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

Primary Science Teaching Trust

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Editorial

• Sarah Earle

The articles in this issue of *JES* all provide different perspectives on science education by exploring experiences for different age groups, from early childhood and older primary pupils, to secondary-age students collaboratively working with primary phase teachers. The article authors also include a wide range of researchers and practitioners, working within and outside of the classroom. The number of practitioner perspective articles in this issue is a positive sign, perhaps demonstrating increasing engagement with research in this open-access publication. *JES* welcomes and supports practitioner authors, so please do get in touch if you would like to share your work with a wider audience.

This issue begins with a research perspective from the early years. **Linda Ahrenkiel, Morten Rask Petersen** and **Helle Hovgaard Jørgensen** explore how a mapping of science practices (the things that children do, such as sort, count, measure, question) can help to explain and support science in early childhood education and care settings.

The next two articles explore out-of-class science activities with older pupils. **Margaret Ritchie, Anna Maria Mackay** and **Clinton Jackson** consider how to support primary teacher confidence by inviting them to work with secondary school students in a summer STEM academy. Whilst the next author, **Ravina Winch,** a teacher in a middle school, investigates embodied cognition to support environmental education with 11 and 12 year-olds as part of a science lunchtime club.

The final two articles take a closer look at science lessons with primary pupils. **Jules Pottle, Tina Whittaker, Sinead Carroll Knight, Jo Guillon** and **Chris Wemyss** use their experience of picture books to explore the development of science vocabulary. **Rebecca Ellis** and **Jo Moore** draw on cognitive science research on retrieval practice to consider how the Explorify resources can consolidate and support learning.

JES is indebted to its Editorial Board, who volunteer their time to review articles for each issue. The Editorial Board list will now be published in each issue, to both recognise their work and also to show the current range of expertise. With this in mind, we would welcome new international board members and authors, so do e-mail the Editor if you would like to find out more.

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Science practices as a tool for spotting and supporting children's investigative actions in Early Childhood Education and Care (ECEC)

- Linda Ahrenkiel
- Morten Rask Petersen
- Helle Hovgaard Jørgensen

Abstract

Science in Early Childhood Education and Care (ECEC) has, in many contexts, recently taken a shift in focus from science content towards science processes. This approach builds on an enquiry approach to science in schools. However, school science and emergent science is not the same and science practices from school cannot be translated directly into the ECEC context. This study shows how a set of science practices developed in and with ECEC practice can help ECEC staff to identify and support science, not only in prepared settings, but also in children's spontaneous play. Through two illustrative cases, the study shows how science practices can help ECEC staff to develop their language in science while also offering science practice as an analytical tool for both practice and research.

Introduction

In the western world, there is a societal focus on how to support children's interest in and motivation for science (natural phenomena) in the early years (Eshach & Fried, 2005; Eshach, 2006). The American reform in the field of science is primarily rooted in *A framework for K-12 science education* (National Research Council, 2012) and the *Next Generation Science Standards* (National Research Council, 2013) and marks a shift in the approach to science from 'learning about science' to 'find out with science' (Larimore, 2020), which has also influenced school curricula in the rest of the Western world. Although these standards focus on science education in school, they also have a large impact on how science looks to children aged 0-6 years (Wilinski, 2017).

Play and curiosity is a main focus in Early Childhood Education and Care (ECEC) and child-led investigations are common. However, science in ECEC contexts is still mostly related to specific adult-chosen science content. Even when we want children to play with science, it becomes instructive and the play activities are prepared by the adults in order to address specific science content (e.g. Bonawitz *et al*, 2011; Bulunuz, 2013; Fleer, 2022; Vartiainen & Kumpulainen, 2020).

Fleer (2022) argues that the approach to science starts with either a sensually science phenomenon, e.g. a rainbow or dew on the grass, or the abstract science concepts such as the refraction of light or state forms of water. In this article, we direct our attention to 'how do we do science?' instead of 'what science should we learn?'. We therefore focus on how and where the children do enquiry and how ECEC personnel underpin such enquiry activities. This approach is supported by Haug, Sørborg and Mork (2021), who argue that we need to focus on science practices in science education and not just on enquiry. Likewise, Johnston (2013) argues that we need to have the same focus in an ECEC context.

In a design-based study on science practices in a Danish ECEC context (Ahrenkiel, Petersen & Jørgensen, in prep.), we identified eleven different science practices (see the section below). The study was conducted as an interplay between field observations in 17 institutions and developmental workshops (n=8) with pedagogical staff from the institutions. The concept of science practices can help to clarify which actions children in ECEC carry out in situations with science, and characterises an investigative approach, thus giving us opportunities to spot and support children's investigative actions. In this article, we use these practices to analyse science activities in ECEC.

The research question is as follows:
How can science practices be used as an analytical tool for informing about children's enquiry in science activities?

First, we give a short introduction to the science practices, followed by two cases as analytical examples. Then, we discuss the possibilities and limits of using science practices as a tool.

