figure 4). They carefully discussed and determined the score for each cup based on its properties and materials. Through this process, the children determined which cup was the best based on the highest score achieved, as shown in Table 5. Each group then prepared arguments to justify their choice of the best cup for everyday use.

Figure 3. Children carried out practical activities to test the properties of the cups.

Table 5. Example of the score graded by one of the children's groups: Cup 4 is considered to be the 'best' cup.

	Cup 1	Cup 2	Cup 3	Cup 4	Cup 5	Cup 6	Cup 7	Cup 8
A	1	2	3	3	2	1	3	2
B	3	1	2	3	3	3	1	3
C	3	2	1	2	1	3	1	1
D	1	3	2	2	1	1	1	1
E	1	2	2	3	3	1	2	3
Total	9	10	10	13	10	9	8	10

Figure 4. Children discussed and scored the properties of each cup.

The teacher facilitated the children's discussion and reviewed each group's answers as they shared them with the class. At the same time, the teacher corrected any misconceptions and mediated the children's conceptual understanding of the properties of materials. The class then engaged in a discussion to explore and challenge the groups' various thinking strategies and to understand why each group had different answers and chose different cups as the best. After all groups had drawn their conclusions, the teacher emphasised that, in science, scientists continually test and challenge previous assumptions and findings.

The integration of scientific enquiry

In this activity, the children learned about the nature of science, specifically that scientific knowledge is tentative and always open to interpretation (Cleminson, 1990). As part of the activity, they used their past experiences to make inferences about the properties of different cups. They also measured different variables and used numbers, making quantitative observations by comparing each cup to a non-conventional standard. Additionally, they interpreted the data they collected by offering rational explanations about their choice of best-scoring cup. All groups also drew conclusions about the other cups, providing reasoning for why their scores were lower than those of the 'best cup'. Through this activity, the children also practised key science skills such as sequencing, prioritising, evaluating and making conclusions (Zimmerman, 2007).

Conclusions

Research indicates that the implementation of enquiry-based science teaching sequences in the classroom was an effective way to engage children in hands-on, interactive learning experiences (Kamarudin & Mat Noor, 2023). In the study, the use of various materials, such as cups, allowed children to observe and classify objects based on their properties, and to develop their science literacy and thinking skills.

The first activity, 'Naming the cups', provided children with the opportunity to observe and classify cups based on the materials that they were made from, using their sense of touch and their prior knowledge to identify and name the cups. This activity aimed to develop children's thinking skills, including processes such as attributing, comparing and contrasting, grouping and classifying, generating ideas, and making inferences. In the study, most of the children were initially unaware of the variety of cups differentiated by their properties. They learned about different types of cups and the materials that they were made from. The second activity, 'Defining the properties of the cups', allowed children to work in groups to discuss and generate ideas about the properties of the cups, such as whether they were waterproof or durable. Children were asked to come up with at least five testable variables, and were given the opportunity to present their findings to the class and justify their choices. This activity aimed to develop children's skills in grouping and classifying, analysing, visualising and synthesising information. In the study, most groups identified numerous variables, some of which were incorrect. However, they were given opportunities to explain their choices, and the teacher corrected their misconceptions along the way. The final activity, 'Grading the cups', enabled children to observe the cups, determine their properties, and then score the cups on a scale of one to three, with the highest score indicating the best cup for everyday use. Children were then asked to justify their choice and engage in a class discussion to challenge and understand different perspectives. This activity aimed to help children to understand the scientific process of continually testing and challenging previous assumptions and findings. In the study, all groups arrived at different results, and they were guided by teachers to draw conclusions. Most importantly, the children learned indirectly that science is tentative, and that the methods and results of investigations can vary, often leading to diverse outcomes.

Overall, the implementation of enquiry-based science teaching sequences in the classroom provided children with opportunities to engage in hands-on, interactive learning experiences, and to develop their scientific literacy and thinking skills. The use of materials such as cups allowed children to observe and classify objects based on their properties, and to work collaboratively and effectively to communicate their findings. These skills included dialogic exchanges, where children actively engaged in meaningful discussions, enhancing their understanding through verbal reasoning and an exchange of ideas. Argumentation played a significant role, enabling students to present and evaluate arguments, a process crucial for scientific reasoning. Social constructivist aspects, such as the 'power of the group brain' as highlighted by Vygotsky (see Erbil, 2020), were evident in the collaborative group dynamics. Working in these groups was relevant as it mirrored the collaborative nature of scientific enquiry and allowed children to learn from and with each other, thereby building a collective understanding and advancing their individual cognitive development.

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Dr. Mohd Syafiq Aiman Mat Noor, Lecturer in Climate Change Education at the School of Education, University of Leeds, United Kingdom.
E-mail: s.matnoor@leeds.ac.uk

Sci-5: a stimulating start to school science

● Christine Preston

Abstract

Stimulating science learning for all children from the start of school is the vision of the Sci-5 professional learning programme. Sci-5 aims to inspire and support teachers to implement a high-interactive science enquiry approach for 5 year-old children in the first year of primary school (Foundation year in Australia). Incorporating early years science education research, Sci-5 was developed over 20 years by an academic teacher-researcher in weekly science classes. The resulting multi-faceted suite of learning experiences and resources were designed and refined in the field. This paper describes the Sci-5 programme, provides key implications for teaching practice, and outlines ensuing research. Dual research aims are to identify teachers' specific professional learning needs to support practical teaching strategies and to enhance the applicability of Sci-5 for use in diverse school contexts.

Keywords: Primary science, enquiry, professional learning, early years, emergent science

Introduction

Every child deserves to experience high-quality science learning at all levels of school. Still, little time is devoted to science learning in pre-schools (Larimore, 2020) and early years science education is lacking, especially in comparison to literacy and numeracy (Roberts, 2021). Young children start school eager to learn in *all* subjects and teachers must avail children of *'their right to engage with the wonders of the natural and designed worlds'* (National Academies of Sciences, Engineering, and Medicine, 2022, p.237). In Australia, most children commence school in Foundation Year as 5 year-olds and their initial experiences provide a pivotal foundation for future learning. This is the age where children's initial views about science and self-perceptions as learners of science form and potentially impact future science-related pursuits (Oppermann *et al*, 2018). I argue that the first year of school is the ideal time to engage children in practical enquiry and inspire a love of learning in science.

Initiatives aimed at increasing interest and fostering careers in science mostly target upper-primary or secondary years. Such efforts are likely too late, because subject perceptions and career aspirations form during early primary school: *'well before a child leaves primary school their "STEM identity" is – or is not – developing'* (Forbes, 2024). The primary school years are crucial in capturing interest in science (Fitzgerald, Dawson & Hackling, 2013) and developing children's science learning trajectories with the narrow achievement gaps (Curran & Kitchin, 2019). Not only is it important that children do science from the start of school, but the learning should also be joyful, engaging and meaningful. Learning experiences in early school science should enable young children to experience the joy and intrigue of science learning as they make sense of the world around them (Earle, 2022). Science surrounds young children in all aspects of their lives; engaging them in exploration and play can aid them to make more sense of their observations. Early years science is important to build a foundation of ideas, language and interest (Earle, 2022) and develop positive dispositions of science (Russell & McGuigan, 2016).

Historically in Australia, science has struggled to be allocated sufficient teaching time in the primary school curricula (Angus *et al*, 2007), in a crowded curriculum comprising six key learning areas: English, Mathematics, Human Society & its Environment, Creative & Practical Arts, Science & Technology, and Personal Development, Health & Physical Education (PDHPE – a mandatory subject). Key issues with children's learning in primary science in England (Bianchi *et al*, 2021) include insufficient timetabling of science time and that young children's curiosity, interests and questions are not being sufficiently capitalised. The Australian Office of the Chief Scientist (2014) advocates *'core STEM education for all students – encompassing inspirational teaching, inquiry-based learning and critical thinking – placing science literacy alongside numeracy and language proficiency as a priority'* (p.20). Science should feature substantially in school curricula to provide balance and to help prepare children for their current and future lives (Stubberfield, 2023). To combat this missed opportunity, regular lessons should be programmed into the weekly timetable from the start of school to ensure that adequate time is given to science learning.

Whilst more science time is pivotal to enhance student learning of science, the curriculum aspects, resource provision, training of teachers and pedagogical approaches are also crucial elements to address. A lack of opportunity for young children to learn science is often blamed on teachers' low science teaching efficacy and limited understanding of science concepts (Roberts, 2021). Primary teachers require support *'to teach science in ways that matter'* to help their children *'better understand why science matters'* (Fitzgerald & Smith, 2016, p.64). Professional learning focusing on science in the first year of school can equip teachers to notice and respond to children's interests, to talk about their ideas and encourage them to think scientifically.

An existing Australian science programme that includes Foundation Year, *Primary Connections* (https://primaryconnections.org.au/) was designed by the Australian Academy of Science to integrate science and literacy. The units of work follow an enquiry and investigative approach incorporating Bybee's 5Es instructional model (Bybee, 1997) and emphasises co-operative learning (Hackling, Peers & Prain, 2007). Primary connections units are ideally taught as complete units, without deviating from the scripted lesson plans, and using the resource materials provided. A strength of *Primary Connections* units is that they provide a fabulous starting point, giving teachers confidence to implement enquiry lessons. A weakness is the view that the literacy emphasis overshadows the science. After using the *Primary Connections* units, many teachers reported (personal communication) the desire to design their own units with greater science practical tasks. The Foundation Year units include some age-appropriate hands-on tasks; however, I recommend a lesson-based, rather than a unit-based, teaching model for emergent science learners.

