The Journal of Emergent Science

Issue 27 November 2024

ASSOCIATION FOR SCIENCE EDUCATION

Primary Science Teaching Trust

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Editorial

• Sarah Earle

A warm welcome back to the *Journal of Emergent Science (JES).* Regular readers may have noticed a little gap in the normal schedule while we agreed a plan for the next three years with ASE and the Primary Science Teaching Trust. We took this opportunity to shift the timeline for *JES* publication to November and April issues, to better match reader preferences evident in the download data. For those interested in contributing to future issues, please see Table 1 below for the new schedule.

Included in Table 1 is mention of reviewing, to both support authors in knowing what happens in between submission and publication, and also raising the profile of the essential role of the *JES* Editorial Board. The current list of Board members can be found in Table 2 below and thanks is given to them for their time in reviewing recent article submissions.

If you would like to join the group, then do get in touch via the e-mail below. Reviewing is a great way to find out about new research and consider alternative perspectives from other nations. I also find it very useful for developing my own writing and thinking!

Table 1. Journal of Emergent Science publication schedule from September 2024.

Submission to the editor	Review and updating	Publication
January	February/March	April
August/Beginning of September	September /October	November

Table 2. The *JES* Editorial Board.

Professor Coral Campbell	Deakin University, Australia
Dr. Sophie Franklin	Primary Science Teaching Trust, UK
Professor Ebru Ersay	Gazi University, Turkey
Dr. Marie Fridberg	Kristianstad University, Sweden
Joelle Halliday	Sheffield Hallam University, UK
Sally Howard	Oxford Brookes University, UK
Dr. Maria Kambouri	University of Reading, UK
Dr. Andy Markwick	University College London, UK
Dr. John Oversby	Science Education Futures, UK
Dr. Jennifer Rudd	Swansea University, UK
Dr. Gideon Sappor	University College London, UK
Dr. Alison Trew	Primary Science Teaching Trust, UK
Dr. Lucy Wood	King's College London, UK

In addition to this invitation to the Editorial Board, I would also like to pique your interest in a new article type that will be exemplified in the next issue.

In an attempt to break down barriers in research, a more collaborative style of article is beginning to appear in publications such as *Postdigital Science and Education* (e.g. Jandrić *et al*, 2023).

A **Collective article** is designed to raise the voices of all involved, replacing the practitioner/researcher divide with a more communal endeavour, recognising all contributors in the list of authors. In our field, this moves teachers from the studied or 'done to' into a more powerful position, providing a sense of agency to tell their side of the story. This kind of article would not be appropriate for all studies, especially since it raises ethical issues around anonymity that would need to be considered before deciding on a collective article style.

The Practitioner Perspective article in this issue strays into this collective territory, with practitioners working with academics and all being named as authors. The Practitioner Perspective article type will continue to be listed as an option, to support those practitioners who, for example, would like to share their own research. The new Collective article category aims to provide an opportunity to a larger number of practitioners, who are not necessarily part of the same project, to each make short contributions. For example, in the next issue, I would like to present a range of viewpoints and experiences around the topic of **teaching primary science in mixed age** or composite classes. All are invited to send a short (e.g. 300 words) example from their setting, to be collated into a new Collective article for the April 2025 issue.

But first to this issue! We begin with **Carol Davenport, Annie Padwick and Joe Shimwell,** who describe their Me, You and Science Too (MYST) project to engage families with children aged 3 to 5 with story-based science activities. In their article on Botanical Folk Tales, **Lily Harper and Kathy Fawcett** explain how their study using podcasts with undergraduates provides an example of the way that stories can help to reduce Plant Awareness Disparity, making adults like us take more notice of plants and consider how to support this in children. In the third article in this issue, **Mason Kuhn and Marine Pepanyan** explain the importance of opportunities to consider doubt in order to support argumentation in primary school science. In the practitioner perspective article, **Zoe Crompton, Zoe Hulme, Christine Siddall, Zoe Tarry, Josh Harper, Lynne Bianchi and Grace Marson** describe examples from a collaborative project to build pedagogical and curriculum bridges for supporting and smoothing the transition from primary to secondary school.

We do hope that there is something for everyone in this 27th issue of *JES*, but if you feel that there is something missing, then do consider whether it is something that you could share from your context.

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Jandrić, P., Luke, T.W., Sturm, S. *et al* (2023) 'Collective Writing: The Continuous Struggle for Meaning-Making', *Postdigit Sci Educ*, (5), 851–893. https://doi.org/10.1007/s42438-022-00320-5

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Using a behaviour change framework to develop an Early Years literacy and science project to support parental engagement

■ Carol Davenport ■ Annie Padwick ■ Joe Shimwell

Abstract

Parental engagement in children's education is an important aim for many schools. This paper presents the development and evaluation of a literacy and science project for families with children aged 3 to 5 in nursery and reception classes at a school in North East England where parental engagement was a focus for development. The project was developed using a Theory of Change and incorporating a behaviour change framework. In total, 87 families took part in the project, which spanned the COVID-19 pandemic. Due to lockdowns, project delivery shifted to an online model and we describe how the behaviour change framework was used to support this change. There was strong and regular engagement in the project by the families, with reasons for non-participation related to work requirements. Families reported that the books were read repeatedly at home after the sessions, but that there was less repeat use of the science activities. Finally, we outline some implications for schools and external organisations when planning similar projects.

Introduction to the project

Me, You and Science Too (MYST) was a science and literacy engagement project co-created by the research team and a primary school in the North East of England, which ran between 2019 and 2021. The school was sited in an area of deprivation, with 50% of pupils receiving free school meals. All 88 families with children in nursery and reception classes were invited to take part in the project, with specific attention given to how to engage families previously considered, by the school, as 'hard-to-reach'. In total, 87 children aged between 3 and 5 and their parents and carers were active participants in the project.

The project had a number of aims: to support parents/carers with skills and confidence to talk about science with their children; to strengthen relationships between home and school; and to improve children's outcomes in reading and science.

Ten storytime and science activity sessions were planned to take place between October 2019 and October 2021. Commercially-published picture books were selected by the research team on the basis of their science or STEM-related content[1]. Simple STEM activities linked to the science in the book were then devised; e.g. for the story *Hey, Water!* (Portis, 2020), families made their own water filters and cleaned some muddy water.

Each session included a member of the research team with teaching experience reading the story aloud and modelling good practice (such as varying pace and intonation whilst reading, taking time to pause and discuss the story as it progressed, asking questions about what happened in the story), parent and child reading the story together, and a simple science activity linked to the theme of the story. After each session, the storybooks were given to the families to keep, along with physical and online materials to extend the reading and science exploration. Families who were not able to attend the sessions were also given a copy of the book and activity by the teacher.

The project received ethical approval from Northumbria University, and all adult participants gave informed consent to take part in the research aspects of the project. Declining to take part in the research did not prevent the family from attending the storytime sessions.

[1] The full selection of books, and accompanying activities, can be viewed at https://nustem.uk/myst/

The project was affected by the Covid-19 pandemic in March 2020, which meant that of the 10 planned sessions, only 8 were delivered: 3 in school, and 5 online following lockdown restrictions.

Parental engagement in literacy and science

Parental involvement with children's education is positively associated with children's academic development and achievement at all socio-economic levels (Axford *et al*, 2019). For young children, there are benefits to both parents and children of developing shared reading activities, including higher parental self-efficacy in helping their children become better readers, and a better relationship (Education Endowment Foundation, 2018; Lam *et al*, 2013). The Book Trust (2023) found that over 60% of parents and carers read regularly with their pre-school children, but 28% did not find reading with their child easy.

Parental attitudes to science can be coloured by parents' own experiences of school (Kaya & Lundeen, 2010) and they may hold stereotypical views about science (Tenenbaum & Leaper, 2003). Parents may also be less confident talking about science with their children than they are talking about literacy and mathematics (Silander *et al*, 2018) and may not recognise 'science' in the informal activities that they do with their children (Hightower *et al*, 2021). Several studies have looked at how stories or picture books can be used to support science learning. This includes teaching of science process skills such as observing, classifying and predicting (Monhardt & Monhardt, 2006) and as a basis for developing science enquiries (Salehjee, 2019).

Although parental involvement is seen as beneficial, there are barriers to this involvement. Hornby and Blackwell (2018) identified barriers to parental engagement, including parents' own negative experience or outdated views of school, limited school opening hours and work-related time restraints for parents, and parents' confidence in their knowledge and ability to engage with their child's learning.

This paper explores a school-based project aimed at maximising family involvement at parental reading and activity sessions.

Theoretical underpinnings

A Theory of Change (ToC) can provide a framework to understand, test and refine the impacts of a particular project (HM Treasury, 2011) and enables articulation of underlying assumptions and how the project is expected to achieve its aims (Reinholz & Andrews, 2020). Typically, it includes a goal, and lays out the intermediate outcomes that are needed to achieve that goal. It is also possible to incorporate programme theory and action models to provide more detail on activities and their implementation (Coryn *et al*, 2011). ToCs often utilise an iterative action research approach to evaluation (Vogel, 2012), which typically involves plan–act–observe–reflect stages in a number of cycles (McAteer, 2013). This allows dynamic changes in an intervention to be responded to.

Many initiatives that use a Theory of Change aim to produce a behaviour change (Breuer *et al*, 2015). Creating and sustaining behavioural change is challenging, but can be achieved (Michie *et al*, 2018). The Behavioural Insights Team[2] developed a simple 'EAST' framework to summarise the literature on behavioural change for policymakers, which can be summarised as 'Make it **E**asy, **A**ttractive, **S**ocial, **T**imely' (Service *et al*, 2014). In the current project, the targeted behavioural change was to increase the amount of reading and science activities that families did together at home.

[2] The Behavioural Insights Team is a commercial organisation set up to (initially) advise UK government. The EAST framework relates to achieving behavioural change and more broadly to https://www.bi.team/

Methodology

A Theory of Change (ToC) model was developed for the project (Figure 1), incorporating a change model that described the mechanisms by which the desired outcomes are achieved, and an action model that described the activity to be delivered, and incorporated the EAST framework principles that underpin these (shaded highlight).

To develop the ToC approach, the research team worked backwards from the project aim of 'Parents and children more confident to talk about STEM'. This aim was chosen as being within the ceiling of accountability of the research team, i.e. an aim that was directly achievable in the duration of the project (De Silva *et al*, 2014). Plausible causal pathways to achieve this aim were identified and developed into a coherent model. Integration of the EAST framework allowed the exploration of the mechanisms to support ongoing engagement. Feedback loops in the ToC that could be explored using an action research approach were identified, allowing for ongoing adjustment of delivery and a depth of understanding about how different aspects of the project worked together.

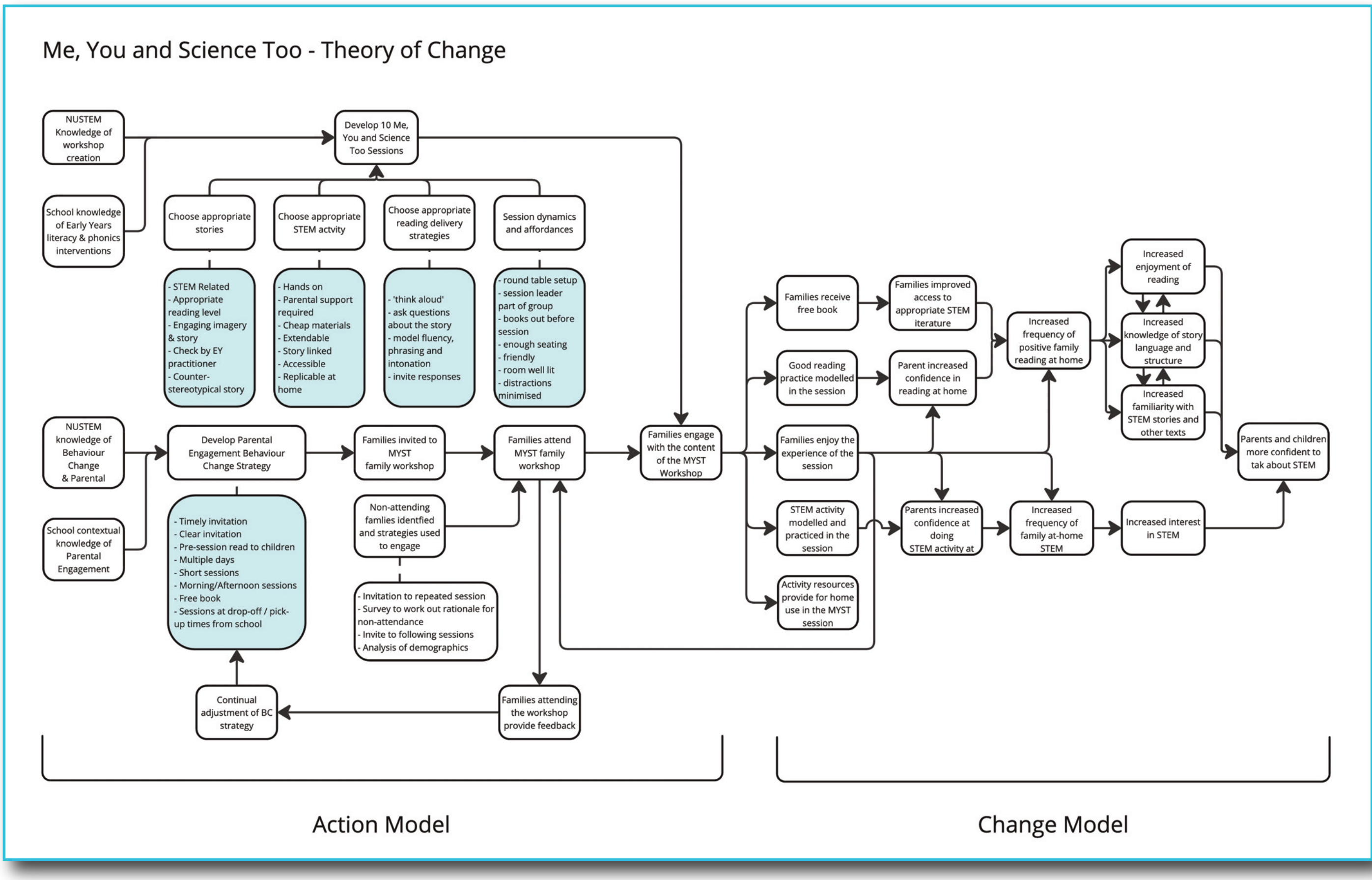


Figure 1. Theory of Change model for Me, You and Science Too (MYST). (Shaded boxes are linked to the EAST framework of behaviour change (Service *et al*, 2014).)