Science practices

When Haug, Sørborg and Mork (2021) argue for an approach towards science practices instead of the overarching concept of enquiry, it is a way to make school science more concrete. This is also a challenge for the Danish ECEC context, but a significant difference between ECEC context and school context is that, while teachers in school are specialised within domain knowledge of science, ECEC personnel are specialised within general pedagogy and child development. The Danish pedagogical curriculum in the field of ECEC (ECEC covers both public and private childcare services for children aged 0-6 years) was revised in 2018 (Ministry of Children and Education, 2018). While the original pedagogical curriculum had emphasis on nature and natural phenomena, the revised curriculum now included a specific focus on an investigative science approach. Some of the central elements in the revised pedagogical curriculum are that the children's own curiosity, children's communities and play must be central. In both the former and current pedagogical curriculum, there is a focus on children's curiosity, wonder and active participation. The difference therefore consists primarily of the investigative science approach becoming an explicit part of the pedagogical curriculum.

A number of challenges is associated with working with science phenomena and science concepts (Barenthien, Oppermann, Anders & Steffensky, 2020; EVA, 2015). In a Danish context, science can lead to diffuse understandings of what a scientific approach is. In this article, we present our work in developing a concept of science practices for children aged 0-6 years, which can be used by ECEC staff in practice, and which focuses on actions. A large part of children's experiences take place through bodily actions and sensory impressions (Fredens, 2018). Here, science practices become an opportunity to connect children's sensory and bodily actions with science phenomena and concepts.

Science practices as an analytical tool

When we direct our attention to what children *do*, it becomes concrete and possible to observe, analyse and develop science situations in ECEC contexts. So far, we have identified eleven science practices within three dimensions: A dimension for exploration, a dimension with (body) language and a dimension on early mathematical awareness (see Figure 1).

The dimension for exploration is characterised by four distinct science practices:

- *The tester who tests* is seen when children are testing (something) based on 'what if'. The practice is a widespread science practice and, for instance, takes place when a child tests where a piece of magnetic toy sticks.
- *The senser who senses* takes place when children experience science phenomena and concepts with all their senses: feeling, hearing, seeing/observing or tasting differences. The word *differences* is important, as it is an attention hereto that makes the practice a part of a dimension for exploration. The senser who senses can be seen, for example, when tasting different fruits and talking about the similarities and differences in taste that the child experiences.
- *The planner who plans* is about involving the children in planning science activities. You can draw, talk about, or find materials together. The practice reminds us that, together with children, we can discuss 'how could we do it? What do we need in order to ...?', etc. The practice is less widespread in Danish ECEC settings, where we find that ECEC staff often plan or think ahead of the child in science situations – thereby, science easily appears as a planned activity and not as a spontaneous part of the ECEC everyday life. However, the practice is very relevant to supporting the child in becoming able to explore and to raise curiosity.

Figure 1. Eleven science practices in three dimensions
(available at: https://www.ucviden.dk/files/180080765/Sciencepraksisser_p_engelsk.pdf).

- *The documentarian who documents* takes place when involving children in documenting science phenomena or concepts, such as taking pictures of a plant from seed to fruit. This practice is known from research contexts, e.g. laboratory journals. In an ECEC context, it is about documenting in different ways via photographs, drawings, etc., which gives children, parents and ECEC staff the opportunity to return to and talk about what they did and experienced in a science situation.

The dimension of (body) language takes into account that children express themselves to a greater extent with their body (non-verbal) than with verbal language. It can be seen, for example, in:

- *The questioner who asks*, where the child asks questions with their whole body, e.g. when pointing, shaping the mouth as an 'o', and/or directing wide-open eyes at a phenomenon.
- *The narrator who narrates* is about children narrating and relates to something that happens or has happened in relation to science phenomena or science concepts.
- *The interpreter who interprets* takes place when children either make their own interpretations of what is taking place, or are supported in interpreting, e.g. a cause-and-effect relationship where a child discovers and expresses 'If I change the slope, the ball rolls'. This practice is characterised by 'if, then' realisations.
- *The arguer who argues* is characterised by 'because', for instance when the children relate to a previous experience from another context with a science concept or phenomena.

The dimension on early mathematical awareness has three science practices:

- *The measurer who measures* is about spotting and supporting situations where measurements are made. The measurement can take place in all units: hands, feet, blocks, centimetres, etc. This science practice takes place when we measure how far a car travels, for instance.
- *The counter who counts* is about counting. This practice could take place during a meal where children count how many cups we need, how many children are not in today, etc.
- *The sorter who sorts* is about objects being grouped, sorted and classified according to different criteria (preferably some that the children come up with).

In the following sections, two cases from field studies are given as analytical examples.

Case 1 How much water can a nappy absorb?

'What is this?', an ECEC staffer asks. 'A nappy', a child says from around the table. 'What is it used for?', the ECEC staffer carries on. 'Peeing', another child responds. 'How much water do you think a nappy can absorb?', the ECEC staffer continues. '4!', a third child quickly responds. 'What if we pour water in the nappy?', the ECEC staffer asks. The children are provided with pipettes and two different measuring cylinders. The children add blue food colouring to the water to make it more visible. They are focused and concentrated on pipetting for quite a while. They are helping each other out with how to suck the water into the pipette. When the graduated cylinders get used, they are eventually thrilled. More and more water is absorbed into the nappy. The children lift the nappy: 'Is it heavy or light?', 'Is it dry or wet?'. The ECEC staffer supports the children's actions with questions. The children squeeze the nappy, lift it, pour more water, and so on – constantly observing and expressing what happens when they do it.