Sci-5 is a niche programme designed for the first year of school to transition from play-based pre-school to enquiry-based school science learning. Two pre-school STEM programmes include *Conceptual Playworlds*, featured in a previous issue of *JES* (Fleer, 2019, 2022, https://www.monash.edu/conceptual-playworld) and *Early STEM Learning Australia (ESLA*, https://elsafamilies.com.au/). *Conceptual Playworlds* approaches STEM teaching by combining imaginary play with imagination in science and has a strong research basis. Fleer's work on *Conceptual PlayWorlds* (2022) provides insight into ways in which play and intentional science learning can be intertwined. Exploratory play, intentional teaching and interactive dialogue are features of the Sci-5 teaching model that underpin this professional learning programme. The Sci-5 programme is a hybrid of play-based and guided enquiry learning experiences and focuses on high student engagement and emergent science learning, whilst *Early STEM Learning Australia (ESLA)* focuses on digital technologies with play-based digital apps and ideas for off-app activities to help engage pre-school and Foundation Year children in fundamental STEM practices (Lowrie & Larkin, 2022). There are many insights in other documents as well, including the Early Years Learning Framework (EYLF) and Australian research (Australian Government, 2009). This paper will focus on the importance of providing a stimulating science programme for 5 year-olds in their first year of formal schooling.

In contrast to *Primary Connections*, Sci-5 has a flexible design, allowing teachers to choose learning experiences to suit their school's context. The programme adopts a more bespoke approach; for example, one school piloting the programme in late 2023 combined the topics of living things with forces and movement to align with curriculum content in other key learning areas. Enabling teachers to make decisions about sequencing to plan custom units gives them autonomy, respecting their professional expertise and knowledge of the needs of children in their classes. This flexibility avoids a 'one-size-fits-all' approach and aims to inspire teachers to use the example learning experiences to create their own lessons using the Sci-5 teaching model. Teachers in other countries can develop similar learning experiences according to their specific curriculum requirements.

I believe that science must be taught regularly in the first year of school and that teachers should be given support to ensure that it is taught in authentic, effective ways. Science needs to be positioned as an engaging and creative discipline that children cannot do without. Such an aim is ambitious, but achievable. In 20 years of experience as a teacher of science with 5 year-olds, I have collected evidence, from first-hand observations and comparison of pre- and post- work samples, that young children can be fully engaged in hands-on, minds-on science learning from the beginning of school. A targeted approach for thinking about and guiding the science learning of 5 year-olds commencing school is needed.

Background and development of Sci-5

My initial experience teaching high school science with 13-18 year-olds and involvement in curriculum development gave me a thorough understanding of secondary curriculum content. Understanding student thinking and learning in science and an affinity with younger children saw me transition to a science specialist role, teaching all years from kindergarten to upper primary (5-12 year-olds). My passion for science education resulted in a career move to university teaching. I was fortunate to be able to continue weekly teaching at the school, which gave me contemporary classroom experience and opportunity to research my practice as a teacher-researcher. I chose kindergarten because I became enthralled with the perspectives and capabilities of young children at the start of their school learning journey.

I began sharing ideas of practice with teacher colleagues in the profession by writing some articles for *Teaching Science*, the Australian Science Teachers Association journal. In 2016, I was invited to write an Early Years Science feature series to provide hands-on activities to encourage early years children's natural curiosity and develop their scientific thinking. Producing four issues per year (up to 2021) led to a substantial resource base. In consultation with the school principal, we decided that I could make my teaching programme and its multiple classroom-ready resources available for the benefit of other teachers. To assist teachers to understand the research underpinning the teaching programme and become comfortable with implementing the learning experiences in their own classroom, I created the Sci-5 Professional Learning programme.

The first phase in the Sci-5 programme was to consolidate the published articles into an e-book resource to make the work easily accessible to teachers (Figure 1). The learning experiences in the book draw on science lessons conducted between 2003 and 2021. Through practitioner research over this significant time, component activities were extensively tested and iteratively improved, incorporating feedback from multiple practising primary teachers who co-taught the lessons. The e-book, available as an existing resource (at low cost with all proceeds going to the Australian Science Teachers Association (https://www.asta.edu.au/resources/books/), is the centrepiece of the Sci-5 Professional Learning programme.

Figure 1. The e-book resource.

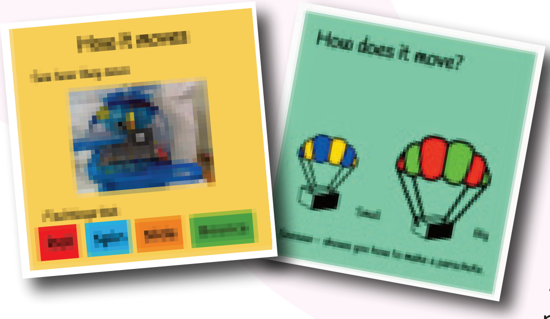
The e-book resource contains teaching strategies, insights into children's thinking, evidence of learning from work samples, and effective and creative ways to explore specific concepts and topic areas. It also includes ideas for practical tasks that teachers can directly use, modify, or be inspired by to create their own learning experiences. The learning experiences in the Sci-5 programme seek to 'push the boundaries' to explore what each child is capable of learning so as not to be superficial, to extend children's thinking and motivate them towards working scientifically (Bianchi *et al*, 2021). Table 1 lists the articles grouped by science domain and shows the range of topics included. The learning experiences comprise three to four per science area, two that focus on STEM and on technologies (design and digital), and four that target development of enquiry skills practices.

Table 1. Structure of the professional learning resource.

Science Domain	Number of articles	Content inclusions
Biology	4	Model animal habitat, Plant leaf exploration, Food from plants, Reasoning about living things.
Chemistry	4	Water wonder – online learning, Material properties, Weaving fabric, Materials testing umbrella.
Earth Science	3	Clothes for different seasons, Simple wind detector, Rock wonder.
Physics	3	Parachute drop, Lego car race, Moving toys.
STEM	2	STEM torch design, STEM scooter design.
Enquiry skills practices	4	Observing using the senses, Drawing like a scientist, Magnify me, Child-led inquiry.
Technologies	2	Digital technologies, Design a bookmark.

The Sci-5 programme also includes other resources to support teaching and learning in specific topic areas such as: interactive e-books for children (Figure 2), videos for teachers, lesson plans and examples via the See Saw e-learning platform.

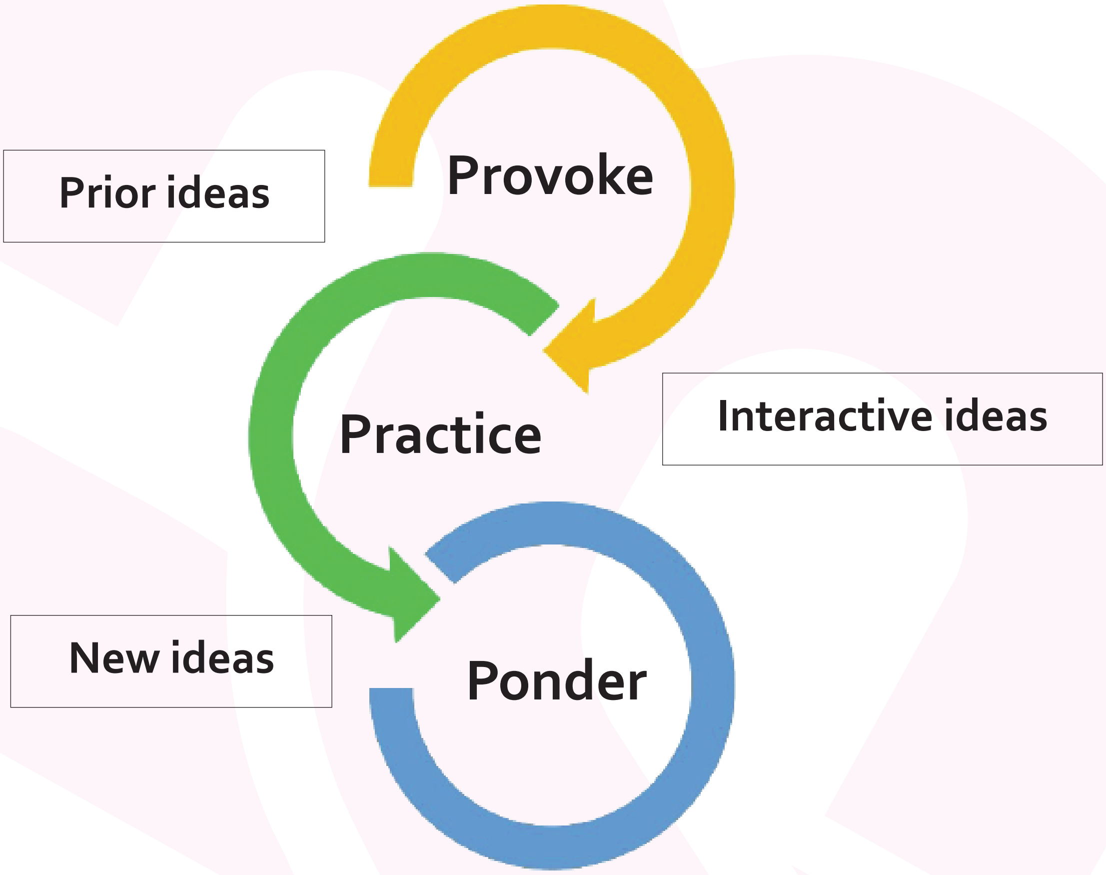
Figure 2. Sample e-book pages.



The Sci-5 teaching model

My approach to teaching science to 5 year-old children '*is grounded in a constructivist, hands-on, minds-on, view of learning*' (Preston, 2022, p.4). My practice draws on 25 years of research in science education informed by my co-edited book *Teaching Primary Science Constructively* (Skamp & Preston, 2021). Through progressive implementation of research on early years science in my classroom, with input from experienced kindergarten teachers, I developed a Sci-5 teaching model on which the learning experiences in the programme are based (see Figure 3).

Figure 3. Preston Sci-5 Teaching model.