The EAST framework provided the structure to develop successful family engagements. In making engagement easy for parents, multiple different timeslots for the same book session were offered to accommodate parents' schedules. The sessions were marketed attractively, including party invitations that assumed attendance, and the classroom teacher encouraged participation through timely reminders about sessions at school drop-off and pick-up. Multiple entry points allowed participation to grow at later sessions through word of mouth within parents' networks. Table 1 below outlines how each aspect of the EAST framework was used to develop the activity. Using an action research approach, after each book session, the planning and resources were reviewed and amended as appropriate.

Table 1. The use of an EAST framework to support engagement with book reading sessions.

East framework	Planning
Easy	Invitations sent home in school bags. Invitations assume parents' attendance, and stated 'only reply if you can't make the session'. Language in invitations was carefully chosen to make sure that the purpose of the session and the times were clear and obvious.
Attractive	Invitations to children aimed directly at them: 'You are invited to...'. Invitations invited children to a storytime rather than overtly to a science session. High quality, visually appealing books chosen. A free copy of the book was given to each family attending a session.
Social	Delivery team read the book during assembly to introduce children to the idea. Repeated invitations and repeated interactions. Classroom teachers encouraged parents to come along at school drop-off and collection times. Activity area set up in a social way around a table, with no obvious lead or expert. The school's communication app was used to advertise and share pictures from the activities.
Timely	Range of time slots available for families to attend (e.g. before and after school on multiple days). Survey to attending and non-attending parents to ascertain the best delivery times. Reminders sent out via the school's communication app before the sessions. Clarity of expectations embedded into the advertising materials.

COVID adaptations

In March 2020, schools in England closed to most children. It was necessary to adjust the project to meet its aims through a different medium of delivery. The ToC was adapted to an online delivery model. Strategies originally used for in-person delivery were supplemented and, in some cases changed, to support online delivery (Figure 2).

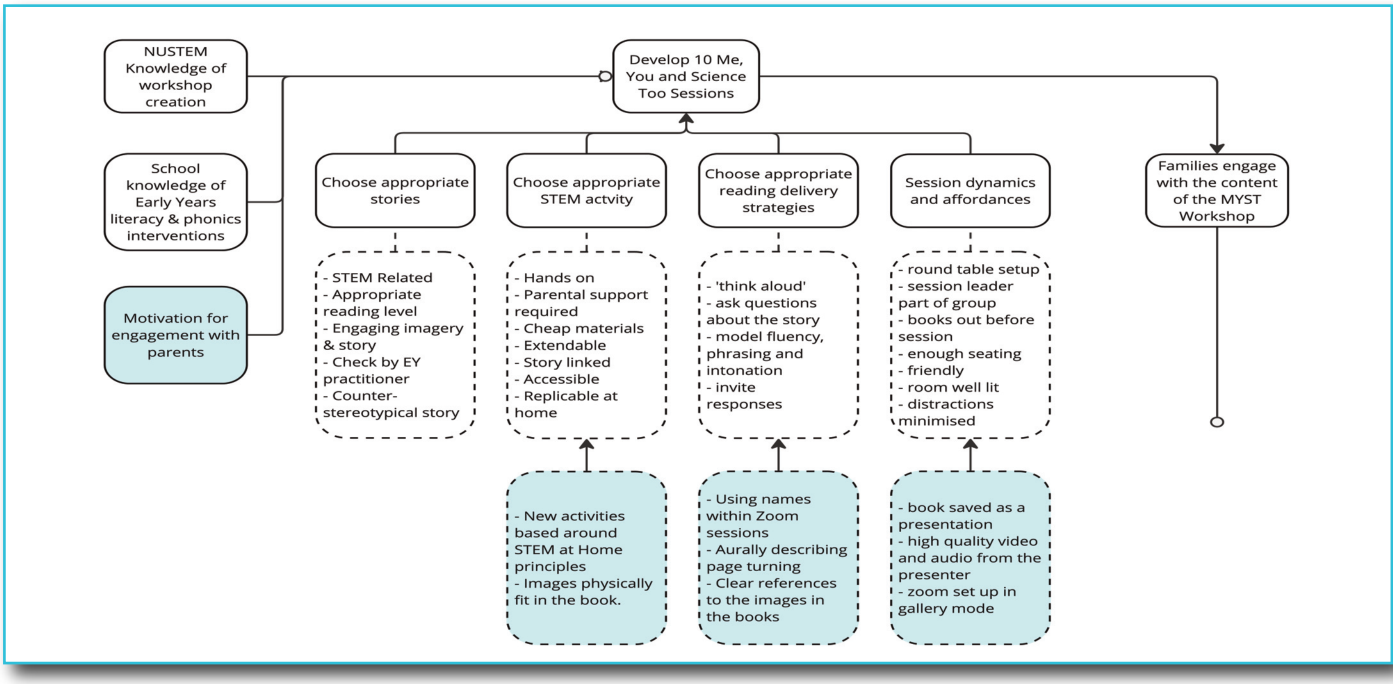


Figure 2. COVID-19 adaptations to the action model section of the Theory of Change. (Shaded boxes indicate how the strategies were changed to facilitate online delivery.)

The behaviour change and engagement aspects were also reviewed using the EAST framework. To keep participation 'Easy', links were sent out in advance through the school's existing home-school communication app, and guidance was shared with families on how to access Zoom. Parents could just 'turn up' and didn't have to book onto sessions in advance. To maintain the 'Social' element of the guidance, families attending the online sessions were encouraged to turn their cameras on so that they could see and interact with other families taking part, and the school's app was used to advertise and share pictures from the activities, as well as provide repeated invitations. Sessions continued to be offered on a number of different timeslots and days to ensure that they were 'timely' for families who might have been working from home or home-schooling a number of children. The school's app was also used to send out reminders just before each session was due to start.

Research tools and data

The evaluation was designed to grow with the project through action research cycles: in the first year evaluating short-term outcomes via light-touch methods, and in the second year evaluating longer-term outcomes using longitudinal data. Data collection was planned through project-monitoring information, feedback postcards, responsive surveys during sessions, posts on school social media, tracked pre- and post-project surveys and post-project interviews with stakeholders. However, the proposed pre- and post-project tracking of participants did not prove adaptable to the move to online delivery methods and could not be completed. The central outcome, 'parents and children more confident to talk about science', which required the longitudinal data, is therefore not included in this paper. Instead, the project used three of the short-term outcomes drawn from the ToC, and reported the extent to which:

- families attended the MYST workshops;
- families engaged with the content of the workshop; and
- families engaged with the content beyond the workshop.

Findings

Due to programme adaptations in response to the COVID-19 pandemic, findings are split into in-person and online delivery.

Outcome 1: Families attend the MYST Workshop

The first book session was offered 10 times and attended by 60 families (68%) (see Table 2).

Dates and times offered	Number of families	Cumulative total
Monday 8:30am	6	6
Monday 9:10am	8	14
Monday 3:15pm	10	24
Tuesday 8:30am	4	28
Tuesday 9:10am	10	38
Tuesday 3:15pm	2	40
Wednesday 8:30am	5	45
Wednesday 9:10am	6	51
Wednesday 3:30pm	3	54
Catch-up session	6	60

Table 2. Times offered for Book Session 1.

Figure 3 visualises the engagement of families across the sessions and highlights how repeated invitations to join or re-engage in the project achieved high levels of involvement with the project overall. At each session, the number of families attending and not attending is presented. Out of a possible 88 children and their families, by the end of the project, 87 were able to engage with the project at some point.

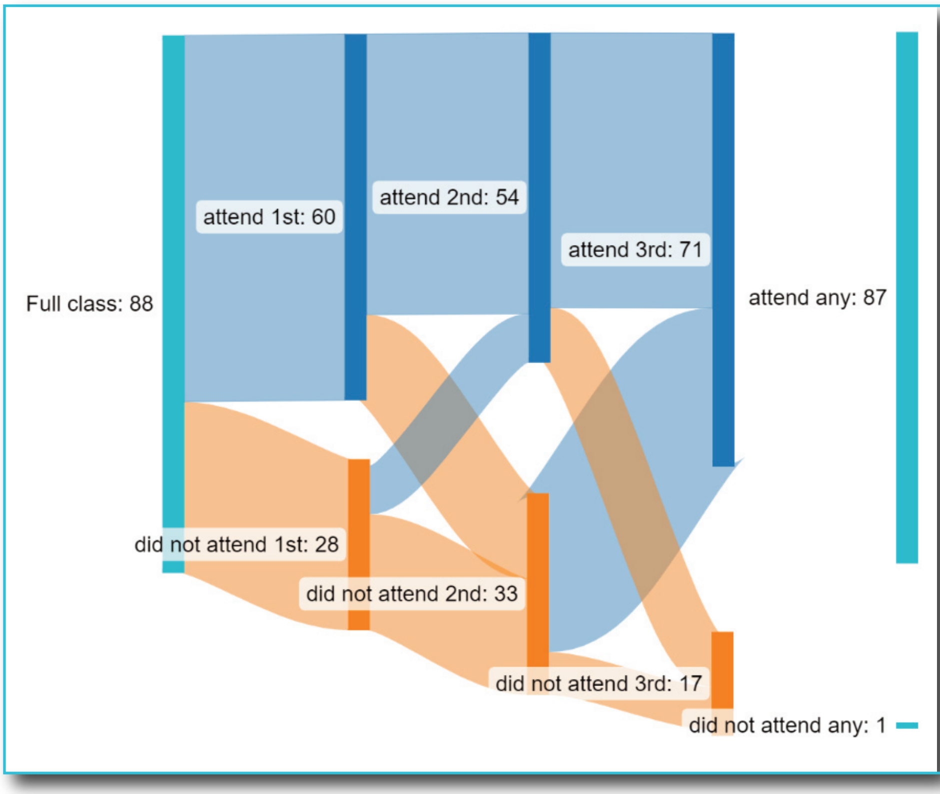


Figure 3. Sankey diagram showing engagement flows across the first three book sessions. Each solid vertical line represents attendance (blue) or non-attendance (orange) at the first three sessions.

The flows between lines represent how many people attended each subsequent session. The turquoise lines represent the full cohort.

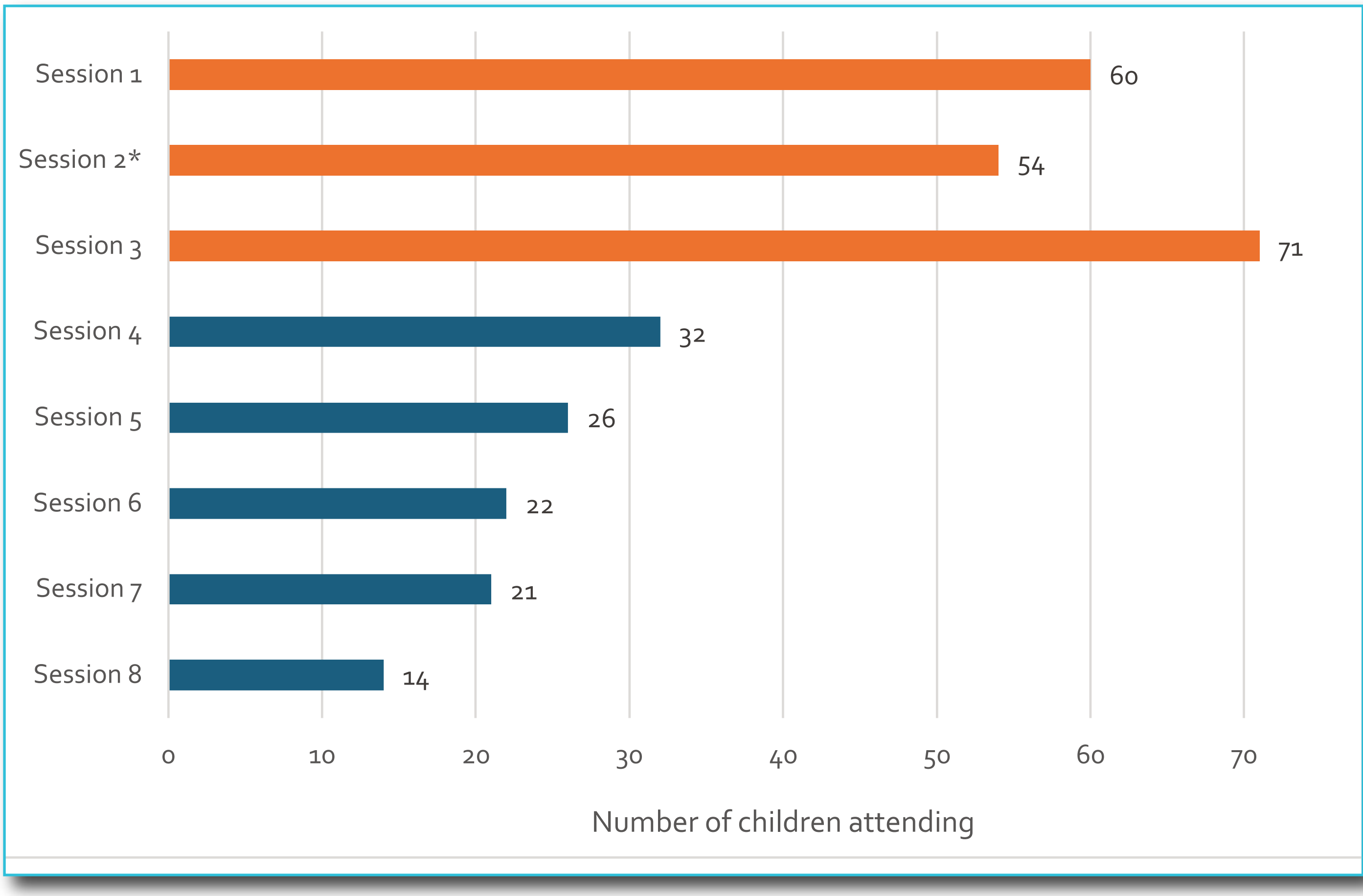
Tracking of individual families across the sessions shows that 67% (40/60) who attended the first book session attended the next two, and 88% (53/60) attended one of the sessions following.