'Why does the water not run out of the nappy? What is hidden inside the nappy?', the ECEC staffer asks. A moment of suspense and doubt: 'A teddy bear!', one child says. Another suggests 'A horse-teddy-bear?'. 'How can we find out what is inside?'. 'Scissors!', a child replies. The children go to get scissors to open the nappies. One child is talking to the nappy: 'Now, you oldie – I shall cut you out', as if he is fighting with something inside the nappy. Eventually, the 'nappy-stuff' (sodium polyacrylate) comes out. The children touch it and the ECEC staffer asks 'How does it feel?'. 'Wet! Cold!', the children reply. When the material in the nappy is on the table, so much happens. The material is poured from one cylinder to another, pipettes are lowered into the blue matter and one child observes the reaction to that action. The matter is popping up. 'Wow!'. The talk is about solid matter, fluid, etc. The children are constantly repeating actions, imitating each other – expressing surprise and wonder, exclaiming: 'OH! – LOOK! – LOOK at mine!'. There is no sign of an end to this wonderful mess.

In this case, the children experience two prominent dimensions for exploration: first, *The tester who tests* when the children investigate what is inside a nappy, or what happens when blue-coloured water is added to a nappy. Based on the imaginative *what if*, the children test what happens. Second, *The senser who senses:* the children experience with their senses – wet, cold, etc. The children notice and talk about it, supported by the ECEC staffer.

The dimension of (body) language is also present in the case. The children ask non-verbal questions when they observe the nappy absorbing the water. 'How can this be possible?' – this is *The questioner who asks*. *The interpreter who interprets* is also present when the children say that there can be a teddy bear inside the nappy. They interpret the softness of a nappy as being like a teddy bear, which they know as soft.

The dimension on early mathematical awareness is present as *The counter who counts*, when the children count – for example, the amount of water that they pour into the nappy.

Together, the analysis with science practices illustrates a picture where all three dimensions of science practices are present. The analysis can be used by the practitioner to identify science practices both in planned activities and in children's spontaneous play. From this, the practitioner can scaffold children's learning in the situation. From a research perspective, the analysis with science practices offers knowledge of the specific context and of which science practices are present. This could be, for example, as part of a mapping of science context quality. This could be, for example, as an analysis of the presence or absence of specific science practices, or it could be as an analysis of how science practices appear together in different science contexts.

Case 2: Marble run

In the playground in an ECEC, Sigurd has stacked five large, soft Lego bricks on top of one another. He spots masking tape: 'What?', he asks. 'Masking tape', the adult replies. 'That', he points. 'Shall we use it?'. He nods. The adult pulls out tape, finds two tubes that can be taped together, and puts the two tubes on top of the bricks so that they balance. Sigurd brings a ball and puts it into the pipe. He notices that the ball does not roll in the horizontal tube. 'If you lift the tube, it will roll out.' Sigurd laughs and tries again. 'You have changed the slope', the adult says, as Sigurd picks up the tube. He repeats his action and the adult repeats: 'You have changed the slope. Sigurd changes the slope'. When Sigurd lifts the tube and the ball rolls downwards, he happily shouts: 'Sloooope!'. Sigurd is barely 2 years old and understands that his action creates a reaction and that changing the slope is the action that creates a reaction in the ball rolling. He does not understand the abstract physics concept of slope, but he does understand the concrete practice that is required for the ball to roll out of the tube.

In this case, Sigurd gains experience with the science phenomenon *marble run* and the physical concept *slope*. Furthermore, Sigurd carries out science practices when working with the marble run. Sigurd experiences dimensions for exploration in the science practice *The tester who tests*, when he tries to see if the ball will roll out of the tube with different positions/slope. *The senser who senses* is taking place when Sigurd is observing what is happening when the ball rolls out of the tube. Together with the ECEC staffer, Sigurd experiences *The planner who plans*, when they find masking tape and he directs the ECEC staffer with his body language (point and nod) and word 'That'. *The questioner who asks* is prominent when Sigurd asks 'What?' and when he repeatedly puts the ball into the tube, surprised and curious. The ECEC staffer supports Sigurd in interpreting what they are experiencing. They have discovered a cause-and-effect relationship (if, then), which the ECEC staffer articulates. In that way, the ECEC staffer acts as *The interpreter who interprets* for the child, and thereby helps to expand the child's vocabulary. At the same time, the ECEC staffer supports Sigurd in a future mindset of science practices and *The narrator who narrates*.

Together, science practices provide a basic picture of what actions can be thought of in constructive work with children in science situations. If situations with science give children the opportunity to take actions, then the science practices come into play around nature and natural phenomena.