The learning experiences were created to draw on children's existing ideas as the foundation for additional learning. Each lesson commences with a **provocation,** such as a question, physical resource, puzzle, or story to trigger prior knowledge and pique children's interest. Acknowledging that 5 year-olds will come to school with previous learning such as pre-school (EYLF, Australian/ Early Years Foundation Stage, in England) and from personal experiences growing up in their world, this stage engages children in voicing their ideas and thoughts, evoking Russell and McGuigan's (2016) view that *'teaching is an interactive pursuit, something done with children rather than to them'* (p.3). This helps teachers to gain insights into children's thinking, to see the world from immature, novel perspectives and to build learning experiences around their emergent science learning.

Most of the lesson time is taken up with **practical** tasks, through which children can explore, discover, create and test their ideas. Through hands-on investigations, children expand their ideas, develop scientific skills, and are challenged to think like a scientist. Throughout the interactive dialogue between children and teacher, they are encouraged to ask and answer questions, which supports their meaning-making. In this way, the children develop understanding of science concepts as they engage in doing science.

The final phase of the learning experience provokes children to **ponder** what they have learnt: voicing new ideas helps to consolidate their shared and individual learning. Children may exhibit and talk about the products of their work and express interest in future directions of learning. Key implications for practice of the Sc-5 approach are summarised in Table 2.

Table 2. Summary of Sci-5 with implications for practice.

Key implication	Practice notes
Provoke – start each learning experience in interesting, engaging ways that activate thinking and elicit children's prior ideas.	Use a stimulus to gain children's attention
	Focus children's thinking on the topic/concept/ problem
	Ask questions to encourage children to express their ideas and consider other people's ideas
	Engage children in preliminary discussion
Practice – include one or more hands-on experiences as essential learning elements. Support children to develop skills and create meaning as they explore and investigate science topics.	Engage children in different practical experiences
	Provide new and repeat opportunities to develop scientific skills and practices
	Support children's thinking and noticing during practical experiences
	Develop sharing, turn-taking and helping each other
	Enable children to do and think like scientists
	Support children to record and communicate ideas using age-appropriate, multi-modal strategies
	Have children generate meaningful representations using drawings and annotations
Ponder – consider the learning from the children's perspective. What do they know, think, or can do now? Where to go from here?	Encourage children to reflect and talk about any new ideas
	Reinforce big idea(s) related to children's learning
	Encourage wonder and to ask further questions

Age-appropriate hands-on tasks

I feel that the strongest element of the Sci-5 programme is the range of hands-on practical tasks suited to 5 year-old children. Every activity has been refined over many years of collaboration with kindergarten classroom teachers. Although teachers may be willing to implement practical enquiry, the challenge is to find tasks that have been specifically designed for emergent science learners. One of my favourite tasks involves children building a Lego car and using paddle pop sticks to measure how far the car goes to answer a question such as: Which wheels make the car go further? Figure 4 shows two girls working together to measure how far the car moves and Figure 5 shows the scaffold to guide children in their first recording of results by colouring in the boxes to represent paddle pop sticks.

Figure 4. Children measuring using pop sticks.

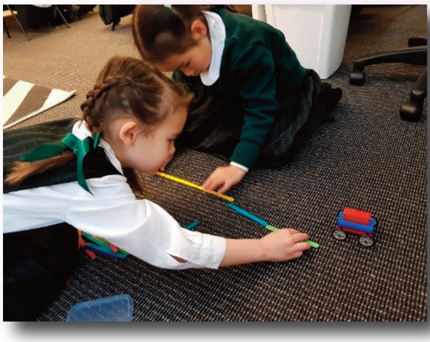
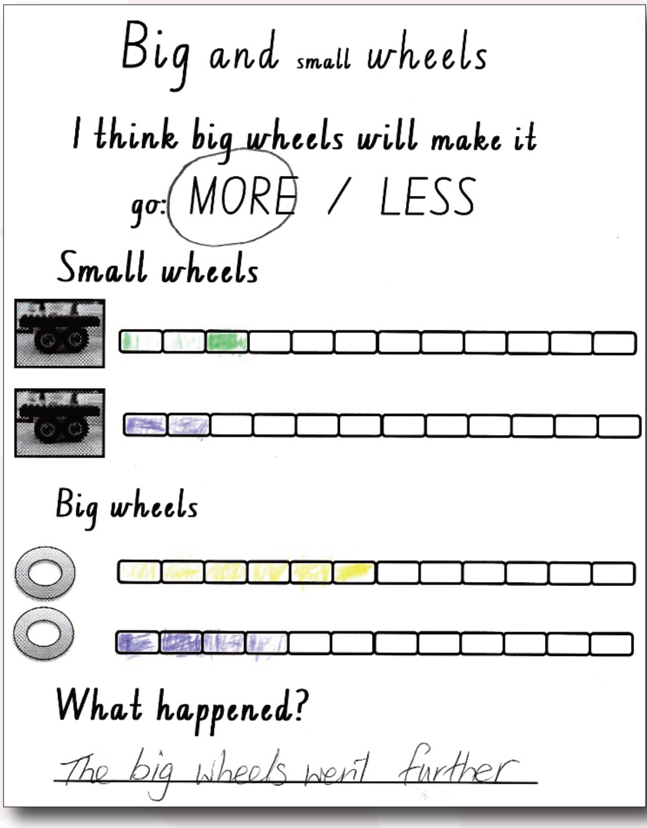


Figure 5. Sample pupil record.



Physical equipment / resources

A range of equipment is needed to implement the learning experiences. It is my belief that you 'can't teach science without stuff'. Fortunately, most of the equipment can be easily sourced and I recommend building up a store of materials that can be used regularly for science lessons. Some teachers whom I have mentored created a 'storeroom' out of disused lockers, which were transformed into a shareable resource space (Preston & Mussone, 2013).

Examples and modelling

As the Wellcome Trust's research reminds us, some teachers *'do not see themselves as 'sciencey'* (Wellcome, 2020, p.9), hence the need for a range of support materials within the programme resources. For example, quotes direct from children in my classes and work samples provide teachers with insight into 'where children are at' in their learning trajectory in their first year of school. Of course, every class is different and learning experiences may need to be adapted to suit the specific learning needs of each group of children. My experience is that the example learning tasks can be adapted to be variously challenging and to be inclusive. A few videos are available that provide opportunities for teachers to view teaching strategies first-hand. For example, a video taken while I was teaching kindergarten how to draw like a scientist (https://youtu.be/S-j_3r4v8vk) demonstrates the use of embodied learning. Gestures and acting out 'tracing the plant in my mind' are demonstrated, together with the children's reactions to my deliberate mistakes. Recent research in informal science centres (Manches & Mitchell, 2023) and my own research in mathematics and science (Preston, Way & Smyrnis, 2022) demonstrate the *'embodied nature of how we think, and the potential to encourage body-based experiences to support learning'* (Manches & Mitchell, 2023, p.23). Viewing examples of practice is a good way to help teachers to see possibilities for teaching kindergarten science.

Current and future research

My kindergarten science teaching experience enabled me to develop a suite of practical learning tasks to connect with the children's lived experiences and stimulate interest in science, but this requires testing in other classrooms to validate my belief that the Sci-5 model is a valid approach to science education in the first year of primary school. The question is whether these resources are useful to support other teachers to adopt and enhance a guided enquiry approach. To provide a strong evidence base for teachers to modify their practice, there must be a clear understanding of their perceived needs, readiness and suitability of support provided (Deehan & McDonald, 2023).

The following research questions focus this enquiry:

1. What are the specific professional learning needs of teachers to develop a child-focused, practical enquiry approach to science in the first year of school?
2. How do teachers perceive the applicability of the Sci-5 resources and learning experiences for their school context?
3. To what extent do the learning experiences engage children in active enquiry learning in science?

The first part of the research (phase 2 of the programme) involves piloting the Sci-5 professional learning in schools with multiple kindergarten teachers to gain feedback on how the resource materials need to be adapted for use by different teachers in a range of school contexts. Two schools participated in the Sci-5 programme in the final school term of 2023. Initial responses from teachers in the pilot phase in 2023 include being delighted about the extent of high-level engagement of children throughout the lessons, and surprise about their prior knowledge of science ideas.

The findings of phase two will inform further development of a Sci-5 professional learning package. In the second part of the research (phase three), the professional learning package will be implemented in a broad range of Australian schools with data being collected on its impact on teaching. Future research may also consider the long-term impact of the Sci 5 programme on children's primary school science learning because of experiencing a stimulating start to school science.

Table 3. Research project phases and timeline.

Phase and year	Details
1– 2022 Resource development	Development of support materials for teachers including publishing an e-book of research-based teaching activities.
2 – 2023-4 Pilot	Test and revise the resource materials and professional learning strategies to enhance applicability for use in diverse school contexts. 5 schools (city and country), 16 teachers (class and specialist).
3 – 2025-6 Upscaling	Implementing the professional learning package in a wide range of schools and evaluating the impact on teacher practice. 30 schools (city and country), 120 teachers (class and specialist).

The aim of the three-phase project is to develop an evidence-based, classroom-ready professional learning package that empowers teachers to implement constructive pedagogy that supports contemporary practice in science teaching and learning in the first year of school. The research is significant because, whilst we know that primary teachers want professional learning, their specific needs in relation to teaching science in the first year of school are unknown. Rarely are teachers provided with in-class teaching support and the opportunity to experience and adapt resources to suit both their teaching and the learning needs of their students. It is hoped that the research will provide insights into factors that will enhance the uptake of professional learning for teaching science and the benefits for 5 year-olds of a stimulating start to school science.