Surveying was used to build understanding of how to support the delivery models. The pre-survey for the first book session (n=52) showed a strong commitment among carers to support their child and their learning. Common motivations for engagement were: 'To do something together' (30%), 'to find out how to help child at school' (15%).

Families not attending the first session were also surveyed (n=5). Despite the small sample size, this indicated that work was a significant barrier. Analysis of project-monitoring information revealed positive strategies used to allow children to attend, with different family members attending different sessions, drawing on wider family networks (parents, grandparents, aunts, etc.) in 13 of the families attending.

The move to online sessions saw a drop in engagement (Figure 4). On average, 26% (23/88) families in nursery and reception attended the online sessions. Session feedback from attending families showed that some were new to the Zoom platform and were experiencing technical difficulties. In a post-project interview, one parent explained the challenges to her participation online: '*There was a couple of chats I did one-handed while juggling the baby, and I'm trying to sort the screen for her to get the multiscreen on and I couldn't remember how to do it. The person was trying to read the book, I'm trying to do it one-handed, the baby is screaming and I'm like you're just going to have to watch it like that for now*.'

Figure 4. Engagement numbers at each book session.
(*Session 2 affected by Norovirus outbreak in the school. Sessions 4 – 8 (blue) were online.)



Monitoring repeat engagements of families at online sessions was more challenging, but available data are indicative of high repeat engagement among at least a small cohort of families. In the feedback survey for the 6th book session, we asked how many previous sessions participants had attended and, of the 8 responses, 4 participants said that they had attended all previous sessions offered, 5 had attended previous sessions in-person, while 3 began attending sessions in the second year.

Outcome 2: Families engage with workshop content

Children were asked to rate how many stars they would give the books in each in-person session. The majority of children enjoyed the books and, overall, 21% gave 4 stars and 75% gave 5 stars. Later feedback from parents in surveys indicated the value in the story-based approach for learning:
'*The story itself and the illustrations to go with it are great conversation starters.*'
'*My daughter spent time talking about each page*.'

A small proportion of families did not return after the first in-person session (11%). One parent highlighted their child's developmental age to engage as a reason: '*Thought it was good and fun for children but my child was too young to really engage*'. Observations from project and school staff also indicated that some carers were becoming annoyed when their child was not listening, or running around. These families did not attend future sessions.

Workshop feedback surveys from the online sessions showed that 82% of parents (14/17) reported that they had enjoyed the sessions, with 65% of parents (11/17) reporting to have enjoyed it a lot. Post-project interviews with parents again reveal enthusiasm for the session model: '*She was always dead happy when she got the book, but once she had done the Zoom meeting all she wanted to do was log back on and do the next one. She wanted to do it again and again. It was hard for her to wait for the next one*.'

Session feedback also indicated that parents felt the presenters had done well to maintain engagement in an online setting and how interactive the sessions were: '*… the story reader involves every child that is on Zoom at that time*' and '*The reader was engaging and had time for each child who was participating*'. Conversations with parents indicated a preference for face-to-face over online models but that, when this was not possible, delivery over Zoom had worked well.

Data collected and analysed against Outcome 2 present evidence that the MYST project was rated highly by those who attended. The project was still found to be enjoyable by those attending the online sessions after COVID-19.

Outcome 3: Families engage in workshop content beyond session

93% of participants who returned feedback postcards for sessions 1 (n = 45) and 2 (n = 34) reported that they had re-read the book again after the session. Feedback from the Headteacher indicated that parents had been keen to share their engagement with the session content at home on the school's digital app. An interview with a parent post-project highlighted the value of engaging with the same content across home and school environments: '*When the "Look Up" story was the bedtime story on CBeebies [BBC], [my child] ran to the screen and said "that's my book"*'.

The science activities used as part of the sessions were also repeated, with 78% (60/77) of participants who returned feedback for sessions 1 and 2 reporting that they had done the activities again. Some activities, such as the constellation tubes (NUSTEM, n.d.), were popular as they could be added into the bedtime routine: '*Me and [child] read "Look Up" at home at bedtime and he loved using his telescope with the torch*'. However, not all families were able to repeat activities: '*I said I was going to probably try and do that again when I had just him and a bit more time, but we haven't*.'

Evaluation of the online post-COVID sessions showed that children were reading the books repeatedly, with 70% of parents re-reading the book '*many times*', and 30% re-reading the book '*once or twice*'.

'"Somebody Swallowed Stanley", she loved that one. She told everyone about it and then we went to the beach and things and suddenly she's "you've got to take your rubbish home because it ends up in the sea". She really notices what the book says.'

Discussion and implications for practice

The MYST project intended to support families to strengthen shared reading and science activities in an informal out-of-school setting. The Theory of Change developed for the project identified a number of short- and medium-term outcomes. As with many outreach or research projects running between 2019 and 2021, MYST was impacted by the COVID-19 pandemic, leading to an adaptation of the delivery method and evaluation plan over the course of the project.

This paper presents findings against three outcomes. The first outcome was 'Families attend MYST sessions' and the data present strong evidence of the involvement of parents and families in the workshops over time and in the face-to-face sessions. The project was also able to retain 25% of families during the challenges of the COVID-19 pandemic. The second outcome was 'Families engage with the content of the workshop' and the data provide evidence that the MYST sessions were rated highly by those who attended. The project was still found to be enjoyable by those attending the online sessions after the pandemic. Finally, the third outcome was 'Families engage with the content beyond the workshop' and the data show that participating families read the storybooks regularly at home after the sessions, but repeated the science activities less frequently.

The Theory of Change also posits a number of longer-term outcomes, including increased parent/carer confidence in talking about STEM, which were not possible to investigate in the current project, but which would be a valuable avenue for future research.

The use of the EAST framework to design the planned delivery provided focus on the needs and requirements of the families. This resulted in high levels of engagement, even with families previously considered by the school as 'hard to reach'. The use of the framework also facilitated the change from in-person to online delivery as a consequence of the COVID-19 pandemic. While families indicated that they would prefer a face-to-face delivery model, remote delivery was still valued by the participants, and could be useful under circumstances where in-person delivery is challenging, e.g. where a project is working across a wider geographical area instead of a single school.

It is important to note, however, that the high levels of engagement required concomitant time and ongoing effort from the research team and school staff. The families were not necessarily 'hard to reach' but 'expensive to reach', both financially and time-wise, because the decision to provide up to 10 separate sessions for each book required much more staff time for delivery than would have been the case if only one session had been offered. For high engagement with families, projects should include funding for school staff involvement. We would also suggest that funders should recognise that projects that are aiming for high levels of engagement from a particular cohort may appear more expensive than other, lighter-touch, projects.

In terms of building stronger relationships between home and school, and promoting family engagement with the project, the use of the school's communication app was very helpful in providing two-way communication. This allowed reminders to be sent out, images from sessions to be shared, and enabled families to feed back on what they had done after the sessions.

Developing a Theory of Change that consisted of an action model and a change model provided a helpful theoretical basis for the planning, development and delivery of the project. Incorporating the EAST framework facilitated a clear focus on the needs of the participants in the project, and also supported the research team to adapt the project in response to the pandemic. Use of such frameworks when planning projects is recommended by the research team as a way to improve the quality of delivery and impact of projects.

Overall, despite the challenging circumstance, the outcomes of the MYST project were achieved and families were facilitated to engage more directly with the school and teachers, and children and their carers re-read the books after the sessions.

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Can botanical folk tales help to reduce Plant Awareness Disparity and aid plant conservation efforts?

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Abstract

In Western society, plants are often overlooked in favour of more charismatic species. This inattention and de-prioritisation can have the effect of hindering progress towards key Sustainable Development Goals and reducing action on the climate emergency. The education system is frequently implicated in causing this Plant Awareness Disparity (PAD), possibly through focusing too much on scientific approaches to biology rather than creating more holistic and emotive connections to the natural world. We describe a small-scale intervention in which participants listened to three short podcasts focusing on the folklore of familiar UK plant species: holly, ivy and mistletoe. The Nature Connectedness Survey (NCS) was used along with additional questions to measure attitudinal changes that were interpreted as a proxy measure for changes in PAD. Significant, positive differences in NCS scores were found for all participants over the three-week intervention period. Results demonstrate the power of simple, storytelling techniques to bring emotion and meaning to teaching about plants, and we advocate for their integration into learning at all levels.

Keywords: Education, plant awareness disparity, ethnobiology, ethnobotany, plant conservation, ecopsychology

Plant Awareness Disparity

Plants comprise around 80% of Earth's biomass and form the basis for most life on Earth, providing shelter, oxygen, food and habitats for almost all animals, as well as sources of medicine, fuel and other materials for humans (Jose *et al*, 2019, Wandersee & Schussler, 1999). Plants also make up a substantial portion of the world's endangered species list, yet receive only a fraction of funding for endangered species, with the majority going towards animal conservation (Allen, 2003; Balding & Williams, 2016).

According to Allen (2003), humans have an innate tendency to ignore plants – seeing a greater inherent value in animals. This has been referred to as Plant Awareness Disparity (PAD) (Parsley, 2020), or formerly 'Plant Blindness': a cognitive bias coined by Wandersee and Schussler (1999) and described as *'the misguided anthropocentric ranking of plants as inferior to animals'.*

What may look like a simple difference in preference can have the effect of hindering motivation and progress towards Sustainable Development Goals (United Nations, 2015) such as 'Quality Education' and 'Life On Land'; policymaking, such as in relation to illegal wildlife trade, which may be affected (Amprazis & Papadopoulou, 2020; Margulies *et al*, 2019); funding for plant conservation and research de-prioritised; and interest in plant biology courses reduced (Allen, 2003; Balas & Momsen, 2017; Ro, 2019).

Plant Awareness Disparity: Causes and solutions

The term 'Biophilia', coined by evolutionary biologist E.O. Wilson (Wilson, 1986), proposed a human genetic affinity with the natural world – persisting through generations even as our actual contact diminishes (Bragg, 1996), though Allen (2003) suggests that human brain chemistry and visual processing systems may have evolved to ignore plants in favour of the movement and variable colours of animals, plants being generally static and of a more similar colouring (Wandersee & Schussler, 1999). PAD researchers often cite the lack of plant relatability for humans (Adamo *et al*, 2021; Amprazis &

Papadopoulou, 2020; Dasgupta, 2017; Richardson *et al*, 2018), with preferences reinforced through the representation of animals in culture, for example as sports mascots (Dasgupta, 2017). A link between urbanisation and 'nature deficit disorder' has also been identified (Aceituno-Mata *et al*, 2021; Knapp, 2019) – defined as harm to humans caused by being separated from nature, and a decrease in the prominence of plants in everyday life as a result of less time spent outdoors. Within a broader cultural shift towards technology and away from nature, words including *dandelion*, *bluebell*, and *mistletoe* have been removed from the *Oxford Junior Dictionary* and words such as *emoji* and *selfie* introduced (Macfarlane, 2017). Richardson *et al* (2018) also found levels of smartphone use and number of selfies taken to be associated with reduced connection to nature.

Schooldays can form a critical period for determining whether people develop an interest in plants (Amprazis & Papadopoulou, 2020; Balding & Williams, 2016; Jose *et al*, 2019), but curricula are often heavily skewed towards human and animal aspects of biology, with only 15% of US biology textbook content focusing on plants, despite recognising plants as an integral part of science education (Allen, 2003; Balding & Williams, 2016; Frisch *et al*, 2010). A more plant-focused curriculum has been shown to increase students' environmental interest (Knapp, 2019), along with their awareness of plants, and likelihood to pursue plant science careers and maintain a connection to nature (Batke *et al*, 2020; Jose *et al*, 2019).

Balding and Williams (2016) suggested that PAD may be improved through promoting empathy with plants, rather than through teaching about biological plant systems. During the *Pet Plant Project* (Krosnick *et al*, 2018), university students were encouraged to form personal relationships with plants that they grew from seed. 73% of students noticed more plants around them after the project, with 68% showing increased engagement in course materials. This supports research by Rugg (1998) identifying two critical factors that determine recall: the degree of attention that we give to something, and the meaning that we ascribe to it. Inattention becomes attention if a stimulus has meaning (Mack & Rock, 1998). Perhaps attributing more 'meaning' to plants might encourage people to pay more attention to them.

The *Five Pathways to Nature Connectedness* (Richardson *et al*, 2017), aimed at repairing the human-nature relationship, found the social and emotional themes of contact, emotion, meaning, compassion and beauty to be more effective predictors of nature connection than knowledge-based activities alone.

The importance of plant folklore

Stories and folklore can be *'frighteningly powerful'* (Haven, 2007; Lowery, 2020; Yoon, 1979), allowing us to *'create meaning from seeming disconnectedness'* (Boje, 1991) and so make sense of the world around us (Denning, 2001). In many cultures, storytelling is one of the most common forms of nature connection for children (Beery *et al*, 2020). But alongside a reduction in time spent in nature and the many plant species disappearing towards extinction (Margulies *et al*, 2010) is a loss of traditional knowledge and stories about nature (Aceituno Mata *et al*, 2021).

PAD specifically has been shown to be influenced by cultural practices, such as storytelling (Dasgupta, 2017). Stories can also enhance learning in children, connect people to past experiences, and change beliefs – especially when used to communicate factual information (Casey *et al*, 2008; Haven, 2007; Hinyard & Kreuter, 2007; Weitkamp & Mermikides, 2016).