Discussion and implications

In the two cases above, we have shown how science practices can be used to clarify the presence of science in children's activities. In the first case, we have a traditional approach to science with the ECEC staffer presenting the nappy to the children in a prepared set-up. Science is not hard to discover in such contexts when the preparation is focused on a science phenomenon or concept. The second case illustrates how science practices are present and can be identified in a less prepared and more spontaneous context. When analysing such a context, we find science practices in an equal amount as in the prepared setting. The usage of science practices as an analytical tool thereby offers the opportunity to open up the recognition of science in, for example, children's play and to support these practices in respect of the play. The practices thereby give the ECEC staff the opportunity to change focus from what can be done with this science phenomenon or concept towards a focus on children's actions and on what the science is in the practices that the children are doing. This of course implies that ECEC staff know the content and can interpret the context as science phenomena or concepts. A finding in the EPPE project (Sylva *et al*, 2004) was that *'freely chosen play activities often provided the best opportunities for adults to extend children's thinking'* (p.13). The science practices presented in this article offer a language to help adults to recognise and promote science in children's spontaneous science activities.

Another approach to the usage of science practices as an analytical tool is that the practices offer a mapping of the frequency of usage. ECEC staff are thereby offered the opportunity to see if their approach includes a wide span of practices, or if it is limited to a few. This calls for a long-range usage of the science practices that could be hard to implement on a daily basis.

Altogether, the science practices offer an expanded view on science and science activities for children, including play and spontaneous investigations. However, in order for them to be an effective analytical tool in reality, they require a systematic implementation among practitioners. In addition, science practices should not be seen as instruments for the checking of different practices. The use of this as a tool involves the ECEC staff in recognising practices, but also requires the same staff to scaffold and clarify the science content to the children.

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Assessing the impact of the STEM Academy model on confidence in STEM in teachers and puplis

. Margaret R. Ritchie ● Anna Maria Mackay ● Clinton Jackson

Abstract

Many UK primary teachers currently lack confidence and skills in Science, Technology, Engineering and Maths (STEM) subjects to help deliver high quality experiences of STEM learning in the classroom that inspire and motivate pupils. There is evidence that primary teachers/probationers would benefit from further training in STEM subjects and that opportunities to engage with and work in partnership with experts in industry and academia may help develop teacher confidence in STEM. The Summer STEM Academy was the first in the UK to bring primary teachers (n=31) and senior pupils (age range 15-17 years) (n=39) into an academic environment aligned with industry and, through structured partnership working, assess the impact of this model on teacher and pupil confidence in and attitudes to STEM. Impact of the STEM Academy was assessed using validated questionnaires completed pre- and post- the event. The results indicate a significant reduction in primary teacher anxiety and increase in self-efficacy associated with improved confidence in STEM engagement and education. There was a significant improvement in pupil attitudes to science and technology and a positive trend in pupil confidence and engagement in STEM.

Keywords: STEM, partnership working, transition, confidence

Aim of the study

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

Background

The *UK STEM Education Landscape* report (Morgan *et al*, 2016) identified the importance of primary schools providing appropriate, accurate and inspiring STEM education to children from an early age, and ensuring that teachers responsible for science are appropriately trained even if they are not science specialists. Currently, only 5% of primary school teachers have a qualification at A-level or above in mathematics or science (Morgan *et al*, 2016), which may influence their willingness to engage in teaching STEM-related activities in the classroom. It is essential that primary teachers are confident and skilled in delivering STEM subjects and use motivational approaches to learning, especially with disadvantaged pupils (Rocard, 2017). Current programmes to develop STEM skills in primary teachers are limited in the amount of STEM that teachers experience and provision of opportunities to promote partnerships that would help address the lack of STEM confidence in student teachers. An intervention to assist primary student teachers in teaching science had difficulty showing any impact (Watters, 1994), indicating the importance of an appropriately organised programme to engage primary student teachers in STEM.

Rationale

The STEM Academy was initiated in response to requests by primary student teachers for a programme of support and training in STEM before entering their probationary year (Ritchie *et al*, 2018). The Summer STEM Academy model was the first in the UK to address the current lack of STEM skills and confidence in primary student teachers, using structured partnerships to develop teacher and pupil confidence and skills in STEM to inspire younger and disadvantaged pupils. This innovative approach to learning and teaching, involving sustainable and structured partnerships (Education Scotland, 2017) between Initial

Teacher Education (ITE) or Initial Teacher Training (ITT) providers, schools, industry and higher education, may help contextualise STEM learning (Ritchie *et al*, 2018), raise awareness of careers involving STEM subjects (Education Scotland, 2015), support transition, further develop meaningful partnerships between schools and industry/academia and promote enquiry-based science learning. This has been shown to help raise attainment (Abdi, 2014) by providing an inspirational approach to science learning (Rocard, 2017; Martina *et al*, 2016), making science interesting, and developing pupils' critical thinking skills (Seraphin *et al*, 2012). There is evidence that partnerships (Ritchie, 2018) enhance student teacher and pupil confidence and attainment in STEM (Parliamentary Briefing, 2017). Increased skills and confidence of student teachers and pupils will support progression and skills development of disadvantaged pupils. The STEM Academy was also designed to increase student teacher science knowledge and insight into good practice and assessment in science, key aspects of ITT/ITE recently highlighted as requiring action (Ritchie *et al*, 2018; Wellcome Trust, 2017). Enquiry-based science education incorporates pedagogical approaches to learning and teaching that can also increase pupil engagement and encourage metacognition, collaborative learning, peer tutoring and feedback (Seraphin *et al*, 2012), which may increase engagement of disadvantaged pupils (Rocard, 2017; EEF toolkit, 2018). The need for primary student teachers to receive support in STEM is highlighted by Kurup *at al* (2019).