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Dr. Christine Preston, Associate Professor in Science Education, University of Sydney.
E-mail: christine.preston@sydney.edu.au

Forest nursery as an ideal backdrop for engaging girls in STEM education

● Rebecca Donnelly ● Helen Bridle

Abstract

This paper explores issues relating to gender equality that are present in early years education and reviews current literature relating to gendered education spaces. In this review, we found that classrooms can be viewed as gendered spaces and that social pressures on children may mean that girls do not have equal access to Science, Technology, Engineering and Mathematics (STEM) resources and toys. Children attending forest nurseries, however, could have more freedom from stereotypical gender norms than those attending classroom-based nurseries. We suggest that moving STEM education outside can reduce the social pressure on young children to conform to gender stereotypes, leading to a higher engagement with STEM.

Keywords

Gender equality, pre-school, STEM education, forest nursery

Introduction

As a society, we are reliant on people working in Science, Technology, Engineering and Mathematics (STEM) (House of Lords Science and Technology Committee, 2022), but diversity in these areas is lacking. One UK-based report found that women make up only 27% of the people working in STEM, with technology and engineering roles being particularly skewed in men's favour (APPG on Diversity and Inclusion in STEM, 2020). Gender Equality is one of the UN's sustainable development goals, and increasing the number of women working in STEM will help to bring us closer to reaching that goal (United Nations, 2015).

However, despite multiple efforts over the past decades, the challenge of achieving gender equality in the STEM workforce still requires a lot of work. Career development theory (Gottfredson, 1981) highlights how career choices become limited early, with children ruling out careers and having gendered career aspirations at a young age (Chambers *et al*, 2018). Recent studies have started to explore the benefits of bringing STEM education to early years settings, considering the role of the environment, pedagogy and the attitudes and interests of the children as factors that are key to broadening perspectives (Padwick *et al*, 2022). These studies emphasise that an important approach to improving diversity in STEM is to start young (Campbell *et al*, 2018; Rippon, 2021).

Pre-school is often a child's first taste of formal education, but children as young as 2 years are influenced by the gender stereotypes found in classrooms (Campbell *et al*, 2020; Halim *et al*, 2014; Régner *et al*, 2014). During early years education, children are learning the social cues that help them develop into productive members of our society, and at this age they are particularly sensitive to what is *'for boys'* and *'for girls'* (Halim *et al*, 2014; Rippon, 2021). Removing barriers to, and increasing participation in, STEM before children see it as *'not for them'* could help to tackle diversity issues further down the line.

With the Scottish government calling for improvements in early years STEM learning (Learning in STEM in early years, 2020), increased provision for outdoor learning opportunities (Out to Play, 2020), and gender-free play environments for pre-school children (Care Inspectorate & Zero Tolerance, 2018), the rise in popularity of forest nurseries in Scotland (Brooks, 2018) provides a unique opportunity to draw attention to the limited research linking these key areas. This paper builds on work by Speldewinde (2022) and Maynard *et al* (2013) by suggesting that taking STEM education outdoors may provide a way of reducing the gender conformation pressures found in early years education, and could increase girls' attainment in STEM by lowering gendered barriers to participation.

Theoretical frameworks

The direction of this work has been informed by place-based learning and feminist pedagogies. Place-based learning is where a connection between learners and their environment allows for learning to happen through hands-on experiences (Yemini *et al*, 2023), while, in feminist pedagogies, more inclusive learning environments are created, empowering children (particularly girls) to challenge traditional gender roles (Shrewsbury, 1997).

In this paper, we argue that outdoor learning environments offer children spaces that are less constrained by traditional gender roles, instead offering children a more inclusive environment aligned more with feminist principles than a traditional classroom. As well as challenging social norms, outdoor learning also provides opportunities for children to explore and engage with their surroundings through hands-on experiences, providing experiential, place-based learning. By encouraging children's inherent curiosity, outdoor learning allows children to discover and make sense of the world around them without any predetermined social pressures.

Classrooms as gendered spaces

Pre-school forms a big part of young children's lives, with 92% of 3 and 4 year-olds in the UK being registered as attending a pre-school (Department for Education, 2022). Children start forming their perceptions of gender and social roles around the age of 2 years (Rippon, 2021), and so pre-school environments provide a key role in a child's lifelong perceptions of gender and its place in society.

Pre-school classrooms are often highly gendered spaces in the way that they are set up, which impacts how children play in them and how acceptable adults deem their play (Børve & Børve, 2017). When accessing STEM spaces set out by pre-school teachers, girls have been shown to be equally interested in the activities as boys (Campbell *et al*, 2020); however, as sessions go on, girls become progressively excluded from the activities by boys (Fleer, 2019). Boys have also been shown to sometimes block girls' access to construction-based play areas (Lyttleton-Smith, 2015). Even when children have equal opportunity to use play items, they prefer to occupy spaces with more activities relating to their own gender identity. This could be because the way that toys are played with differs between genders, with girls using building materials to build for a purpose (such as building a zoo), whilst boys build as they play (Hallström *et al*, 2014). The physical set-up of a pre-school can impact the way in which children interact in the classroom; for example, having a dolls' corner can confine girls to the peripheries of a classroom, whilst the nature of 'boys' toys' such as cars and weapons require more space, and thus are often found being played with in the centre of rooms. This division of space then limits children, with girls, for example, becoming unwilling to enter spaces occupied by boys (Børve & Børve, 2017).

Gendered access to STEM toys

Toys can further exacerbate the gender imbalance found in classrooms, with boys accessing play items such as building blocks more frequently than girls (Prioletta, 2018). Blocks are known to promote STEM and engineering thinking through allowing children to practise spatial thinking (Bairaktarova *et al*, 2011; Gold *et al*, 2021). Children in classrooms, however, don't have equal access to blocks and construction-based toys, with boys pushing girls out of shared building spaces (Bagiati & Evangelou, 2016) and girls trying to join in by taking on secondary roles through passing blocks to boys rather than building themselves (Hallström *et al*, 2014).

This lack of access to play equipment that supports STEM learning has a lifelong impact, as toy choice as a young child has been linked to undergraduate degree choice, with women who preferred to play with spatial toys such as blocks as children being more likely to study STEM subjects as undergraduates (Moè *et al*, 2018). Some toy manufacturers have attempted to address this gender imbalance with a 'pinkification' of STEM toys. It has been found, however, that not only is this not beneficial to girls, but that it is actively harmful to boys, with young boys performing worse on spatial building tasks when told to use pink, purple and white construction materials rather than primary-coloured materials (Mulvey *et al*, 2017).

Gender in natural spaces

The way in which children express themselves in outdoor environments is different from that in the classroom. Observations of children in nature show that they engross themselves in the exploration and manipulation of the environment, challenging themselves physically and creatively. As natural environments and the items within them were not created with a predetermined social purpose in mind, they support ungendered play and discovery (Chawla, 2021).

However, the impact of being outdoors on children's gender identity does appear to depend on the proximity to the child's school. Studies by Decker and Morrison (2023) and Hine (2023) looked at primary-aged children engaged in forest school or nature-based interest groups and found gender conformation to be more salient in outdoor settings with, for example, boys choosing to use sticks as weapons and girls using sticks as pretend animals in need of care. However, both studies did also find that outdoor spaces provide a space where the exploration of gender non-conforming play is more acceptable than in a classroom (Decker & Morrison, 2023; Hine, 2023).

On the other hand, studies observing nursery-aged children attending outdoor sessions away from their usual school or nursery site found natural outdoor spaces to be significantly less gendered than classrooms (Änggård, 2011; Waller, 2010).

Early years education is no stranger to outdoor learning, with the very first recorded nursery school in New Lanark, Scotland being designed to allow children to experience the outdoors (Martin, 2017). Nature pre-schools are a way of life for many Scandinavian children, with time outdoors and away from the classroom being typical in all but the worst of weather conditions (Beate & Sandseter, 2014), and countries that embrace their indigenous roots such as New Zealand often have early years curricula that focus on place-based learning, such as *Te Whakariki*, which naturally lends itself to outside learning (New Zealand Ministry of Education, 2017).

These outdoor spaces afford children freedoms that are not attainable in classroom environments, enough space to be themselves, and to be *by* themselves. The reduced pressure from the physical environment, no longer being in close proximity to others, and the freedom from manufactured and consumerist play items allow children the space to explore their gender identities and result in a much less gender-focused environment (Änggård, 2011; Decker & Morrison, 2021; Frödén, 2019).

The clothing that children wear at nursery impacts the way that they express their gender identity, which in turn impacts the way that others interact with them, often resulting in gendered exchanges (Halim *et al*, 2014; Meland & Kaltvedt, 2017). At forest nursery, this pressure is reduced when everyone is wearing waterproof clothing, particularly when the nursery has given every child identical-looking items. This outerwear can have the effect of creating a barrier between a child and the dirt, allowing children to engage more freely with nature and removing the worry for girls of maintaining their status as *'careful, clean girls'* (Mycock, 2019).

In outdoor environments, there are few differences between the activity levels of girls and boys and, whilst there is sometimes a gender difference in the types of play in which children engage, overall, outdoor environments provide a much less gendered play space and provide children with more opportunities to engage in counter-stereotypical play (Änggård, 2011; Waller, 2010).

Implications for practice: STEM learning in natural spaces

Giving children a space in which to learn and grow with a reduced pressure on gender conformity allows both girls and boys to realise their full potential (Speldewinde & Campbell, 2021). Activities exploring place-based learning, such as learning about native plants and animals, help to foster a sense of responsibility in children and afford them a sense of wonder and appreciation of the natural world (Hughes & Maaita, 2023). This wonder can stimulate children to start questioning their environment and allows them to discover STEM topics in a child-led and natural way (Campbell *et al,* 2018). This freedom to explore what is interesting to the child is key for fostering a love of learning and a lifelong interest in STEM, with positive childhood experiences with STEM being cited at a reason for pursuing a STEM career (Dorsen *et al,* 2006).