For many non-Western communities, storytelling is part of a learning process that encourages the conservation of the land by making it culturally relevant and engendering a respect for nature (Baker, 2013; Biome Ecology, 2017; Jones *et al*, 2008; Lowery, 2020; Riley, 2010; Chaudhuri, 2008), with traditional beliefs playing a crucial role in maintaining biodiversity and storytelling linked to the preservation of natural areas and endangered species (Colding & Folke, 1997; Singh *et al*, 2017). Plants are often highly regarded for their roles in everyday human life (Knapp, 2019), largely due to the integration of ethnobotanical folklore (Cooper *et al*, 2012). Conversely, in many Western societies this inter-generational transmission of cultural knowledge is often reduced to fragments of plant folklore, such as using dock leaves for nettle stings and the 'magic' of finding them nearby when needed (Shannon *et al*, 2017).

Though much conservation work is still led by traditional science, favouring knowledge over curiosity (Batke *et al*, 2020), conservation organisations have long recognised that storytelling increases public engagement in campaigns (Shreedhar, 2021). A storytelling approach has been shown to increase science comprehension, strengthen human-plant relationships, and portray 'static' plants as complex and significant (Balding & Williams, 2016; Mascia *et al*, 2003; Sanders *et al*, 2020).

In the Amazon Basin, salvaging plant lore has become an urgent conservation goal (Schultes, 1986) and, in India, biodiversity conservation heavily relies on folklore (Pramanik & Nandi, 2019). A '*deep cultural erosion process at global scale'* (Aceituno-Mata *et al*, 2021) sees non-renewable biotic resources being lost due to a lack of traditional knowledge on how to sustain them (Osemeobo, 1994), and wild plants used for centuries for food, medicine and materials are in danger of disappearing (Simkova & Polesny, 2015).

Individuals with greater nature connection are more likely to behave in pro-environmental ways (Richardson *et al*, 2017; RSPB, 2020), and folklore has been shown to be ecologically important in addressing the human-nature disconnect (Schmonsky, 2012). Hunter (2020) identified a need for further research into the impact of folk stories on attitudes towards nature. Folkbiology has the potential to encourage a more sustainable future (Medin & Atran, 1999); animal folklore has benefited various species' conservation (Bhatia *et al*, 2021; Dhee *et al*, 2019; Holmes *et al*, 2017; Hopper *et al*, 2019; Jeeva *et al*, 2006; Murga, 2020; Orlove & Brush, 1996; Saj *et al*, 2006). Given the urgency of nature recovery and the need to mitigate the negative effects of the climate emergency, might childhood folk tales therefore hold the key to positive change by helping us to see plants as more than simply a 'backdrop for animals'? Here, we explore whether exposure to a few simple stories about familiar and common UK plants can produce a measurable change in PAD.

Materials and methods

The intervention

The primary aim of this project was to investigate whether botanical folk tales in the form of a podcastcan reduce PAD and, by extension, whether storytelling can be an effective means to promote plant conservation.

Participants were invited to take part in a three-week study. This consisted of three podcasts sent by the researchers to all participants, one per week for three weeks. A survey questionnaire was used to determine levels of PAD and plant connection before and after the intervention.

Participants

Volunteer participants were all undergraduate students (n=20) on conservation courses at UWE Bristol, England. Though research suggests more plant conservationists are needed (Balding & Williams, 2016) and these individuals are aiming to pursue conservation careers, there is often a strong focus on animal biology in terms of both core course content and optional modules chosen. This is also an important target group for this research as school/university can be a critical period for determining whether or not young people develop an interest in plants (Amprazis & Papadopoulou, 2020; Jose, Wu & Kamoun, 2019; Balding & Williams, 2016).

Participants were not told that the study concerned PAD specifically, only that it was researching nature connection. The study was approved by the University of the West of England Research Ethics Committee.

Nature Connectedness Survey

Nature connectedness is known to be an important psychological construct underpinning motivation and behaviour towards a sustainable future (Richardson *et al*, 2019). Though a variety of tools exist (e.g. *Inclusion of Nature in Self Scale* (Schultz, 2001); *Nature Connectedness Index* (Cheng & Monroe, 2010); *Nature Relatedness Scale* (Nisbet *et al*, 2009)), here the *Nature Connectedness Scale* (NCS) (Mayer & Frantz, 2004) has been used for its ability to quantify participant connectedness both pre- and post-intervention. This measure has been shown to have good predictive validity and to offer a broad, nuanced analysis of nature connection and emotional responses (Navarro *et al*, 2017).

The NCS survey comprises 14 Likert-scale questions, with the maximum possible test score of five and where a high value represents a high level of nature connectedness. Additional free-response, multiple-choice and relevant demographic questions provided qualitative data relating to participants' attitudes towards plants and responses to the podcast experience and allowed for some demographic analysis. Participants were asked to describe their favourite plant or animal and asked about their hobbies and interests in order to identify any themes in participants' attitudes towards plants as expressed in their own words.

The full survey (Qualtrics, 2022) was completed by all participants before the intervention and repeated once all three podcasts had been listened to.

Creating the podcast

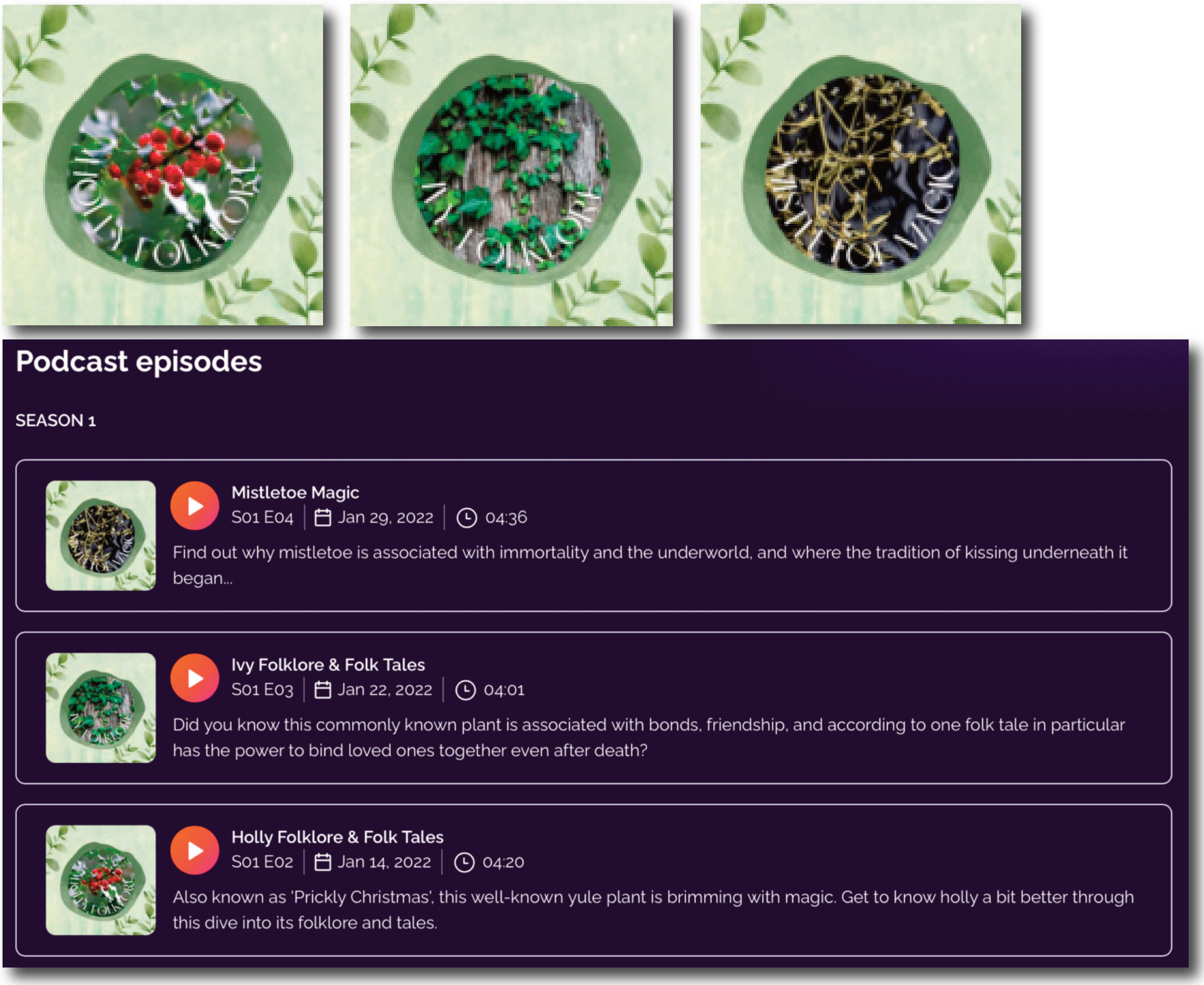


Figure 1. Podcast cover thumbnails for holly, ivy and mistletoe, created using stock images from *Unsplash* and the editing software *Canva*. Also seen in context on RSS podcast homepage screenshot.

Three short audio podcasts of less than five minutes' duration were created by the first author, each focusing on a common UK winter plant and its associated folklore.

Podcasts were the medium used for this intervention as they can be listened to remotely, are easily accessible and can be uploaded to multiple free platforms. Podcasts have been shown to be effective for primary, secondary and tertiary science education (Sutton-Brady *et al*, 2016; Frisch *et al*, 2017), particularly shorter ones that allow pupils to maintain focus (Jung, 2021; Riddell *et al*, 2021). For example, Borgia (2009) found that teacher-created podcasts benefited the science learning of fifth-grade (age 10-11) students.

Mistletoe (*Viscum album*) and ivy (*Hedera*) were chosen as species that have, despite their cultural familiarity, been removed from the *Oxford Junior Dictionary* (Macfarlane, 2017). Holly (*Ilex aquifolium*) was chosen for its fairy folklore and endangered species status (Morris, 2010).

Each podcast incorporated the three elements of 'springboard stories' identified by Denning (2001) as essential in cause-focused storytelling: connectedness, strangeness and comprehensibility. Storytelling was favoured over facts, with complex scientific language avoided, since narrative approaches to ecological learning have been shown to be more effective (Hunter, 2020).

Meaning has been shown to increase connection (Boje, 1991), and content was designed to make the three species feel more relatable and to encourage empathy. Each episode began with a 'floriography', exploring the meaning behind the plants' names, and included references to folk medicine, since the perception of utility has been found to counteract PAD in education (Pany, 2014; Pany *et al*, 2019). Birdsong was also used to increase nature connectedness (Ferraro *et al*, 2020; Richardson *et al*, 2017).

Unexpected and humorous folklore introduced a sense of strangeness. Psychological development theory (Erikson, 1950) suggests that humans pay more attention to the unexpected, and that humour is effective in podcast learning (Riddell *et al*, 2021).

All episodes are available at:
https://rss.com/podcasts/naturestales/?_gl1*1gjig8n*_gcl_au*NjQwMDQ0NDI5LjE3MjY5OTIwNDI
and scripts available on request from the second author.

Results and discussion

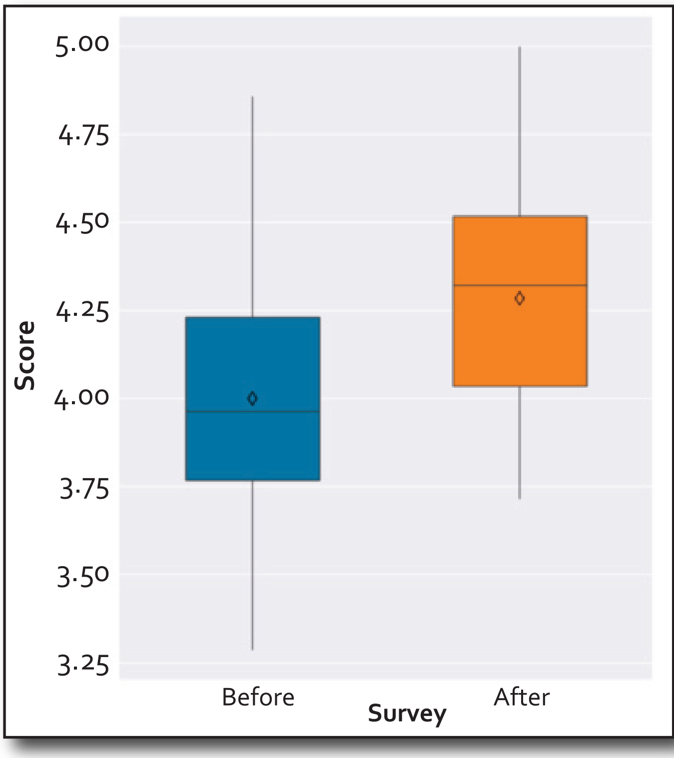
Mean scores were calculated for each participant and each question in the survey. A paired t-test was used to compare results for both the pre- and post-intervention. The mean, whole cohort, pre-intervention NCS score (n=20) was 4.0, with a post-intervention mean of 4.3 (Figure 2). Despite the relative small number of participants, this change was statistically highly significant (p= 0.00013).

Analysis of score changes by question

For 13 of the 14 NCS questions, mean response values were higher post-intervention, with only one question (Q14) showing no change (Table 1).

However, changes were uneven across the survey, with some questions showing greater difference between pre- and post- testing than others. Q3 ('I recognize and appreciate the intelligence of plants'), Q6 ('I often feel a kinship with plants') and Q7 ('The Earth belongs to me as equally as it does to plants') showed the greatest increases, of +0.5, +0.65 and +0.4 respectively. Questions with the smallest changes were: Q8 ('I understand that my actions affect the plant world') and Q14 ('My personal welfare is independent of the welfare of the natural world'), with a difference of +0.05 and 0 respectively.

Figure 2. Mean whole-cohort *Nature Connectedness Survey* scores pre- and post-intervention.



These differences, over the course of listening to three short podcasts, suggest a reduction in plant awareness disparity (PAD) and the development of a more nuanced and complex view of plants and our place within the natural world.

The podcasts followed the recommendations of Ro (2019) that plant representation in stories allows people to view plants as part of a larger natural system of which they are a part rather than separate from, and those of Knapp (2019) that, in order to reduce PAD, *'humans should be considered as part of the natural system, rather than outside and above it'.*

Table 1. Mean scores for *Nature Connectedness Survey* questionnaire questions, showing change. (*Note that, for questions 12 and 14, the value of the response is reversed such that a higher score equates to greater nature connectedness.)