Design and implementation of the STEM Academy model

The Summer STEM Academy was designed to provide training in STEM to pre-probationer primary teachers and senior secondary pupils over two days. Approximately 25 pupils (aged 15 to 17 years) and 25 pre-probationer primary teachers participated at each STEM Academy, in addition to academic and industrial experts. Workshops related directly to industry and university research and activity providers' and STEM Ambassadors' areas of expertise. A pilot STEM Academy took place in 2018. Impact of the 2018 model on pupils and teachers was assessed using validated questionnaires and, due to the highly positive impact found, two STEM Academies took place at two separate locations in 2019. The format and programme for all the STEM Academies was consistent over the two days. A limitation of the initial STEM Academy was the lack of ethical approval, which reduced the numbers from whom data could be collected for publication. A further limitation of the STEM Academy was accessibility of the workshops in a UK setting. This was addressed whereby workshops were chosen to ensure that they were available to schools across the UK, as far as possible. A strength of the STEM Academy was due to the group design, where secondary pupils explained the science associated with each workshop to the primary student teachers, therefore helping to improve their confidence in delivering STEM in a primary classroom. This built upon another key feature of the STEM Academy model, namely the co-creation of a STEM-based activity that secondary pupils could deliver in a primary setting.

Summary of the STEM Academy Programme

Each Summer STEM Academy brought student primary probationers and senior pupils together with STEM researchers from academia and industry. Activities were designed to promote confidence in STEM delivery and understanding, including the design principles of high quality and curriculum-linked STEM activities. Participant groups consisted of 2-3 primary probationer teachers and 2-3 senior pupils. During Day One, groups undertook team-building activities in engineering (an innovative challenge – developing resources for the disabled), forensic science and also molecule hunts for bio-molecules and everyday molecules, followed by a co-creation activity involving speed dating with industry, including STEM Ambassadors and academia. There was an evening social event consisting of a science ceilidh relating scientific processes to the dance floor. During Day Two, groups participated in a variety of STEM-related workshops led by researchers and industries, providing a variety of contexts and careers involving STEM. These included Solar Energy, Astrobiology, F1 in Schools Car Design, Astronomy with Space Research, Science Communication, Molecule Building, Air Race Challenge, Genetics and Coding. After lunch, participants undertook industrial experience within a Science Innovation Centre (Biocity Scotland) and, in collaboration with researchers, co-created activities for delivery to a variety of audiences. The Science

Innovation Centre could easily consist of a visit to a local industry. Many workshops could be replicated in England, Ireland and Wales, as they are available online and via STEM Ambassadors. Combined expertise ensured that activities and resources developed practical and critical thinking skills, and skills in educational pedagogy. Activities and resources developed in the Academy could be further developed and disseminated by participants, with one activity from each Academy being chosen as an exemplar for the following year. Pupil participants could further participate in a Personal Recognition in Academic and Industrial STEM Education (PRAiSE) award. To achieve this award, secondary schools had to demonstrate their involvement/collaboration with at least one partner organisation, e.g. industry or academia, including STEM Ambassadors and evidence of pedagogical approaches that promoted enquiry-based learning and metacognitive approaches to learning through engagement with primary schools and school communities. This engagement with primary schools was a key outcome of the STEM Academy. Secondary pupils delivered workshops that had been co-created during the STEM Academy to primary schools during follow-up to the STEM Academy. Furthermore, primary student teachers had access to partners who could assist with delivery of STEM-based activities within a primary setting.

During follow-up to the STEM Academy, each primary probationer and each participating secondary school were provided with access to presentations, workshops, activities and resources. Primary probationer teachers and secondary schools could also request support for development of projects within primary settings demonstrating progression through the primary and secondary science curriculum.

Method for evaluation of the STEM Academy

All delegates attending each STEM Academy completed a pre-event validated evaluation questionnaire (van Aalderen-Smeets *et al*, 2012; van Aalderen-Smeets, 2013) during registration at the start of the event and before attending any lectures or workshops. Questionnaires were granted ethical approval by the University ethics committee. Delegates also completed a post-evaluation questionnaire, which contained the same questions and included additional questions about the value and relevance of the STEM Academy and suggestions for future events. The evaluation questionnaire questions assessed confidence in science and technology and opinions/attitudes to science and technology. Questions associated with confidence were split into a variety of categories associated with key components of confidence, i.e. self-efficacy, context dependency, anxiety, enjoyment, relevance, and difficulty.

Each questionnaire question used a Likert scale, seeking agreement or disagreement with a statement, on a scale from 1 to 5:

1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree.