The outdoors provides children with opportunities for real-world contexts for STEM learning, challenging educators to act reactively to children's discoveries rather than planning STEM learning ahead of time (Speldewinde, 2022). The lack of toys with a prescribed purpose forces children to be more creative; for example, a simple stick can become a tool or a building material. With a simple bit of imagination, sticks can provide multiple opportunities for children to engage with engineering and technology (Speldewinde & Campbell, 2022). Spatial reasoning, a precursor skill for complex mathematics, is a skill that both girls and boys can practise without judgement in outdoor spaces by climbing trees (Gull *et al,* 2017; McCluskey *et al,* 2023). Throwing stones into puddles gives rise to opportunities to explore momentum, forces and even the chemical properties of mud. And, with seedlings, bugs, stones, eggshells and countless other natural wonders, the opportunities for exploring natural sciences are limitless.

Conclusion

Diversity in STEM is an area with room for improvement, and exploring ways of increasing engagement with STEM during early years education can only be beneficial. Pre-school classrooms often struggle to provide the equal access to the STEM resources that our children deserve. By increasing the forest nursery provision available to our young children, we can increase their opportunities to learn in a less gendered environment.

With outdoor education, children who otherwise would struggle to engage with STEM are given the opportunity to explore their world, free from the usual artefacts that could constrain them in a classroom environment. Additionally, fostering the natural sense of wonder with which all children are born empowers them to grow their own interests and build their critical thinking skills.

The outdoors also provides a real-life context for many scientific phenomena that are difficult to engage with in the classroom – water cycles, Moon phases, and projectile trajectories are all topics within reach of discussion whilst on a walk in the woods. There is however, work to be done. Overstretched early years staff need the time and training to become comfortable with bringing their work outside, and parents used to the rigours of the classroom may need convincing of the benefits. However, by bringing STEM outdoors, we can make it accessible to everyone.

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Rebecca Donnelly is a PhD student at Heriot-Watt University,.
E-mail: rd2032@hw.ac.uk

Helen Bridle is Associate Professor at Heriot-Watt University.
E-mail: h.l.bridle@hw.ac.uk

Epistemic insights: Climate justice and sustainability through an interdisciplinary lens

● Lewis Morgan ● Sophie Nelson

Abstract

With rising average global temperatures resulting in the drastic transformation of our planet, the necessity for climate change education has never been more apparent. The severity of the transformation is outlined by Begum (2022) who reports that 'The impacts of climate change and extreme weather events have adversely affected, or caused the loss of ecosystems including terrestrial, freshwater, ocean and coastal ecosystems, including tropical coral reefs; reduced food security; contributed to migration and displacement; damaged livelihoods, health and security of people; and increased inequality' (p.9).

This article will explore how a Climate Ambassador knowledge exchange project, delivered across ten primary schools in Leeds, developed pupils' and teachers' knowledge and understanding of climate change, climate justice and sustainability, whilst developing a sense of belonging to understanding and taking positive actions that support mitigation of this global issue.

Underpinned by the principles of the Epistemic Insight approach (Billingsley et al, 2018), adopting a multidisciplinary approach, sessions attempted to break through the barriers that climate change education and, often science itself, present. The project ran for twelve weeks and culminated in a team of 'Climate Ambassadors' from each primary school attending a conference, based at Leeds Trinity University, where pupils and teachers shared both their learning and their responses to 'big questions' about the climate and their place in tackling this global concern.

Keywords: Climate change, climate justice, sustainability, epistemic insight, multi-disciplinary, belonging

Introduction

'Climate literacy should not just be for decision makers of today: it is an essential life skill that our leaders of the future must possess' (Hoath & Dave, 2022, p.9). Although referring to school leaders in this context, the Hoath and Dave report outlines the importance of collective action of all. Changes in the earth's climate have been taking place at a rate that is unprecedented and, consequently, it is vital for young people to understand climate change, be educated about the related social issues and investigate how they are stakeholders in the climate crisis (IPCC Report, 2022).

For this to happen, it is imperative that teachers, as well as the young people whom they are teaching, feel prepared and confident in supporting meaningful collective action and understanding. Teaching the Future surveyed over 7500 teachers and found that 70% of teachers during their Initial Teacher Education, or since qualification, have not had training that is adequate for them to educate students on climate change (Teaching the Future, 2021). Underpinned by a recently published framework (Hoath & Dave, 2022), and continuing the success of a pilot project in 2022, our knowledge exchange project supported teachers, leaders and teacher educators to begin to embed climate change, climate justice and sustainability into the curriculum, modelling and resourcing a series of sessions, accessible across the primary age phases (5-11 years).

We identified that learning about climate change involves complex scientific concepts, including Earth Systems, atmospheric chemistry, and long-term trends, which many find difficult to comprehend. Climate change education often requires individuals to connect these scientific concepts with real-world impacts, societal issues and potential solutions. This interdisciplinary nature adds another layer of complexity, as learners need to navigate both scientific and socio-economic dimensions.

Furthermore, the children in our primary schools, and the communities around them, are confronted with increasingly significant and complex global challenges. These issues, specifically that of climate change, mean that the future demands a better understanding of scientific information and its use in everyday decision-making (Kaakinen *et al*, 2023). For our participants to be able to attempt to find solutions to these problems, the gap between their perceptions and views compared with scientific knowledge and understanding must be acknowledged. This aligns with Hoath and Dave (2022), as they suggest that at the core of sustainability and climate change education is the need for children and young people to be able to engage in collective action, adapt and apply their skills and knowledge in decision-making, whilst having sufficient knowledge to face future environmental challenges, and this was a key theme that ran throughout the project.

We regarded growing science capital as an important factor in how people can understand and interact with the global challenges. The concept of science capital, developed and expanded upon through the Science Capital Teaching Approach (Godec *et al*, 2017), is positioned as increasing the understanding of how different forms of capital (scientific literacy, attitudes, experiences) work together to shape an individual's engagement with science (Archer *et al*, 2017). The overall aim of measuring and investigating the level of someone's science capital is to close the current STEM gap and to get more children and young adults to engage in STEM subjects (Padwick *et al*, 2023). Dr Anjana Khatwa, Earth Scientist and presenter, outlines that *'much of the narrative concerning climate change naturally sits within the STEM subject area'* (Hoath & Dave, 2022, p.9). However, what happens if you have low science capital? What happens if you believe that science isn't for you and that you feel so disconnected with the subject that you can't help or contribute to helping find a solution? If we position tackling climate change, addressing climate justice and sustainability as being part of the STEM subjects, then offering this restricted lens to view the problem and solutions may not be sufficient. A multi-disciplinary approach must be adopted, and our project aimed to bridge this gap by utilising the Epistemic Insight approach (Billingsley *et al*, 2018).

Rationale: Why use epistemic insight as an approach to tackling climate change education?

Whilst many consider teachers to be 'in the business of' imparting knowledge to their pupils, rarely might they expect teachers to encourage pupils to interrogate the very nature of knowledge, how this is acquired and what 'truths' underpin their beliefs. And yet, creativity and critical thinking are recognised by the Organisation for Economic Co-operation and Development (OECD) as essential skills required by young people to solve the complex problems of the future (OECD, 2019). It is widely acknowledged that global warming is one such problem, with future generations set to experience stronger negative effects of climate change in years to come (IPCC, 2022), and therefore it is essential to explore practical strategies that teachers can integrate into their curriculum. In addition to developing both pupils' and teachers' knowledge and understanding, this should also seek to empower young people to act against climate change (Schreiner *et al*, 2005) and encourage creative and critical engagement with the topic, to enable them to respond to the effects of this global issue with meaningful actions (Stevenson *et al*, 2017).

Epistemic insight, defined as 'knowledge about knowledge' (Billingsley *et al*, 2018), builds upon the view that the epistemic goal of education should extend beyond providing pupils with a predetermined body of 'true beliefs' to call upon and, instead, develop cognitive agency by enabling pupils to determine truths for themselves (Pritchard, 2013). Acknowledging that pupils *'need a working knowledge of how disciplines can work together to address real-world questions'* (Billingsley & Hazeldinemay, 2020, para.2), the approach was taken because it offers an opportunity for interdisciplinary learning, which encourages pupils to see beyond the constraints of individual subject disciplines and enables them to appreciate both the power and limitations of science (Billingsley, 2017). Use of the 'Discipline Wheel', discussed below, allowed the organisation of knowledge and the application of critical thinking when answering 'big questions'.

Research suggests that, where attempts are made to include climate change in the curriculum, links are most often made with the knowledge base underpinned by the science and geography curricula and, yet, the issue is far more holistic (Greer *et al,* 2023). The increasing effects of climate change will have an impact upon almost all aspects of our lives and thus it is the role of educators to not only impart knowledge and challenge misconceptions around the topic, but also to instil a sense of belonging that enables pupils to connect to the issue and value their own role as contributors to positive solutions.

Monroe *et al* (2017) recognise that a common theme of effective climate change education relates to making content personally relevant and meaningful to learners, and Hodson (2003) acknowledges that *'those who act are those who have a deep personal understanding of the issues (and their human and environmental implications) and feel a personal investment in addressing and solving the problems'* (p.657). By creating and exploring 'big questions' relating to this issue and instigating discussion across the subject disciplines, pupils are invited to make these connections, share their own experiences and beliefs, and evaluate different perspectives. This, in turn, makes the climate change discussion accessible to all pupils, shattering the *'subject silos'* (Billingsley & Hazeldinemay, 2020) that often alienate those with low self-efficacy, or interest in STEM subjects, inviting everyone to join the climate conversation.

Asking 'big questions': The Climate Ambassador Project

Over twelve weeks, ten groups of 'Climate Ambassadors', a group of Key Stage 1 (ages 5-7) and Key Stage 2 (ages 7-11) children, and their teachers, from primary schools across Leeds, engaged in weekly sessions based on climate change, climate justice and sustainability. In many schools, the 'Climate Ambassadors' had to write an application letter to be part of the group because the interest in the project was so high. Acknowledging that research indicates that to deliver effective climate education, teachers themselves require a broad knowledge and understanding of the topics (Leve, 2022), academics worked alongside teachers to co-create session plans and resources prior to each session, combining subject-specialist knowledge and classroom pedagogy. Working collaboratively was important, as academics needed key information about the context of the classroom and school to enable material to be as accessible as possible. Due to the numerous widespread locations of schools involved, sessions mainly took place online, where teaching ideas and materials were discussed.