NCS question	Pre-intervention survey mean score	Post-intervention survey mean score	Difference
1. I feel a sense of oneness with plants.	3.95	4.3	+ 0.35
2. I think of plants as belonging to the same community as me, the natural world.	4.4	4.65	+ 0.25
3. I recognize and appreciate the intelligence of plants.	4	4.5	+ 0.5
4. I often feel disconnected from plants (reversed).	3.55	3.9	+ 0.35
5. I often feel a sense of wonder and/or magic when I think of nature.	4.45	4.7	+ 0.25
6. I often feel a kinship with plants.	3.2	3.85	+0.65
7. The Earth belongs to me as equally as it belongs to plants.	4.05	4.45	+ 0.4
8. I understand that my actions affect the plant world.	4.7	4.75	+ 0.05
9. I am part of the web of life.	4.55	4.75	+ 0.2
10. I feel that all inhabitants of Earth, including humans and plants, share a common 'life force'.	4.1	4.4	+0.3
11. Like a tree can be part of a forest, I feel embedded within the broader natural world.	3.9	4.2	+ 0.3
12. When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature (reversed)*.	3.7	4.05	+0.35
13. I am only a small part of the natural world around me. I am no more important than the grass on the ground or flowers that grow.	3.85	4.1	+0.25
14. My personal welfare is independent of the welfare of the natural world (reversed)*.	3.55	3.55	0

Table 2. Results for free-response survey questions.

Participant	What is your favourite plant?	What is your favourite animal?	Do you have any other hobbies/ interests?
1.	Sunflower	Seal	Arts, crafts
2.	Rose, edelweiss, orchid	Cat	Reading
3.	Succulents, cacti, plants that are alien in appearance, roses	Reptiles, frogs, toads, dogs	Writing, painting, psychology, animal-keeping, singing, music, stitching
4.	Willow tree	Wolves and whales	Being in nature, reading, writing
5.	Peace lily, orchid – it's amazing seeing my peace lily grow	Whale shark	Running/walking in nature, going to the gym. Anatomy, animal behaviour, veterinary medicine
6.	Bluebells, snowdrops (second survey)	Tapirs and guinea pigs	Reading, walking, drawing, nature, music, writing, wildlife
7.	Oak tree	Elephant	Painting
8.	Venus fly traps	Wolves and orcas	Singing, ukulele, guitar, being active, hiking, exploring
9.	Vegetables, willow tree (second survey)	Rabbit	Swimming, animals, cooking, socialising
10.	Breadnut tree, foxgloves – I think it changes	Again, I think it changes. Mantled howler monkey, Mustelids are my favourite family	Music, mammals, hiking, psychology, dancing, skateboarding, wildlife
11.	Baobab tree	Leopard	Sport, diving
12.	New Zealand fern, after listening to podcast 2, I have become really intrigued by ivy. It is now one of my favourites	Snakes, Brazilian Boa	Dancing, singing, running, gym, snowboarding, piano, botany, boxing, conservation, sailing, free diving, hiking
13.	Fern moss, ferns	African elephant	Photography, reading, walks in nature
14.	Snake plant, snowdrops (second survey)	Elephant	Nature, animals, gym, art, walking
15.	Echeveria succulents	Parrots	Spending time with animals, art, veganism, ice skating
16.	Lavender	I can't decide	Socialising and walking in nature, e.g. park or beach
17.	Lily of the valley	Horses	Pottery, painting, reading, going for walks, spending time with animals and friends, anything that relaxes me
18.	Don't have a favourite	Tortoise	Film and photography
19.	Sunflower	Insects	Resource management sustainability
20.	Poppy	Cats	Zoo visits with my children, animals

Results for free-response questions

Almost half of the twenty participants (n=8) cited 'animals' as an additional interest, while no participants listed 'plants' and only one cited 'botany', indicating a general preference towards animals consistent with PAD theory (Balding & Williams, 2016).

Half the participants (n=10) mentioned either 'walking in nature' or 'hiking'. However, this did not appear to have a significant bearing on the individual PAD score, since the overall scores for these participants increased by an average of 0.31, while participants not mentioning them increased by an average of 0.26. This supports existing research that simply spending time outdoors does not dramatically increase a person's nature connectedness, unless it incorporates one of the *Five Pathways to Nature Connectedness* previously mentioned (Richardson *et al,* 2017).

In the first survey (carried out in December), no participants cited *Galanthus* (snowdrop) as their favourite plant, while in the second survey (January), two participants mentioned it as their favourite. This suggests that species preferences, rather than being fixed, may reflect seasonal changes, since snowdrops are more visible in January than December. Alternatively, a post-intervention reduction in PAD may have caused them to notice snowdrops more.

Participant 12 mentioned podcast Episode 2 as having impacted their choice, stating that it had 'really intrigued' them and made ivy one of their favourite plants. However, the same participant listed 'botany' in their hobbies, suggesting a pre-existing interest in plants that might have increased their receptiveness to storytelling and folklore that mitigates PAD. Participant 3 commented that their favourite plants are 'any that look alien in appearance', aligning with the part of PAD theory suggesting that humans are drawn to features that stand out rather than that blend in – the latter being something that plants often do, especially when not in flower (Wandersee & Schussler, 1999).

Demographic data

Demographic questions provided some context for NCS changes in respect of participant characteristics, though there was relatively low diversity across the cohort with respect to the specific questions asked. All were students on an ecology course at UWE Bristol; 19 were born between 1993 and 2002 (6 born in 2000). Only one was a parent, and most grew up in the southern UK, though there were also participants from Brunei, Spain, the Netherlands and the US. Work by Richardson *et al* (2017) suggests that place of birth is generally not a factor that influences nature connection.

The majority of participants (16 of 20) were female (n=16) with only three male and one trans male. Literature suggests that women tend to have slightly greater connectedness to plants than men (Wandersee & Schussler, 1999) and results here agree with this (mean NCS scores: male = 3.6, female = 4.1), though the small number of men taking part means that differences are not statistically significant. The one trans participant had the largest initial plant connection score of the genders, highlighting the potential weakness of simple binary categories.

Pre-intervention, only 5% of participants said that they preferred plants over animals, increasing to 10% post-intervention. This doubling suggests that interest in plants can increase within a short period and supports research showing that young people have an inherent interest in plants if exposed to suitable information (Batke *et al*, 2020).

Asked to choose between a visit to a zoo, botanical garden or nature reserve, most participants chose the nature reserve both before and after the podcast intervention (n=16). However, the number selecting 'zoo' decreased from three to just one, and two participants selecting 'nature reserve' in the first survey changed to 'botanical garden'. These shifts suggest that the podcasts may have impacted participants' interest in visiting zoos versus a botanical garden or nature reserve.

Though changes were consistently positive, the extent to which changes reported here were sustained is unknown since follow-up surveys were beyond the scope of this study. However, this would be valuable data to collect.

Conclusions

The intensity of the climate and ecological crisis calls for innovative and effective educational approaches that promote engagement and the development of pro-environmental behaviours.

In England and Scotland, school curricula (Department for Education, 2013; The Curriculum for Excellence, 2010) generally delineate between science, humanities and the Arts (Osbourn, 2009). In Northern Ireland and Wales, teachers are encouraged to link science with other subjects (Northern Ireland Curriculum, 2007; Curriculum for Wales, 2022). Research notes the positive impacts of cross-curricular teaching at primary level (Kelly, 2012) and there would seem to be considerable potential for closer integration of primary science content with other curriculum aspects such as creative writing and spoken English, history and geography, and the use of plants as a focus for visual art.

There is also a need identified for a greater educational focus on plants in particular (for instance by Allen (2003), Balding & Williams (2016), Frisch *et al* (2010)). Though the primary phase includes several specific mentions of plants and their relationship to other living things, Thomas *et al* (2022) point to a low acceptance of the value of multidisciplinary approaches within plant education – something that is undoubtedly more easily realised at this stage. A narrative, Arts-based approach could be used to complement and enhance science learning and provide additional routes into science as part of a broader cultural knowledge and understanding, without compromising scientific 'accuracy'. The study reported here illustrates how the union of these subject areas has the potential to bring plants into everyday life, with the significant increase in NCS scores found after exposure to only three short podcasts demonstrating an impact of emotion-based storytelling that foregrounds connection to nature over separation from and control over it (Kurth *et al,* 2020).

Whilst science education undeniably delivers important understanding of the natural world, folk tales can offer a rich and more personally resonant experience for the learner, allowing them to simply 'be' in nature without the need for conventional scientific sense-making (Bragg, 1996; Osbourn, 2009). These stories can be found through online searches, or in books such as *Botanical Folk Tales of Britain and Ireland* by Lisa Shneidau.

We advocate for the integration of storytelling within science at all levels, enhancing the benefits of both disciplines and acting to mitigate against the development of PAD (Amprazis & Papadopoulou, 2020). This intervention is, we argue, exciting for its simplicity and effectiveness. As an approach, it is easily replicated, easily scaled and can be adapted to a range of formats that appear likely to have similar potential (e.g. in-class reading, creative writing, pictorial storyboarding). Whilst our science undergraduate participants might reasonably have been expected to have high pre-existing levels of engagement with the natural world, this fact makes the significant increase in their nature connectedness all the more interesting, and gives us reason to be hopeful about positive outcomes for learners of all ages exposed to similar interventions.

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Improving argumentation: teaching doubt management to support primary students' evidence selection

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Abstract

Over the last few decades, it has become a staple of reform-based science education that teachers promote student argumentation in the classroom. As researchers continue to evaluate ways in which teachers create productive environments for argumentation, a recent trend in the field has focused on how they manage student doubt. When teachers adopt instructional practices that align with contemporary standards, a more diverse range of instructional aims should be considered. Recent studies have focused on teachers raising, maintaining and reducing doubt throughout their lessons (Chen et al, 2019; Chen & Jordan, 2024; Starrett, 2024). In this study, we set out to trace the relationship between teachers' doubt management during lessons of student-led argumentation and how those 8-9 year-old students select evidence. The findings suggest that primary-aged students who had a teacher with a reform-based orientation were better at selecting claims that had empirical evidence. Students taught by a teacher with a more traditional approach (i.e. direct instruction) were more likely to ignore the empirical evidence and select misconceptions with plausible mechanisms.

Keywords: Argumentation, enquiry, talk moves, primary, reasoning

Introduction

For decades, science education researchers have promoted argumentation as a tool for students to use to make sense of scientific phenomena (Duschl, Schweingruber & Shouse, 2007; Ford, 2012; NRC, 2012). When teachers adopt instructional practices that align with contemporary practices like those adopted in Australia, Europe and the United States, they should be encouraged to promote argumentation as a way to enhance enquiry (see National Curriculum in England (Department of Education, 2013); Australian Curriculum, Assessment and Reporting Authority (ACARA, 2022); Promoting Inquiry in Mathematics and Science Education across Europe project (PRIMAS) (Dorier & Maab, 2012), Next Generation Science Standards (NGSS Lead States, 2013)).

As researchers continue to dissect ways in which teachers create productive environments for students to construct claims based on evidence, a recent trend in the field has focused on how they manage student doubt during argumentation (Chen *et al*, 2019; Lammert, Hand & Woods, 2024; Manz, 2015; Strat & Jegstad, 2024). Manz (2015) noted that a critical aspect of scientific enquiry is that it places doubt at its centre and requires students to use reasoning to reduce their doubt. To cultivate productive moments of uncertainty, educators employ approaches where they introduce phenomena and ask students to explain their existing knowledge. Next, the students consider multiple claims that explain the phenomenon or question at hand, with the teacher asking questions that lead students to consider the strengths and weaknesses of the evidence for those claims. Finally, teachers attempt to reduce uncertainty by making a case for claims with evidence backed by reasoning.

In a practical sense, these researchers ask teachers to begin enquiry by raising doubt, allowing students to explore their doubt through investigation, and resolving that doubt through argumentation about the evidence that they collected (Chen *et al*, 2024). Asking teachers to consider adding doubt-management strategies to their pedagogical practices will require them to consider how students select evidence and ask them why it supports their claim (Chen *et al*, 2019).

Developmental psychologists have shown that young students use personal observation to make causal inferences about nature and even ignore empirical evidence that conflicts with their viewpoint (Hewson & Hewson, 1984; Inagaki & Hatano, 2006). However, studies that have evaluated how students select evidence have not considered whether a teacher's instructional strategies impact how a student considers evidence for their claim. In this study, we set out to evaluate the relationship between teachers' doubt management strategies during lessons of student-led argumentation and measure how those students select evidence on a task with multiple plausible answers. The following sections will discuss why doubt management and student evidence selection are important aspects of teaching science.

Doubt management

This study focused on doubt management because, for students to learn how to engage in evidence-based reasoning, they would have to learn to manage uncertainty. Learning science includes learning how to think like a scientist. This practice consists of raising questions, examining evidence, constructing a claim, considering alternative viewpoints, and applying reasoning to explain why the evidence for one claim is more substantial than the other. In order for teachers to create an environment for students to attempt these practices, they need to create opportunities for students to work through their uncertainties.

Young learners engage in causal inference about the world around them as they actively work to make sense of the environment in which they find themselves. Research suggests that children (and adults) ignore or distort data that might contradict prior beliefs (Brownlee, Ferguson & Ryan, 2017; Kuhn, 1989; Yang & Carless, 2013; Zimmerman, 2000). Other researchers have shown that individuals reason by co-ordinating data with informal claims, but it is common for students to look for data that fit their claim instead of considering the plausibility of competing ideas (Brem & Rips, 2000; Koslowski, 1996; Techawitthayachinda *et al,* 2019; Chen *et al,* 2019).

Scholars have studied how teachers with different pedagogical approaches manage doubt, and one key difference between a reform-based and traditional approach is the focus on instructional aims (Chen *et al,* 2019; Engle, 2011; Reiser, 2004). Teachers with a more traditional epistemic orientation aim would consider the transfer of knowledge as the primary goal of their instruction (Alexander, 2017). These teachers would likely keep doubt to a minimum by using lectures or other didactic instruction to introduce a concept, followed by examinations and more direct instruction to reduce student doubt. In this scenario, students would receive evidence second-hand from the teacher, or the teacher would explain the pattern of covariation found in the data.