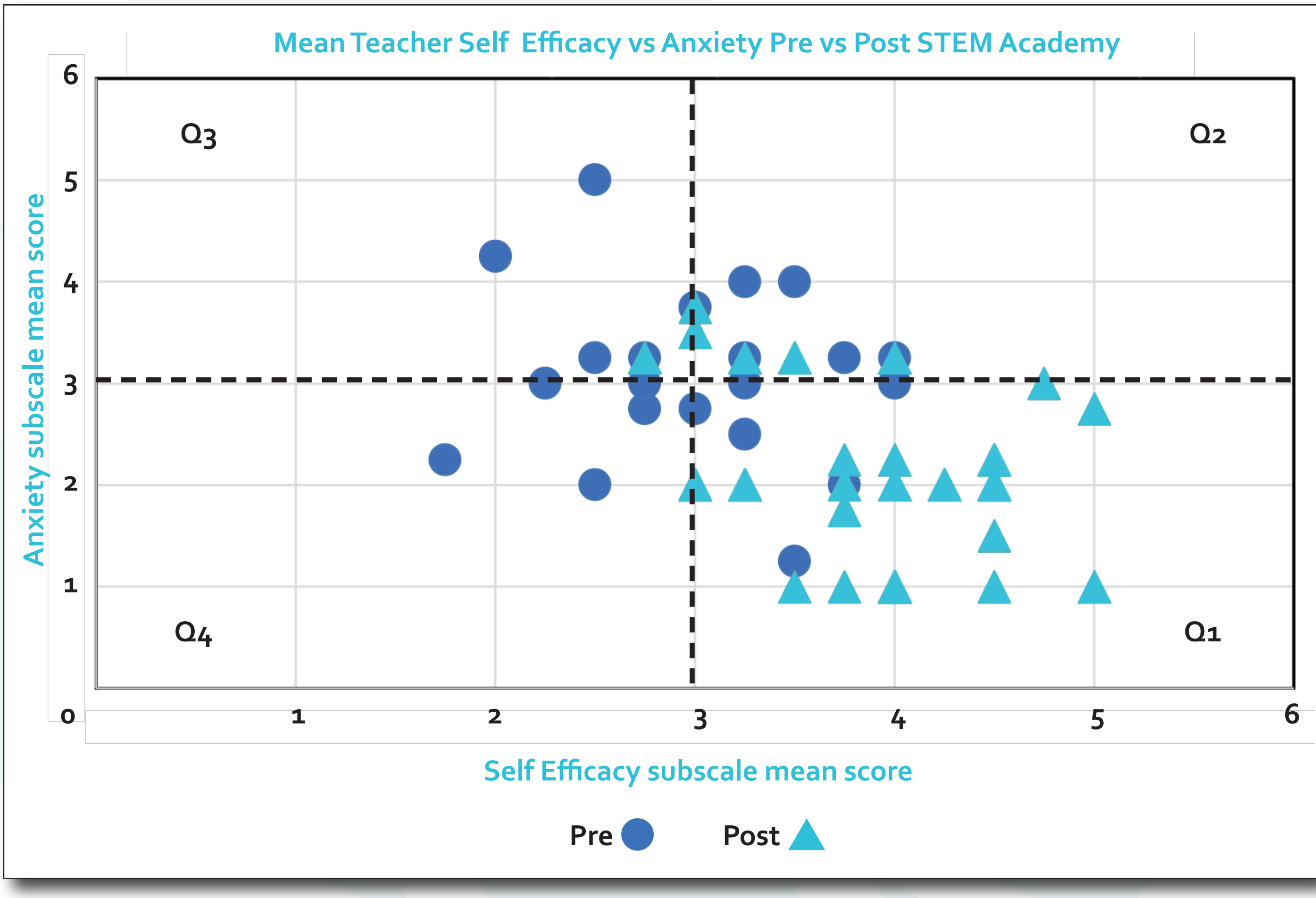
Completed evaluation questionnaires were collected and only responses from completed pre- and post-event evaluation forms were used for analysis of the data.

Data were paired for each participant. Mean values were calculated for each delegate's pre- and post-response in attitudes and each confidence category, i.e. self-efficacy, (perceived) context dependency, anxiety, enjoyment, relevance, and difficulty. Mean values pre- and post- were subsequently used to create scatter plots of anxiety vs self-efficacy, anxiety vs enjoyment and (perceived) context dependency vs self-efficacy.

Results

During the three STEM Academies that took place, probationer pre-service primary teachers (n = 83) and senior pupils (n = 76, age range 15-17 years) from a variety of secondary schools situated within 14 local authorities across Scotland participated in the event.