Initial sessions, led by teachers and leaders in participating schools, elicited pupils' prior knowledge and conceptions of the content, before developing understanding of key terminology and learning about the evidence for, and causes of, climate change. In addition, sessions also explored the inequities related to climate justice and the concept of sustainability; exploring opportunities for learners themselves to *'take the individual and collective action to change society and care for the planet'* (UNESCO, 2023, para.1). To extend the reach of this learning, within each session a simple aide-mémoire was created by participants, in various forms, such as a thought cloud, a picture, a glossary of subject language, or a significant fact, with an expectation that this would be shared, post-session, with colleagues and the wider student body.

Aware that instigating action is *'partially an outcome of knowledge but also depends on attitudes and beliefs, and it is these attitudes and beliefs that will affect what students learn and take away from our classrooms'* (Busch & Osborne, 2014), and following several sessions developing knowledge and understanding, the Epistemic Insight framework was introduced. By introducing the Discipline Wheel (Billingsley & Hazeldinemay, 2020, para.2) and the concept of 'big questions', both teachers and pupils were asked to consider how the themes of climate change and climate justice bridge subject disciplines, and were encouraged to explore the strengths and limitations of subject specialisms and how this informs our thinking and perceptions (Billingsley *et al,* 2018).

Figure 1. A summary table of the suggested timeline of the sessions.

	Key questions to think about…	What is the aim?
Initial sessions	• What do children already know about climate change? • Where can we learn more about climate change? • What is causing climate change now and what has led to these changes? • What cause is having the biggest impact? • What can I do and where do I fit in? • What can I get my family, friends, school, community to do? • What is climate justice? • Why is climate justice important? • Who in the world is most affected by climate change?	• To elicit pupils' prior knowledge and understanding • Develop an understanding of key terminology and learning about the evidence for, and causes of, climate change • Explore the inequities related to climate justice and the concept of sustainability • Explore opportunities for learners themselves to take individual and collective action • To begin to develop a sense of belonging to and ownership of the potential positive solutions for climate change
Building on understanding and organising knowledge	• What is a 'big question'? • How do we form a 'big question'? • How do we answer a 'big question'? • What is the Epistemic Insight framework? • How can I use the Discipline Wheel?	• Consider how the themes of climate change and climate justice bridge subject disciplines • Explore the strengths and limitations of subject specialisms and how this informs our thinking and perceptions • Select a 'big question' and use the Discipline Wheel to identify subject disciplines that could contribute to a response
Forming and answering the 'big question'	• What is our project 'big question' going to be? • What are we going to produce as the outcome for our project?	Possible ways of sharing your 'big question' and what you did could be… • Produce a poster, factsheet or leaflet • Record a group presentation • Create an advert – written, or for TV! • Create a PowerPoint and present it to the group • Write letters and read them to the group • Create a breaking news story or create a newspaper • A comic book • Artwork • Record a group song, dance or rap

Figure 2. Epistemic Insight Discipline Wheel (Billingsley *et al*, 2018)

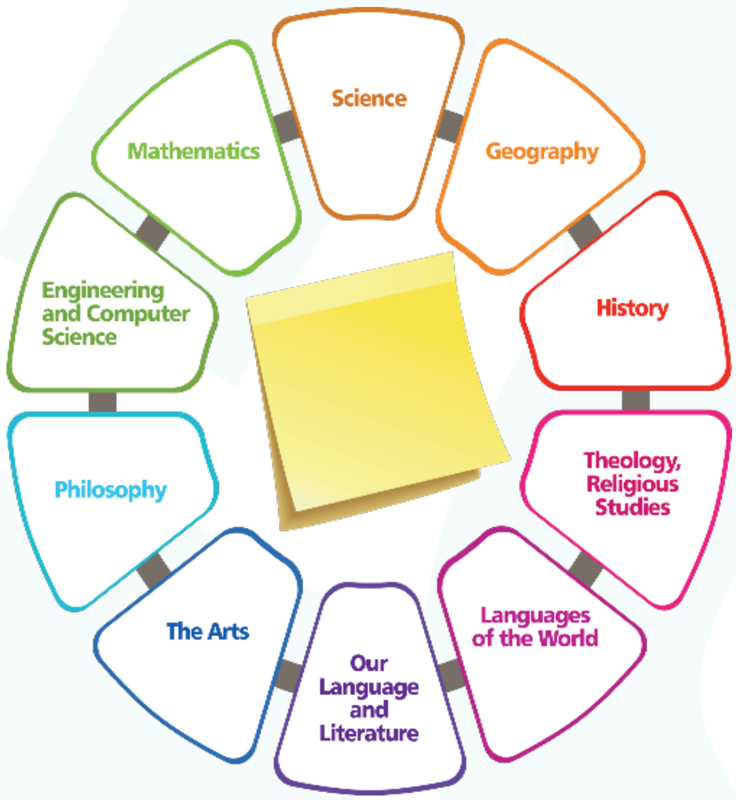
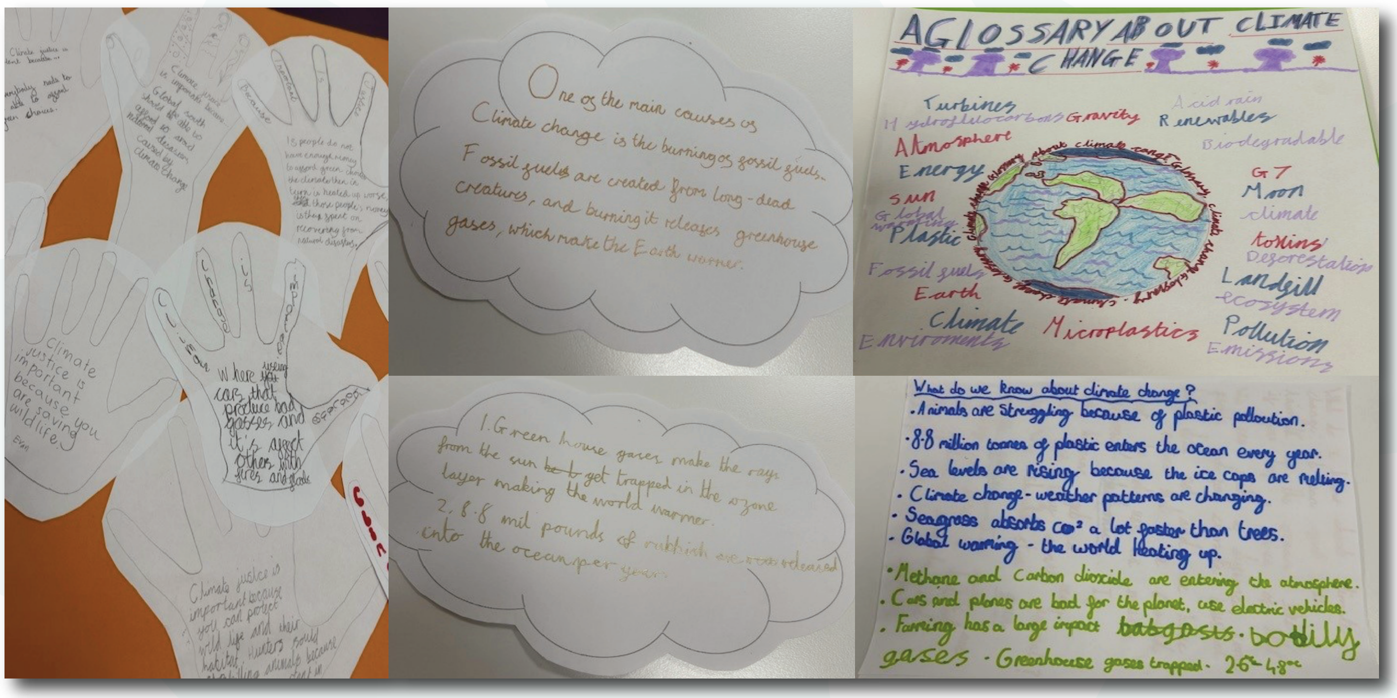


Figure 3. A collection of work that the children completed in the initial sessions, based around knowledge and understanding.



Following this exploration, each team of Climate Ambassadors selected a 'big question' related to the session content that they had encountered and used the Discipline Wheel to identify subject disciplines that could contribute to a response. For example, the question 'Why doesn't everyone make an equal contribution to tackling climate change?' provoked discussion across the disciplines of science, geography, philosophy and psychology.

Some examples of other 'big questions' are:

- Global North or the Global South. Who is to blame?
- Do I need to care about climate change?
- Who is to blame for climate change?
- Why should I try to be sustainable in my daily life?
- How will climate change affect me?

To present their findings, Climate Ambassadors were subsequently invited to a Climate Ambassador Conference at Leeds Trinity University, where they were asked to present evidence produced during sessions, deliver their response to their 'big question' through a chosen medium, such as a poem, news report or piece of drama, and share the wider impact of the project in their school. Some examples are shown in Figure 4.

An example of a poem created by St Chads's C E Primary School exploring Climate Justice through the lens of different subjects:

Why doesn't everyone do the same,
To tackle global warming and make a change?

We need to be creative and make the links,
Let's hear what the geographers think…

The Global North, the Global South,
The different between, is what it's all about.
The climate divide isn't fair,
The biggest culprits go on without care.

The space between the nations,
causes a lack of communication,
The distance clouds our understanding,
And our knowledge needs expanding.

(St Chad's C E Primary School, n.d.)