Chen *et al* (2019) examined how teachers with a more reform-based orientation manage doubt and found three significant patterns concerning uncertainty. They showed that teachers use a pedagogical approach, where they raise, maintain and reduce doubt. When teachers use this type of approach, they introduce doubt by asking students to explore a phenomenon (*raise*), then ask students to engage with that doubt through investigation (*maintain*), and finally ask students to present their understanding after argumentation (*reduce*). This student-centred approach problematises students' experience (Engle, 2011; Reiser, 2004), which presents opportunities for them to manage doubt through conversation and evaluate the strengths and weaknesses of the evidence (Chen *et al,* 2019). When teachers problematise scientific phenomena, they position the challenge of resolving the uncertainty as the aim of their instruction. For students to work through the problem, they need to be presented with evidence and then allowed to decide if it helps to support their claim.

Evidence selection

Reform-based instruction asks students to construct claims based on evidence and explain them through reasoning. This approach is similar to how professional scientists must consider all plausible mechanisms that explain the phenomenon that they are investigating, but must remain epistemically vigilant and support the claim that has superior evidence. Authors of contemporary science standards promote this *process* of science as a form of instruction, because research has shown that students in grades as early as Kindergarten are developmentally capable of providing evidence for their claim and explaining why the evidence supports it (Mayer *et al*, 2014; McNeill, 2011; NRC, 2007).

However, Zimmerman (2000) postulated that young children tend to ignore or distort data that contradict their developed beliefs. Hewson and Hewson (1984) noted that when infants take in information about their environment, they make assumptions about it. Before students enter formal education, they construct explanations about the natural phenomena that they encounter, and it is challenging to get students to change those ideas. Research has shown that simple direct instruction is an inefficient way to change those ideas (Chi, 2008, 2009; Hewson & Hewson, 1984; Sinatra & Mason, 2013).

Our project placed emphasis on evaluating teacher discourse and how teachers fostered student thinking about evidence in the classroom. Our interest lies in collecting data to ascertain if these types of learning environments could alter young students' inclination to select a certain type of justification for their claim. These data will aid in addressing the following questions:

Research questions

What type of feedback patterns do teachers use to manage student doubt?
Does the way in which teachers manage doubt during lessons impact the way that primary-aged students select evidence to support their claim?

Participants

In this study, twenty-two second-grade teachers and their 145 students (all aged 8 or 9) served as the participants. All the teachers in the study participated in a ten-day professional development (PD) programme that expanded over two summers. Specifically, the PD was influenced and designed around the research-based Science Writing Heuristic (SWH) (Keys *et al*, 1999; Hand, 2002) and Argument-Based Strategies for STEM Infused Science Teaching (ASSIST) (Kuhn & McDermott, 2017; Kuhn, 2022) approaches to teaching science. All the students in the study attended federally identified low-income schools in a large, urban school district in the Midwest region of the United States. The twenty-two teachers ranged from 1 to 18 years of teaching experience, and all participated in two years of professional development.

The PD programme in which the teachers participated had 53 attendees, and all participants were interviewed using Luft and Roehrig's (2007) Teacher Beliefs Interview (TBI). The TBI is a semi-structured seven-question interview with coding maps that capture the subject's epistemic orientation toward teaching science (Luft & Roehrig, 2007). To meet the expectations of a category, teachers had to provide answers that aligned with at least five of the seven characteristics of that category. The traditional end of the spectrum is defined by its teacher-centred treatment of science as facts. In contrast, the reform-oriented end of the spectrum treats science as dynamic and socially constructed through student-centred approaches to instruction. The participants were interviewed a week after the PD was completed. The authors selected all eleven teachers who scored as more 'traditional' on the TBI and then randomly selected eleven of the nineteen teachers who scored as more 'reform-based'. Hence, an equal number of teachers in the study had divergent epistemological aims.

Methods

Two forms of data were collected to measure the teachers' beliefs about teaching. TBI data were used to establish the teachers' epistemological views of teaching science. Next, to collect data on how teachers manage uncertainty, the authors asked each teacher to record multiple videos of a lesson where students would be confronted with doubt. Each teacher recorded four videos teaching a science lesson where students collected data about phenomena and were asked to make sense of their observations and information available to them. Specifically, teachers were provided with the prompt:

'Record a typical lesson after your students have collected data from an investigation and they attempted to make sense of their observations'.

Recording the lesson after students collected data allowed the researchers to view how much the teacher supported student-student discussion, how they promoted student negotiation, or if they interjected with the correct answer to the question that students were debating. Each video was 25 minutes long and was submitted throughout the school year (Video 1: September, Video 2: November, Video 3: March, Video 4: May).

Two coders evaluated transcripts of their videos to analyse teachers' doubt management strategies. Initially, each reviewer used an *a priori* approach to code the transcripts and categorised the teacher feedback as a dual or single aim (see Tables 1 and 2), using a framework established by Techawitthayachinda *et al* (2019). The reviewers coded the transcripts as 'Dual Aim: Argument and Content' and 'Single Aim: Content' (See Table 1). A high level of agreement was found between the coders on what was considered a single aim statement or a dual aim statement ($\kappa = .771.\ p < 0.05$).

Next, the total number of dual aim teacher statements was divided by the total number of instructional statements to get a mean number of dual aim statements per video (X=8.3). Teachers with more than 8.3 dual aim statements in all four video submissions were categorised as such, and all other teachers were labelled single aim. Next, the authors compared the TBI results with the qualitative data from the transcripts of the teachers' instruction; all eleven reform-based teachers fell into the category of dual aim and all eleven traditional teachers were considered single aim.

Table 1. Coding scheme for teachers with a dual aim.

Code	Definition	Doubt Management Strategies		
		Raise	*Maintain*	*Reduce*
Dual Aim Doubt Management and Content	Teacher feedback and questioning attempted to help students manage doubt, achieve an understanding of how to construct an argument and learn the content of the standard.	Teacher asked students to share their observations and questions after collecting data in the investigation.	Teacher presented competing ideas to the students and asked them to discuss why they think their answer was correct.	Teacher showed students the correct answer and discussed why the answer was correct.
		Transcript Examples		
		"Why do you think some of the flowers grew and others didn't?"	"Some people think the flower needs water and other people think the flower needs water and sunlight. What do you think?"	"See how the flowers that were placed by the window grew and the flowers we put in the closet didn't? Flowers need sunlight and water."

The coders used another a priori coding scheme similar to Chen *et al* (2019) by defining talk moves into examples when the teacher raised doubt, maintained doubt and reduced doubt (see Tables 1 and 2). A high level of agreement was found ($\kappa = .765$. $p < 0.01$). These data were necessary because they validated the TBI as a predictor of instructional decision-making and gave us data on how teachers managed doubt in an actual classroom setting.

Code	Definition	Doubt Management Strategies		
		Raise	*Maintain*	*Reduce*
Single Aim Content	Teacher feedback and questioning focused primarliy on managing doubt to help students understand science content but little to no focus on helping students construct reasoned arguments.	Teacher asked leading questions and allowed little variability in student choice.	When a correct claim was raised by a student the teacher "built up" that claim and did not ask the students to counter or think about other possible answers.	Teacher provided the answer or directed student to a resource with an answer quickly after argumentation was initiated. Many examples of premature closure where the teacher tried to direct students to the correct claim before uncertainties were fleshed through dialogue.
		Transcript Examples		
		"Did anyone notice that the flashlight is pointing down and the light is up on the ceiling?"	"Did everyone hear what Sarah said? She said that baby bunnies have two big ears like their mommy. Does everyone see this?"	"So we all agree, and repeat after me, a force is a push or pull that changes an object's motion."

Table 2. Coding scheme for teachers with a single aim.

To measure how students evaluate data, the authors created two animated videos using cartoon-creation software (see Images 1 and 2). The authors created the videos to determine how students would interpret the claims of individuals who used direct evidence vs those who used plausible explanations. Videos were used instead of presenting the students with a written transcript because the students in the study were all around 8 years old, with varied reading comprehension abilities. Having the students watch the videos instead of reading a transcript reduced the possibility that the students misinterpreted the questions due to lack of reading comprehension.

In the videos, two characters argue about a scientific phenomenon, with competing explanatory claims. Each set of characters present different types of evidence for their claim and the participants were asked which claim they support. One set of characters pose a question, conduct an experiment and use the results of the investigation for their evidence. The other set of characters refute the original group's claim and the evidence from their investigation. Instead, they provide a plausible mechanism to support a claim that is a common scientific misconception. We asked the teachers in the study to give us a concept that they would teach during the school year and made a video that reviewed that concept.

Image 1. Image from the cartoon that the students watched.

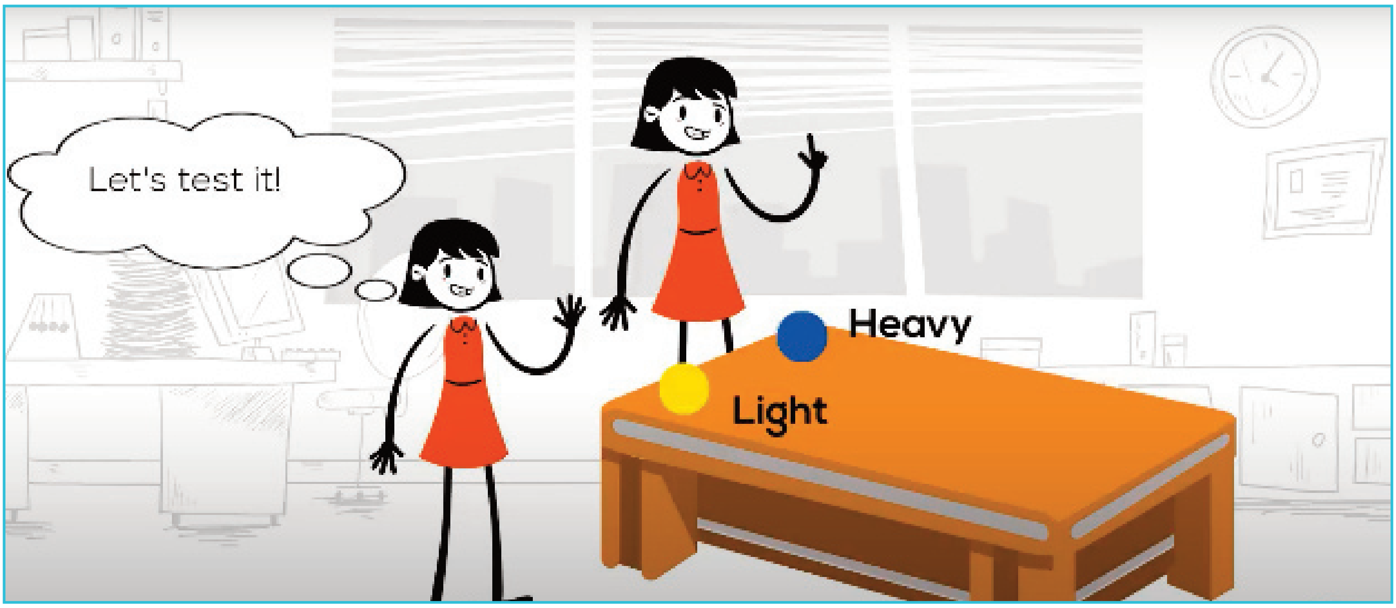
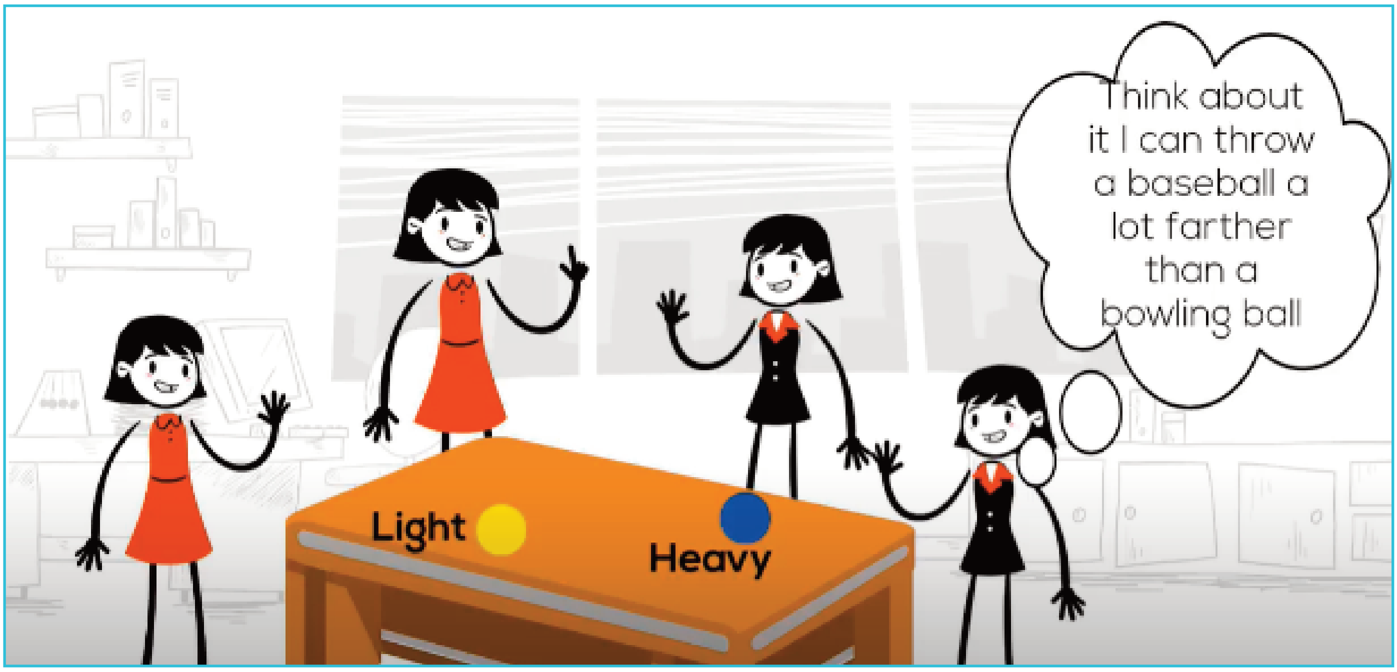


Image 2. Another image from the cartoon, where a plausible mechanism was introduced.