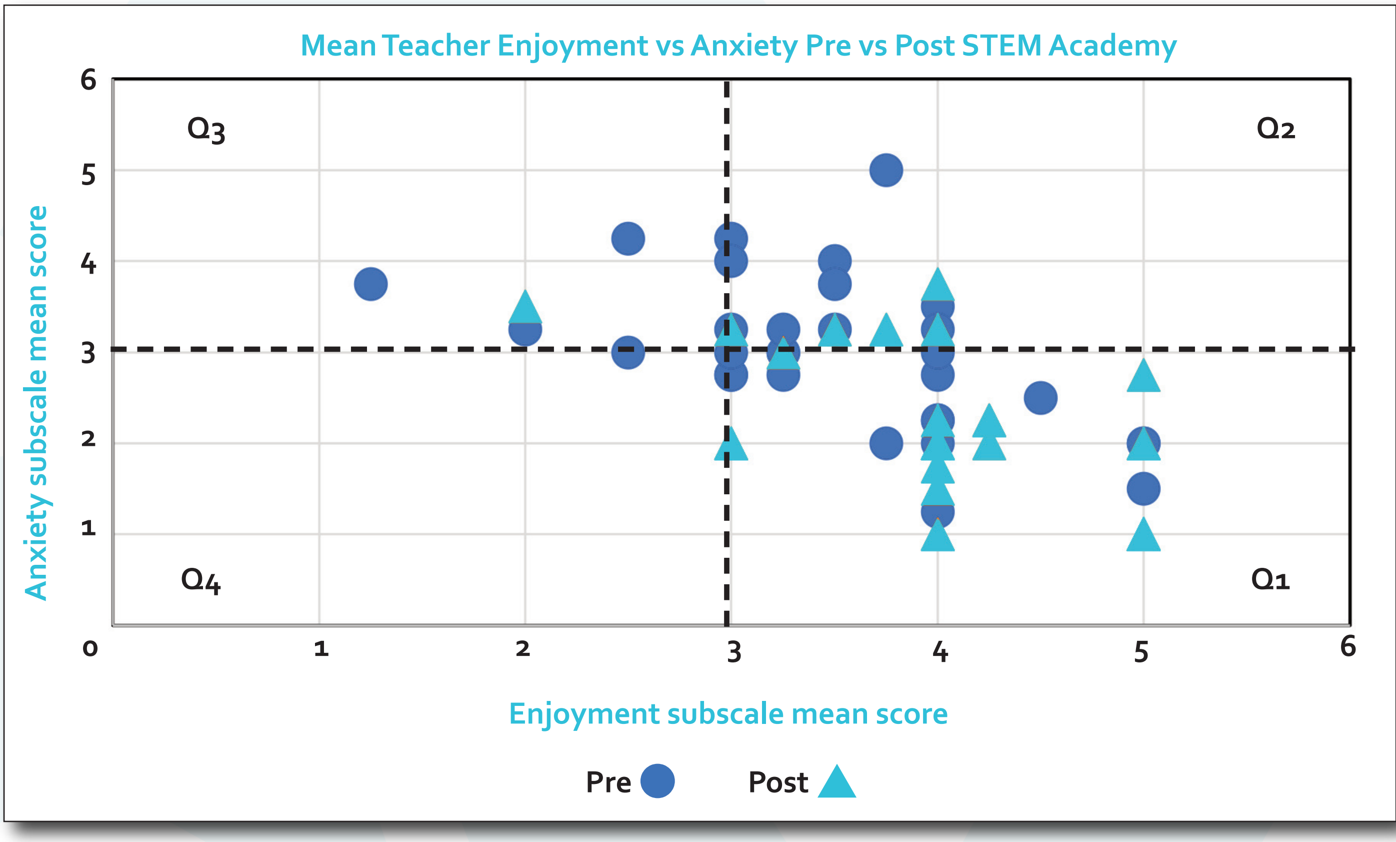
Results Panel A



Self-efficacy vs Anxiety quadrant allocation – teachers (n=31).

Quadrant	Pre-STEM Academy	Percent of total Pre-STEM Academy	Post-STEM Academy	Percent of total Post-STEM Academy
1	**7**	22.6	**23**	74.2
2	**7**	22.6	**4**	12.9
3	**11**	35.5	**3**	9.7
4	**6**	19.4	**1**	3.2

Results Panel B



Enjoyment vs Anxiety quadrant allocation – teachers (n=31).

Quadrant	Pre-STEM Academy	Percent of total Pre-STEM Academy	Post-STEM Academy	Percent of total Post-STEM Academy
1	**11**	35.5	**22**	68.8
2	**10**	32.3	**5**	15.6
3	**8**	25.8	**2**	6.3
4	**2**	6.5	**2**	6.3

Results Panel C

Self-efficacy vs Context Dependency quadrant allocation – teachers (n=31).

Quadrant	Pre-STEM Academy	Percent of total Pre-STEM Academy	Post-STEM Academy	Percent of total Post-STEM Academy
1	**10**	32.3	**14**	45.2
2	**4**	12.9	**13**	41.9
3	**15**	48.4	**4**	12.9
4	**2**	6.5	**0**	0

Note: Panel A shows a scatterplot for pre-service/probationer primary teacher participants mean Anxiety score versus mean Self-efficacy (SE) scores.

Panel B shows a scatterplot for pre-service primary teacher participants mean Anxiety score versus mean Enjoyment scores.