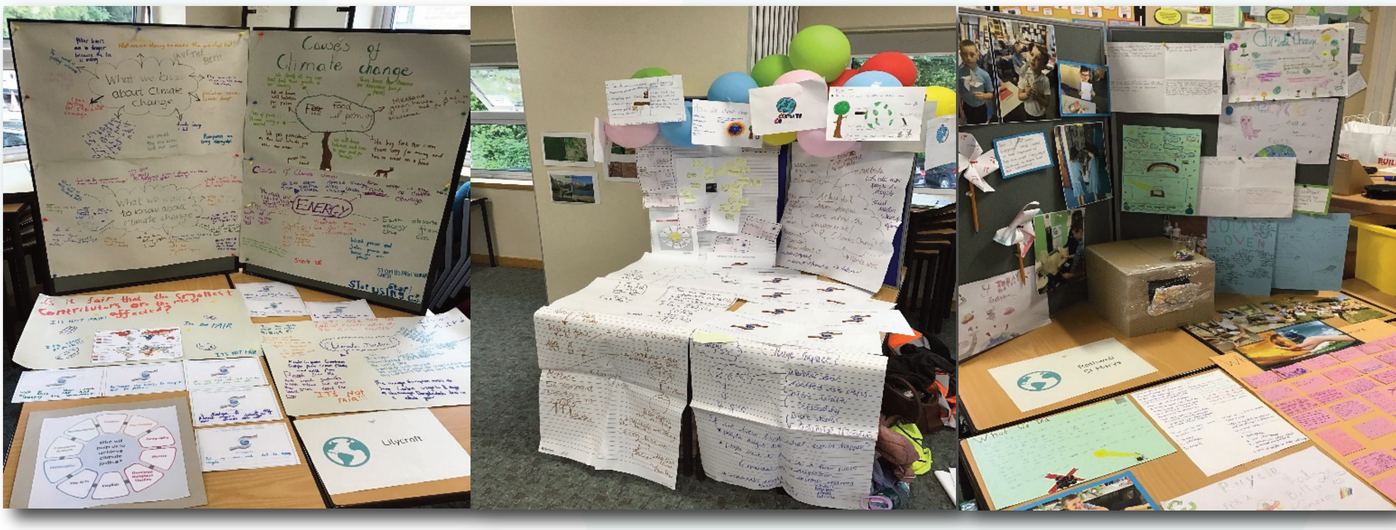


Figure 4. Examples of what each school produced alongside the presentation of their big question.

Implications for practice

Through engaging with the project, teachers and pupils identified both an increased knowledge and understanding regarding climate change, climate justice and sustainability, and a greater sense of belonging, feeling both motivated and accountable for contributing to climate action.

'This is an important issue and I want to share ways we can make a difference with other children in my school and the community' (Year 3 student, age 8-9).

'I didn't realise how climate change affected different people and places across the world. I think if we can educate more people about this, they will want to make a change' (Year 5 student, age 10-11).

'Participating in this project has developed my confidence in teaching about this important and sensitive subject. I have a much greater understanding of the topic and how to approach this with the children in my class, and I have been able to share this with the wider school' (Year 5 teacher & Science Subject Lead).

'Our Climate Ambassadors are developing a range of initiatives to educate others and promote active engagement in tackling the climate crisis…Look out for our weekly tips on Twitter and upcoming events' (St Chad's C.E. Primary School, n.d.).

In research conducted by UCL's Centre for Climate Change and Sustainability Education surveying teachers' practice and professional development in relation to climate change and sustainability education, Greer *et al* (2023) identify a strong trend relating to those teachers who have accessed professional development based on the subject, and those who include this 'often' or 'very often' in their teaching. This correlates with feedback from teachers and subject leaders participating in the project, who acknowledged increased confidence in delivering this content and making meaningful connections across the curriculum, far beyond the Climate Ambassador sessions.

In addition to increased competence in the delivery of climate education, by introducing the Epistemic Insight approach, teachers and pupils have been exposed to an exciting opportunity to work beyond and across the compartmentalisation of subjects (Billingsley *et al*, 2018), reinforcing the idea that *'Big questions and complex real-world problems can rarely if ever be addressed through science alone'* (Billingsley & Hazeldinemay, 2020).

Competente (2019) reports upon the lack of content and teaching strategies offered to pre-service teachers regarding climate change and, as lecturers in Initial Teacher Education, we have witnessed the benefits of this knowledge exchange through the engagement of academics across a range of subject specialisms and the impact that the project has had upon their identity as credible climate educators and instigators of change. This has in turn enabled us to reflect upon meaningful incorporation of the topic, and pedagogical approach, across the curriculum of our trainee teachers, continuing to reinforce the benefits of the interdisciplinary nature of the Epistemic Insight approach (Billingsley *et al*, 2018).

Conclusion

The positive impact of the project on the understanding of climate change, climate justice and sustainability, seen within the quotes above, and the value of an interdisciplinary approach have resulted in a desire to expand the project's reach, extending the offer to a much wider partnership of schools and pupils. We feel that the knowledge gained throughout the twelve weeks can be nurtured and further developed by working alongside some 'subject knowledge-rich' experts in workshop style sessions. Using 'subject knowledge-rich' experts in the workshops is important, as Calderhead and Miller (1985) expressed the need for high levels of subject knowledge in teachers as they are then able to tailor their knowledge of the content, which is hopefully abundant, to the context of the classroom or school. Given the vast range of experience and knowledge of climate change that commonly exists, this is an essential skill for being able to educate successfully on climate change. The intended workshops will be designed to build upon the children's existing knowledge and embed an ever-deeper sense of belonging to the subject, providing a better opportunity to cover some of the more complicated issues relating to climate change. Now that teacher confidence and competence has risen, we are excited to include the teachers in the tweaking and reviewing of resources and sessions so that, again, a wider sense of belonging from the teaching staff is achieved and they can become the subject knowledge-rich experts teaching the future of tomorrow.

Acknowledgements

We would like to thank all the pupils and primary school colleagues who participated in this project. We would also like to thank Professor Leigh Hoath (Leeds Trinity University) for her constant inspiration, guidance and support.

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Lewis Morgan, Senior Lecturer in Primary Education, Leeds Trinity University.
E-mail: l.morgan@leedstrinity.ac.uk

Sophie Nelson, Senior Lecturer in Primary Education, Leeds Trinity University.
E-mail: s.nelson@leedstrinity.ac.uk

Working with external partners to support climate change education through a focus on design

• Lucy Wood • Heather King • Melissa Glackin

Abstract

In this paper we reflect on the opportunities and potential pitfalls encountered when schools work in partnership with external organisations. To illustrate wider issues, we examine the implementation of a pilot project aimed at introducing the role of design in the context of climate change in the primary setting. Our data comprise observational field notes of activities in situ, interviews with participating teachers, focus groups with children, and interviews with designers who led the activities across five different schools in England. In reviewing the data, we highlight the need for partners to build upon each other's skills, genuinely co-creating activities and co-leading lessons. Most importantly, we call for all climate change initiatives to be grounded in children's realities and provide ample opportunities for children to be agentic.

Keywords: Climate change education, professional design, school-based partnerships

Introduction

Requirements for the broad, multifaceted teaching and learning of environmental education – including climate change – in the primary curriculum in England are limited. For example, while the importance of children developing an understanding of climate change has been acknowledged (Department for Education (DfE), 2022), the science curriculum simply specifies that '*environments can change and this can sometimes pose dangers to living things*' (p.20). In the design and technology curriculum, meanwhile, it is suggested that teachers should draw on relevant contexts, including the local community and the wider environment, to help children engage in design processes. However, no emphasis is placed on the interconnection between design ideas and pressing local or global environmental issues such as climate change. In short, there is currently no overarching priority, unlike the situation in previous curricula (see DfE, 2014), for making relevant connections relating to environmental and climate concerns across different disciplines.

Confounding the lack of policy relating to climate change education, we note that primary school teachers often lack the confidence and capacity to teach science and/or design topics, largely due to a paucity of specific professional development opportunities and limited curriculum time allocation in many schools (Bianchi, Whittaker & Poole, 2021). Given these pressures, schools often welcome the contribution of external partners. However, here it is important to note that establishing and sustaining these relationships takes time, consensus, resources and a shared rationale (for example, see Herne, Adams, Atkinson *et al*, 2013).

In this paper, we examine a pilot programme led by a small charity, Climate Change All Change (CCAC) (see https://cc-ac.org/about), in which designers from a variety of disciplines formed partnerships with primary schools to engage with content related to climate science, the impact of global climate change, and the nature of design (including professional design practice) in responding to climate change. The partnering designers from the fields of architecture, landscape design, urban design, permaculture and fashion worked with upper Key Stage 2 primary classes (Years 5/6, ages 9-11) over an extended period (c. 4-6 months), including four in-class sessions, on a design task that involved the children developing a response to a changed world of 2050. For example, children working with a couture fashion designer learned about bio-design and engaged in making sustainable textiles, with the ultimate aim of designing a fashion outfit suitable for climates in 2050. Children working with landscape designers and architects, meanwhile, spent time mapping their local environments and learning about habitats, before seeking to design homes fit for the future.

Each co-design project ended with a presentation from the partner designers to reveal a professionally-produced design concept of the children's work. The results of the project – children's designs and designer-produced visualisations of such designs – were exhibited in school, and some were also displayed in local public institutions.

We, a team of researchers from King's College London, were invited to evaluate the pilot programme. In this paper, we reflect on the evaluation data and ask:
What factors are key to the success of this type of partnership relationship?
What can other prospective partnerships learn from this process?

In particular, we discuss the unique affordances of design-based projects when addressing environmental issues/climate change content, and consider how bringing expert designers into schools can shape the learning experiences of primary aged children.