All 145 students in the study watched Video 1 at the beginning of the school year (fall/autumn) and video 2 at the end of the year (spring). The videos presented empirical evidence first and plausible mechanisms second. This order was intentional, because the plausible mechanism supported the misconception and opposed the direct evidence that the first group of characters provided. We wanted the participants to hear the misconception and plausible mechanism last before we asked them the questions.

After the students watched the videos, they were asked two questions and a follow-up question based on their initial response to clarify: 'Which group are right?'
'Why do you think they are right?'

- *So, are they right because they did a test?*
- *So, are they right because they said they can throw a baseball farther than a bowling ball?*

If the participant answered that the characters who used empirical evidence were correct, the follow-up question was *'So, are they right because they did a test?'* If the participant answered that the second group (who used plausible mechanism) was correct, the interviewer asked the second follow-up question, *'So, are they right because they said they can throw a baseball farther than a bowling ball?'* The follow-up questions were used to clarify why they selected the group that they did. The data collectors recorded the interview and transcribed the answers, then noted which type of evidence (empirical evidence or plausible mechanism) the students selected in the fall/autumn and spring. See Table 3 for a breakdown of the videos.

Table 3. Summary of the two videos shown to the participants in the study.

	Fall Video	Spring Video
Question	What will happen if a heavy and light ball are pushed with the same strength?	What will happen if a heavy and light ball are dropped from the same height?
Claim #1	The heavy ball will roll farther.	The two balls will hit the ground at the same time.
Claim #1 Evidence	Empirical Evidence - In the video the first set of characters push the balls and the heavy ball rolls farther.	Empirical Evidence - In the video the first set of characters drop the ball and they hit the ground at the same time.
Claim #2	The light ball should roll farther.	The heavy ball should hit the ground first.
Claim #2 Evidence	Plausible Mechanism - In the video the second group of characters claimed the first group is wrong because they can throw a baseball farther than a bowling ball.	Plausible Mechanism - In the video the second group of characters claim the first group is wrong and their evidence is they saw someone accidentally drop a bowling ball once and it fell really fast.
Common Misconception (Allen, 2019)	Light objects should always move farther than heavy objects when pushed.	Heavy objects fall at a faster rate than light objects.

Results

The students who had a teacher with a reform-based orientation and focused on a dual aim (doubt management and content) changed their evidence selection for empirical evidence from 24% in the fall/autumn to 75% in the spring, and a significant change in their choice of a plausible mechanism (fall/autumn 76% to spring 35%). In addition, the students who had a teacher who focused on a single aim (content) had a shift in empirical evidence (fall/autumn 33% to spring 37%) and plausible mechanism (fall/autumn 67% to spring 63%). The change in evidence selection for the reform-based/dual aim teachers was statistically significant after a *t*-test was conducted (see Table 4).

Table 4. Student evidence selection patterns at the beginning and end of the school year.

Teacher's Aim *Student Answers*	Fall Selection	Spring Selection	Change
Reform-Based / Dual Aim- *Empirical Evidence*	17 (24%)	53 (75%)	Δ + 36 ***
Reform-Based / Dual Aim - *Plausible Mechanism*	54 (76%)	18 (25%)	Δ - 36 ***
Traditional / Single Aim - *Empirical Evidence*	21 (33%)	23 (37%)	Δ + 2
Traditional / Single Aim - *Plausible Mechanism*	42 (67%)	40 (63%)	Δ - 2

Note: '***' = $p < 0.001$; '**'

Findings from the study

The main finding in this study is that a significant number of students taught by teachers with a reform-based approach switched from selecting a common misconception with a plausible mechanism to a correct claim backed by empirical evidence. The students in classrooms with traditionally oriented epistemology continued to select the misconception for their claim and the plausible mechanism as evidence. We saw this in the data for students with a traditional-orientated teacher focused on content. The students taught through a direct instruction approach and given the correct information by the teacher were found to select the misconception. However, a statistically significant number of students taught by a reform-based teacher did not hold on to the misconception.

These data are interesting because reform-based teachers use different approaches to managing student doubt. These teachers managed doubt through dialogic questioning patterns and allowed students to construct claims through peer-to-peer discussion. This may have impacted the higher percentage of students who shifted to empirical evidence because those students were allowed more opportunities to wrestle through their uncertainty. These teachers asked students to consider multiple ideas when investigating a claim, instead of telling the students which claim the evidence supported.

Also, the results of this study align with the dialogic moves used to manage uncertainty in what Michaels and O'Connor (2015) defined as 'Productive Talk', in which dialogue is described as a fit between the students' ideas and evidence that either confirms or contradicts the student's original claim. In this study, how teachers used dialogue to manage uncertainty resulted in a significant number of their students overcoming the common misconceptions presented in the videos.

The eleven teachers who scored as 'traditional' on the TBI used almost no opportunities for dialogic discourse and instead used more authoritative feedback to reduce doubt. These teachers used a feedback loop of initiate-respond-evaluate (IRE), where the teacher raises doubt with their initial question and then reduces doubt by telling the student if they are 'right' or 'wrong'. In their videos, the teachers allowed minimal opportunity to maintain doubt, and the students were not involved in maintaining doubt at all due to the authoritative nature of the discussion.

The reform-oriented teachers aimed to deepen dialogue by encouraging students to focus on one idea at a time and explore the reasons behind supporting or rejecting a claim. This approach invited critique into the discussion, a talk move that was notably absent from the transcripts of the teachers with traditional orientations.

One key implication for professional development from this work is that supporting teachers with traditional views of instruction in transitioning to more reform-oriented approaches could involve encouraging them to expand their repertoire of talk moves. When teachers are planning their science lessons, our findings indicate that a lesson's aims should also include the development of argumentation skills, whereby students discuss and debate ideas. Teachers who used single aim doubt management strategies relied more on teacher testimony, which might have led to a greater reliance on plausible mechanisms. Understanding and managing doubt is critical for students to learn about the practice of science, which constantly questions assumptions and preconceptions of our knowledge of the natural world. As researchers and practitioners look for ways to improve science instruction, having future teachers think about managing student doubt properly should be considered when developing their pedagogical toolkit.

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Dropping off a cliff or flying high? Primary-secondary transition

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■ Josh Harper ■ Lynne Bianchi ■ Grace Marson

Abstract

Concerns about a dip in pupil progress and attitude to science in the transition from primary to secondary school have been well documented and yet persist (Ofsted, 2015, 2023; Steidtmann et al, 2023). This transition project, developed from Bianchi and Turford (2022), involved teachers from 12 schools working together and brings a fresh perspective to a long-standing challenge. We examined what a group of primary and secondary teachers can do to address the issue, given time and support to work collaboratively, as well as access to recent research and inputs from key figures in the science education community. How the transition project impacted four teachers at a personal and professional level is explored through two case studies.

Keywords: Transition, progression, pedagogical bridge, curriculum bridge

Introduction

Transition from primary to secondary school at the age of 11 has been a focus of research for many decades due to perennial fears of lack of progress in science (Earle, 2022). This dip in attainment is compounded by inequality, since pupils from lower socio-economic backgrounds make less progress at the start of secondary school (Social Mobility Commission, 2017). In addition, Nag Chowdhuri *et al* (2021) report a general decline in pupils' attitudes to science from 11 years old onwards, and fewer young people choosing to study science subjects in later years.

The move to secondary school can be a challenging period in a child's life, as it occurs during adolescence and has an impact on emotional wellbeing (Spernes, 2022), so it could be argued that the lack of progress and change in attitude to science is a consequence of this unsettling time. However, the decline in engagement with science continues across secondary school, while attitudes to English and mathematics change little (Barmby *et al*, 2008). Allen (2016) suggests that the dip is due to repetition of curriculum content, differences in pedagogy (from collaborative in primary school to teacher-led in secondary school) and disappointment – children expect to carry out science experiments in science labs, but instead spend much of the time writing.

In this work, the authors draw on findings from a 2-year transition study that sought to explore pedagogical and curriculum bridges in science between schools located in the North West of England. They focused on working with in-service teachers to identify teaching and learning approaches that could improve the consistency and progression of pupils' experience of science learning across primary and secondary. The aim was to improve transition from primary to secondary by developing inclusive approaches to science curriculum progression and practice. The project involved five science teachers (from four secondary schools) and eight primary science subject leaders (from eight primary schools). All 12 schools were located in an administrative district that operates a selective system, where pupils attend non-selective secondary schools or sit an entrance examination to attend their preferred grammar school. This results in secondary schools working with 20 or more primary schools spread over a wide geographical area, arguably making the issue of a smooth transition even more challenging.

Method

The group of teachers met 12 times across two years – six afternoons face-to-face (for which the project paid for supply cover to enable teachers to attend) and six twilight sessions. They received the following professional development sessions:

Face-to-face sessions (2.5 hours)	Twilight sessions (1.5 hours)
1. Introduction and observing practice	2. Science Capital Teaching Approach and inclusion
3. BEST (Best Evidence Science Teaching)	4. Powerful ideas and curriculum design
5. Curriculum progression and vocabulary	6. Evaluation of Year 1 and plans for Year 2
7. Funds of Knowledge and inclusive practice	8. Inclusively inspiring all pupils in STEM
9. Developing an understanding of transition	10. Support writing case studies
11. Celebration event – presenting case studies to Headteachers	12. Support writing case studies

The first session introduced teachers to the five 'bridges' that span the primary/secondary divide (Sutton, 2000):

- The 'managerial/bureaucratic' bridge;
- The 'social and personal' bridge;
- The 'curriculum content' bridge;
- The 'pedagogical' bridge; and
- The 'management of learning' bridge.

This was accompanied by the research evidence about children bored by repetition and a notable quotation from *Muddle in the Middle: 'Why are they teaching that again in Year 7? They did it in Year 4'* (Sutton, 2000, p.25). Of these five bridges, teachers agreed that those within their control were the curriculum and pedagogical bridges. None of the teachers had observed science teaching outside of their own type of setting, so this was their gap task before the next meeting – to observe and reflect on similarities and differences in inclusion, pedagogy, learning and vocabulary.

Each session included inputs from relevant experts in the field, links to research evidence and opportunities to collaborate in small groups. Other gap tasks included trialling different approaches, collecting pupil voice data, and activities to maintain the close links between primary and secondary, for example, by attending the annual Great Science Share for Schools (an annual science communication campaign where pupils ask, investigate and share scientific questions with peers). At the end of the first year, each small group of collaborating primary and secondary teachers planned their own research question relating to either the 'curriculum bridge' or the 'pedagogical bridge'. The teachers worked collaboratively, alongside developing strategies to support transition within their own setting. What follows are two case studies, written by the primary and secondary practitioners, about the impact of the project on their own practice and beyond.

Case Study 1: Curriculum bridge – Language barriers to working scientifically when transitioning from primary to secondary

Secondary science teacher: We decided to focus on the scientific language that teachers used and the curriculum bridge from primary to secondary. Many of the secondary teachers were not aware of the way that working scientifically approaches were termed and encouraged in primary schools, including: research using secondary sources, comparative and fair testing, observation over time, pattern-seeking, and identifying, classifying and grouping. They are not explicit in the secondary science curriculum. This lack of continuity in key terminology from primary to secondary school could make it more difficult for pupils to transition from primary science. The transition to secondary school comes with a new environment, usually a laboratory, with new equipment, such as gas taps, so when teachers use new terminology to describe an aspect of science in which children previously felt confident, this compounds the transition issues.

We asked the pupils in the final year of primary school and first year of secondary school to complete a short questionnaire about their views on science. The 10 year-olds highlighted that they enjoy science at primary and look forward to moving on to secondary school science. By the time they started the first year of secondary school, pupils claimed that they did not remember much about science and had not done much science at primary school. This may be due to the issues regarding when and how often science is carried out in the final year of primary school due to Standard Assessment Tasks (SATs) in English and mathematics. Science is awarded a higher status at secondary school, often due to parental expectations, and the fact that science General Certificate of Secondary Education (GCSE) is compulsory, so that it now finds itself 'up there' with English and mathematics. This may in part explain why pupils forget to recognise the high level of competency that they held when they left primary school. Science at secondary school is 'new'.

In the future, we plan to deliver in-house science training for our staff to develop their understanding of the five strands of scientific enquiry from the primary curriculum, so that secondary science teachers understand the language used at primary. This will support pupils' confidence and understanding, and it will strengthen the curriculum bridge, enabling pupils to link their prior learning to a new context. We will use the logos associated with the five strands on posters in our labs and teaching PowerPoints, as these are recognisable from primary school. These will be integrated into the schemes of learning for 11 year-olds as a scaffold for transition, then gradually removed as pupils become more familiar with the secondary curriculum.

The relationship now between secondary and primary, in terms of science, is much stronger and is a partnership that we will continue to make use of and benefit from. We are currently working on another science project together that has stemmed from this one and which is providing even more opportunities for scientific enquiry and transition possibilities. There is also the potential to include further primary schools and other secondary subjects to extend and support transition in the future. Our aim is that everything we mentioned above will have a significant impact on the children's retention of scientific knowledge, their use of scientific terminology and the reduction of their anxiety regarding transition to secondary.