Climate change education

Educators have long recognised the importance of teaching children about the nature and significance of climate change. Many pedagogical initiatives have been proposed and implemented, with varying foci and with varying outcomes (see, for example, Strachan & Davey, 2022; Dolan, 2022). In their review of literature regarding the provision of climate change education, Greer and Glackin (2021) identify key interrelated features that they suggest underpin an effective approach. They argue that the overarching quality required is a vision of (climate change) education that is open to alternative perspectives beyond sustainable development as part of perpetual economic growth, which promote an equitable coexistence of humans with all species across the planet (Sterling, 2017).

This alternative vision embraces the other important qualities: (1) accepting that climate change is a complex issue and that this complexity should be acknowledged (Stevenson, Nicolls & Whitehouse, 2017); (2) recognising that disciplinary knowledge is necessary but insufficient, as learners need to critique different sources and develop problem-solving skills (Kagawa & Selby, 2010); (3) acknowledging that local solutions can contribute to a global response, with a social justice-oriented perspective (Lotz-Sisitka, 2010); and (4) enabling young people to become participants in their communities' response to climate change, with a sense of agency for personal and collective action (Rousell & Cutter-Mackenzie-Knowles, 2020).

For primary school contexts, research findings suggest that programmes seeking to explore with children ideas related to climate change should help them to understand that there are no simple solutions to complex problems, and that we need many skills and many diverse ways of thinking to try to resolve parts of such problems. Initiatives should also give children opportunities for meaningful participation, acting as agents of change, rather than seeing themselves as merely inheritors of future climate change problems. Design ideas and processes can provide a valuable context for children to consider environmental issues and how they might be addressed.

Methods

To examine the impact of the CCAC pilot programme, we adopted an interpretivist approach, collecting qualitative data through lesson observations, interviews and focus groups. The programme was implemented from January to October 2022 in five state-funded schools from across England, representing urban and non-urban communities. For each school, observations were made during two extended morning or afternoon sessions, with field notes supplemented by teaching and learning artefacts. Towards the end of the project, focus groups were conducted with pupils (n=37). The participating designers (n=6) and partnering class teachers (n=10) took part in one-to-one, semi-structured interviews. The data collected provided evidence for the project evaluation, and were then further analysed for this study.

Through an iterative review of the data between three researchers, we identified recurring themes relating to key success factors for the partnership relationship (Braun & Clarke, 2022). To consider what prospective partnerships might learn, we also drew on Greer and Glackin (2021) to frame our focus on climate change education.

Findings

First, we discuss the research question *'What factors are key to the success of this type of partnership relationship?'*

a. Partnership projects can benefit all parties and are to be welcomed.

The commitment and passion of incoming experts, together with their expertise in a topic, can clearly motivate students and teachers. Moreover, the specialist nature of a partnership encourages schools to carve out time to the project, creating space for children to engage. Many partnerships also provide schools with pre-prepared resources and equipment. As a result, gains in children's learning, and in their attitudes to a topic, are likely to increase. Several children within the CCAC pilot programme expressed views about how the project had given them a better understanding of climate change and a desire to make a difference:

'I didn't know anything about climate change until [the teacher] was explaining it and we were talking about it over and over with [the designer]'
(Student focus group, School D).

Notably, the programme was also perceived to be beneficial from the perspective of the teachers and the designers, as the following quotes demonstrate:

'I think I now feel more hopeful about the future. And I think that's what children need to be feeling, because otherwise they'll feel if it's going to be like this, we can't do anything. I think it gave them power. And I think that's what's really strong' (Teacher interview, School B).

'This feels like the most significant project of my year' (Designer interview, School E).

b. Input from 'professionals' in a primary context is a powerful way to showcase future careers.

Prior to CCAC, most children had not met 'a designer'. By the end of the project, the majority of children were able to recognise that designers work in a variety of roles and fields from fashion to architecture. Children clearly felt inspired when considering future careers in design and many commented that the career would offer a good salary and high status, whilst enabling them to work in a job directly related to sustainability as the following indicates:

'I enjoyed it as it's opening up new jobs. If I didn't know about sustainability or fashion designers, I wouldn't have liked to be one. If I hadn't known what it was, I wouldn't have known if I wanted to be it. It's opening up new jobs, and it's good because it shows children can do what they want, what they put their mind to'
(Student focus group, School A).

c. To support children's agency, climate change-focused educational activities should focus on the here and now.

When setting design tasks, it is important to make connections to children's own lived experiences and local contexts (Lotz-Sisitka, 2010). Further, whilst futuristic scenarios may promote imaginative expression, it is essential to recognise that climate change is happening now: there is thus a moral need to support children to engage in processes that can address the current situation. Tasks should, therefore, be designed to give children autonomy and agency to make a difference.

An example of this would be a design task prompting children to respond to a tangible climate-related scenario happening currently in their own settings (localised flooding/drought; extremely hot summers) *and additionally* to develop a communication brief for a particular audience (local building developers, councillors, etc.). This would not only allow children to develop key design and communication skills, but also equip them with solutions that they could share in their communities, and key skills and insights to use in advocating for the planet. Further, as Rousell and Cutter-Mackenzie-Knowles (2020) have argued, it is important that any activity does not avoid or minimise reality. Indeed, there is a need to encourage children to think explicitly about the complex, wider impacts of climate change on other communities and more-than-human species around the world – key features of research-informed meaningful climate change education (Sterling, 2017; Stevenson, Nicolls & Whitehouse, 2017).

If activities are not grounded in reality, and if children are not supported to engage in finding solutions in the here and now, there is a danger that the idea of climate change becomes a hypothetical fantasy, as the following exchange between a researcher and a child illustrates:

Researcher: *Would you like to live here [in an environment that has been subject to extreme flooding]?*
Child: *Yes!!*
Researcher: *Even if all the land was flooded?*
Child: *Yes, it doesn't matter because I would just swim to my friend's house. And it's OK because I am a good swimmer. I hope it does flood.*

Further, in thinking concretely about steps that can be taken now – such as lobbying for environmentally-friendly measures in the local environment – young people can gain practical skills that can help to ameliorate, or at least give voice to, any forms of eco-anxiety (fear, despair, anger about the ecological crisis (see Pihkala, 2020)) that they might be experiencing.

We now turn to our second research question, *'What can other prospective partnerships learn from this process?'*

From our analyses, we would argue that there is one key lesson: ***Partners need to recognise each other's strengths and play to them.***

For example, in our evaluation, we noted that the introduction of new approaches and unfamiliar presentation techniques can be both exciting and daunting. The children were unanimous in their appreciation of the activities: their excitement was as palpable as the energy and commitment displayed by the incoming designers. However, there were also moments of discomfort.

Specifically, projects with a design-based learning approach can disrupt standard patterns and require different ways of working, including group work. Such practices are arguably needed after the privations of the pandemic. However, providing more open tasks to children can present real challenges, particularly when coupled with introducing a new discipline of design and new concepts associated with climate change. The following quote illustrates the discomfort experienced by some children:

'[The designer] tells the children that they're going to start by drawing their school. They could draw a plan, or a section. Some of the children appear daunted and are struggling to work only from memory. Some ask for more details and are told they can draw in pencil or pen or however they want. They are told it doesn't have to be accurate and several look even more worried. Some children fish out rulers and rubbers but don't get much further. The back row of boys each draw a generic football pitch' (Field notes, School E).

Here it is worth noting that, in our experience, most teachers will seek to carefully manage tasks involving creative expression in the primary context, not least to enable activities to fit with children's expectations and abilities. Joint planning of activities between teacher and incoming partner is therefore essential to identify ways in which to structure tasks to best support learners, especially given inflexible timetabling slots and constraints with materials. Indeed, the central importance of joint-planning was subsequently acknowledged by all participating designers, as the following demonstrates:

'I think we were being too ambitious in places. We hadn't understood that some ideas – like scale – would take longer to explain and learn. Due to changes in the schedule, some parts got compressed and others were elongated, and it was very difficult to for us to change our ideas quickly enough' (Designer interview, School C).

In summary, to benefit fully from the complementary strengths of the incoming partners and the host primary school teachers, respective strengths should be identified and acknowledged upfront. Sessions should then be co-planned, incorporating the novel approaches and content specialisms of partners, but grounded in teachers' pedagogical expertise and deep understanding of the children in their class, drawing on the relevant expertise of both designers and teachers.

Conclusion

Working in partnership with specialist organisations and professionals, schools can be supported to deliver impactful climate change education. Incoming experts can provide schools with inspiring contemporary examples of how issues relating to climate change are currently being thought about and tackled. But, to do this most effectively, teachers and external partners must build upon each other's skills, genuinely co-creating activities and co-leading lessons. Furthermore, schools need to support incoming experts to learn and apply appropriate ways of working in the primary setting, whilst also being open to how best to benefit from the expertise, enthusiasm and skills of partners.

Finally, it is important to recognise that teachers are uniquely placed to have a deep understanding of children's cultural backgrounds, including parents'/carers' occupations, and local cultural and geographical places of interest. Such insights are invaluable in the development of activities that provide a greater sense of ownership and opportunities for children to be agentic. As one teacher from School C observed, a partnership project addressing design skills and climate change concepts prompts new learning, new skills, and a new readiness for responsibility:

'We have seen how mature and capable the children can be when they are inspired and encouraged' (Teacher interview, School C).

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Acknowledgements

The programme described in this paper was led by the charity, Climate Change All Change (CCAC). The authors would like to thank CCAC, the designers, teachers and schools that participated in this research.

Lucy Wood is a Lecturer in Chemistry Education in the School of Education, Communication & Society, King's College London.
E-mail: Lucy.2.wood@kcl.ac.uk

Heather King is Professor of Science Education in the School of Education, Communication & Society, King's College London.

Melissa Glackin is a Reader in Science Education in the School of Education, Communication & Society, King's College London.

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Referencing examples:

Book

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

Chapter in book

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Journal article

Reiss, M. & Tunnicliffe, S.D. (2002) 'An international study of young people's drawings of what is inside themselves', *Journal of Biological Education*, **36,** (2), 58–64

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