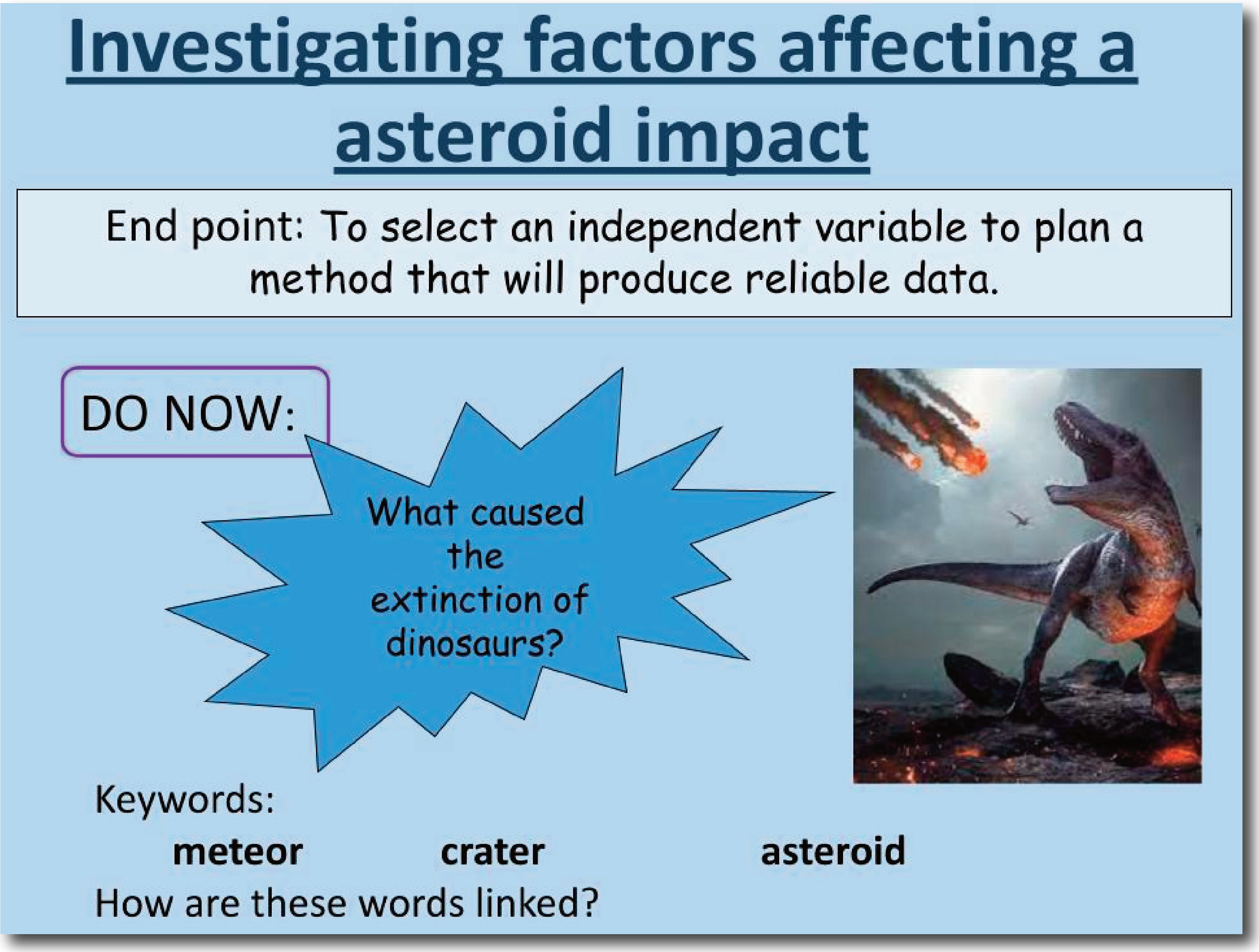
Primary science subject leader: During my visit to secondary school, I was struck by the fact that secondary teachers no longer refer to 'fair testing' but instead discuss validity of data and conclusions. Therefore, we have included the terminology of validity, reliability, repeatability, accuracy and precision into the final year of our primary school schemes of learning to ensure a smoother transition into secondary school science. We speak to the children about how the content that they are learning when they are 10 years old is going to be built upon in secondary, and how we are building a good foundation of scientific knowledge now. We have a much closer relationship with secondary school colleagues to talk as science leaders, ask questions and communicate/highlight important aspects of our curriculum.

Case Study 2: Pedagogical bridge – Fostering pupil decision-making and independence during scientific enquiry

Secondary science teacher: I was interested in seeing what a science lesson looked like and what resources were available in a primary school. I wanted to know how much science pupils were exposed to before they arrived in my classroom at the local secondary all-boys school. When I visited the primary school, I saw that the biggest difference between pupils in primary and secondary was independent learning. The 10 year-old pupils in a mixed attainment class had more responsibility for their own learning, as they were using knowledge organisers to retrieve information about the cardiovascular system. They worked efficiently and calmly under very little instruction from the teacher.

This observation made me question why we treat our pupils, in the first year of secondary school, almost as if they haven't already produced, or are not capable of producing, work such as writing longer-answer questions or problem-solving. It made me question why we sometimes hold back scientific concepts when this can create misconceptions. My enquiry then led to the question: Do we make our pupils back-pedal? Why do we do this, and is it causing pupils to disengage as they don't feel as if they are making progress?

Figure.1 PowerPoint slide introducing secondary pupils to the meteor activity.



Casserly and Wood (2023) advocate for the benefits of giving pupils choice in their science practical and learning. This article supported me to consider how I could encourage choice and retain safety in the classroom. I altered a unit on forces to replicate the lesson written about in the article, allowing pupils to choose which variable they were going to investigate. The lesson is called 'Investigating factors affecting a meteor impact'. The pupils first discussed the connections between meteors and the extinction of dinosaurs, then looked at craters on the Moon and discussed what could affect the size of the craters (see Figure 1). They produced and followed their own method, working out control variables through trial and error, rather than just being told to follow instructions regimentally to avoid behaviour issues. The pupils were allowed to select their own equipment and easily gave a justification for choosing that piece of equipment when asked.

I collected staff and pupil voices to see what the impact had been on changing the way in which the practical was taught. I was concerned that some behavioural issues may have arisen; however, teachers reported that all pupils were engaged and wanted to solve the problem. Pupils were asked to recall their learning and what they had done and spoke with confidence and excitement, as they were happy to tell me what variable they had chosen, what was difficult to control and what the outcomes were.

The Head of Science summarised the impact of the project on our school:

'By allowing more choice in the scheme of work, pupils have developed their ability to use empirical methods confidently to investigate a scientific question, the pupils appear more engaged and have transitioned from being passive learners to active learners in science'.

Primary science subject leader: Since becoming a teacher 9 years ago, I have become more and more aware of how the profession has faced an increasing amount of pressure and restraint. Much of the pressure comes from sources out of the class teacher's hands, with one of the biggest pressures being time – how can we fit all these lessons into one week, into one day? Sadly, my colleagues and I feel that this pressure often results in lessons being more prescriptive than exploratory, especially in science. As science subject leader in my primary school, I have seen this result in experiments being modelled rather than carried out by the children, videos used instead of a practical task, and many more time-saving hacks that teachers have adopted to fit in the bursting curriculum.

During the project, I was introduced to the Great Science Share for Schools (GSSfS), which inspires young people to ask, investigate and share scientific questions with new audiences (SEERIH, 2024), and decided to carry this out in my school. I provided staff with resources to support them matched to the age range that they taught. Interestingly, staff were incredibly nervous and unsure of the GSSfS. Through discussions, I discovered that this was due to the child-led aspect. They were 'scared' about what the children would decide to focus on. However, when we explained to the children that they could lead experiments on what they wanted, based on the story that we watched, there was a wave of excitement across the school. The school was suddenly filled with budding scientists eager to get started.

To support my colleagues, and to ease their nerves, I gave them the most precious asset: time. I took away the constraints of other lessons and gave them a full day dedicated to science, nothing else to be squeezed in, no 'quick readers' to be heard, nothing but science. With our resources ready, children eager and 5 hours at our disposal, we were off. I was lucky enough to be able to see all the amazing discussions and experiments going on. Children know about my passion for science, so when I entered a classroom or an outdoor space, they rushed to show me their work: *'Look at what we planned, I wanted to see which place in the school would affect how the speed of the spinner dropped and Miss Smith let me!'* There was a buzz – pure excitement (see Figure 2).

I felt as if my enquiry question was being unequivocally answered: *Yes, science would be more interesting to children if it was child-led.* At the next staff meeting, I asked staff how the day had gone, and it was reported as an overwhelming success. All the staff had enjoyed the day and, more importantly, they saw the benefit of letting children lead their own learning. One staff member said *'I have never seen every child in my class so engaged with science and want to be involved in the discussions'.* Children said that they had enjoyed sharing their findings and investigations with their peers, teachers, Headteacher and parents, as well as seeing other children's projects.

Figure 2 Primary pupils investigating paper spinners.

This enquiry and these findings have changed the culture in our school. Staff now have less fear in allowing children the opportunity to lead their learning. Just as importantly, we now see the importance of linking our science with the community, our family and friends. I have seen classes working together and swapping findings, and a class present their STEM topic work to a younger class to excite them for what they have in store next year.

Final thoughts

This two-year project has been an appreciative enquiry, with a legacy of change in the curriculum and pedagogical bridges for the teachers and schools involved. The final word is from one of the secondary teachers, who has been teaching for 18 years, and who spoke about her transformation during the Celebration event at the end of the project:

'I feel like less of a teacher and a bit more of a researcher in my classroom because I'm going, right, how did the kids respond to this question? What are their misconceptions? Why did you think that, even though it's the wrong answer? So, I say, "Why? Why are you thinking that?" So, I'm collecting that information and then teaching from that, rather than assuming what they know'.

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PSTT News

PSTT's Regional Mentors: Empowering primary science education

Since its launch in 2017, PSTT's Regional Mentor Programme has become a cornerstone of PSTT's efforts to elevate primary science teaching. Regional Mentors offer tailored guidance to schools, Multi Academy Trusts, Initial Teacher Education providers and other STEM organisations, adapting their support offerings to meet specific needs. Each Mentor is not only a specialist in primary science, but also a PSTT College Fellow, bringing deep expertise and a wealth of experience in helping others to lead and teach the subject.

The Programme is underpinned by a personalised approach. Mentors take the time to listen and understand the challenges faced by educators and organisations, ensuring that the support they offer bis relevant, practical and sustainable. Long-term partnerships are key to this initiative, leading to meaningful and lasting improvements in primary science education.

To date, the Programme has positively impacted over 5000 schools and countless educators across the UK and beyond. A recent survey highlighted the far-reaching benefits of this initiative, confirming its value in nurturing a passion for science in both teachers and their students.

'We have 26 schools across our Trust. The impact of [the Regional Mentor's] work has been incredible. Firstly, our science subject leaders have developed their own subject knowledge greatly. The Regional Mentor continues to support KCSP [Kent Catholic Schools Partnership], building on the close working relationship developed with the Partnership's leadership team and science leaders. They are now able to develop all staff within their own setting, leading staff meetings, running workshops, team teaching and modelling good practice. Secondly, teachers' subject knowledge overall has improved significantly thanks to [the Regional Mentor].'

Deborah Wakelin, School Improvement Advisor, Kent Catholic Schools Partnership

What have schools experienced by working with a Regional Mentor?

- 99% agree that working with a Regional Mentor has made them a more confident and effective science leader.
- 97% agree that working with a Regional Mentor improved their school's science curriculum.
- 94% noticed an improvement in the quality of teaching at their school.*

**Impact data found on this page was collected from 105 educators – including teachers, science subject leaders and Senior Leaders – who participated in our Regional Mentor Programme from 2018 to 2022 and agreed to be surveyed.*

Bespoke science support for you and your school from the PSTT

How can a Regional Mentor support you?

- One-to-one science leadership support.
- Teacher training.
- Curriculum development.
- Planning support.
- Network meetings.
- INSET days.

The Primary Science Teaching Trust's team of Regional Mentors are all primary science experts and award-winning teachers. They provide tailored, high-quality support – either in-person or online – to schools, groups of schools, Multi Academy Trusts, Initial Teacher Education providers and other STEM organisations. Whatever your primary science needs, our mentors offer guidance on any aspect of the subject, helping to elevate teaching standards and enhance student engagement.

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For more information on how the Regional Mentor programme can benefit your school, please visit: **https://pstt.org.uk/support/regional-mentor-programme/**

Primary Science Teaching Trust

Contributing to JES

About the journal

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

Contributing to the journal

Authors are invited to select the article type that suits the findings they would like to share:

- **Original research**: both small-scale practitioner research and larger projects welcome (maximum of 3000 words, excluding references).
- **Research review:**summary of a larger project or a review of current research in the field (maximum of 2500 words, excluding references).
- **Research guidance**: utilising relevant examples to provide support for practitioner research (maximum of 2500 words, excluding references).
- **Practitioner perspective:** considering application of research from the viewpoint of the practitioner (maximum of 2500 words, excluding references).
- **Collective article:** bringing together a range of perspectives from multiple authors (maximum 3500 words, excluding references).

Guidelines on written style

Contributions should be written in a clear, straightforward style, accessible to professionals. When writing your article, please follow this guidance (do get in touch if you would like further support with writing in an academic style):

- Include a clear title, a 150-word **abstract** that summarises the article and up to five keywords.
- Use subheadings to break up the text e.g. Introduction, Method, Results, Conclusions.
- Tables and figures are useful for readers. For images, high resolution jpegs should be sent separately and the author is responsible for permissions.
- Use UK spelling and single 'quotes' for quotations.
- Avoid acronyms and technical jargon wherever possible and no footnotes.
- There should be a section that considers the **implications** of the research for practice, provision and/or policy.
- Include information about yourself (e.g. job title, email) at the end of the article.
- Contributors should bear in mind that the readership is both national UK and international, so please use children's ages (not just school grades or years) and explain the context of the research.
- For in-text references, use (Author, Date) e.g. (Johnston, 2012). If there are three or more authors, the first surname and *'et al'* can be used.
- Include a reference list (examples below), set out in alphabetical order.

Referencing examples:

Book

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

Chapter in book

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

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

Submission and Review

Articles submitted to *JES* should not be under consideration by any other journal, or have been published elsewhere, although previously published research may be submitted having been rewritten to facilitate access by professionals in the early years and with clear implications of the research on policy, practice and provision.

JES is a biannual online publication.
Copy deadlines are usually: January for the April issue and August/beginning of September for the November issue.

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

Submitted articles are reviewed by the Editor, Editorial Board and/or guest reviewers. The peer review process generally requires three months. *JES* is keen to support publication of articles from practitioners, so do get in touch if you would like further assistance.

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