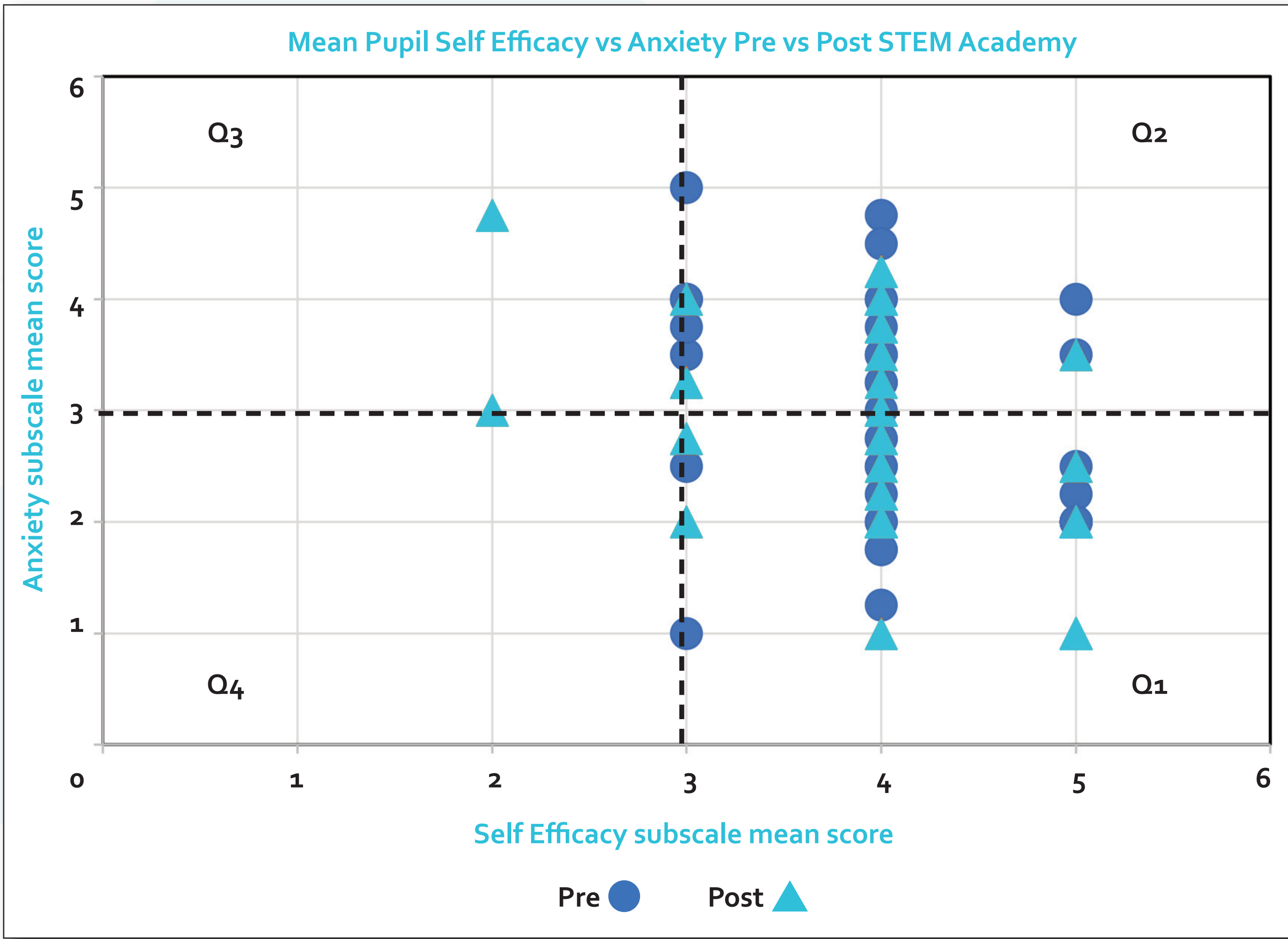
Panel C shows a scatterplot of pre-service primary teacher participants mean Perceived Context Dependency (PCD) scores versus Self-efficacy scores. Dashed lines reflect the cut-off point for the quadrants. The quadrants: Q1= High potentials; Q2= Promising; Q3= reluctant; Q4= indifferent. For Panel A, a Self-efficacy (SE) score >3 is quadrants 1 and 2; SE ≤ 3 is quadrants 3 and 4; Anxiety ≥ 3 is quadrants 2 and 3; Anxiety < 3 is quadrants 1 and 4. For Panel B, an Enjoyment score >3 is quadrants 1 and 2; Enjoyment ≤ 3 is quadrants 3 and 4; Anxiety ≥ 3 is quadrants 2 and 3; Anxiety < 3 is quadrants 1 and 4. For Panel C, a Self-efficacy score >3 is quadrants 1 and 2; Self-efficacy ≤ 3 is quadrants 3 and 4; PCD score ≥ 3 is quadrants 2 and 3; PCD < 3 is quadrants 1 and 4.

Summary table (n=31)

Descriptor (teachers %)	**Affective Control** Self-efficacy vs Anxiety		**Affective State** Enjoyment vs Anxiety		**Perceived Control** Self-efficacy vs Context Dependency	
	Pre	Post	Pre	Post	Pre	Post
High Potential (Q1)	22.6	74.2	35.5	68.8	32.3	45.2
Promising (Q2)	22.6	12.9	32.3	15.6	12.9	41.9
Reluctant (Q3)	35.5	9.7	25.8	6.3	48.4	12.9
Indifferent (Q4)	19.4	3.2	6.5	6.3	6.5	0

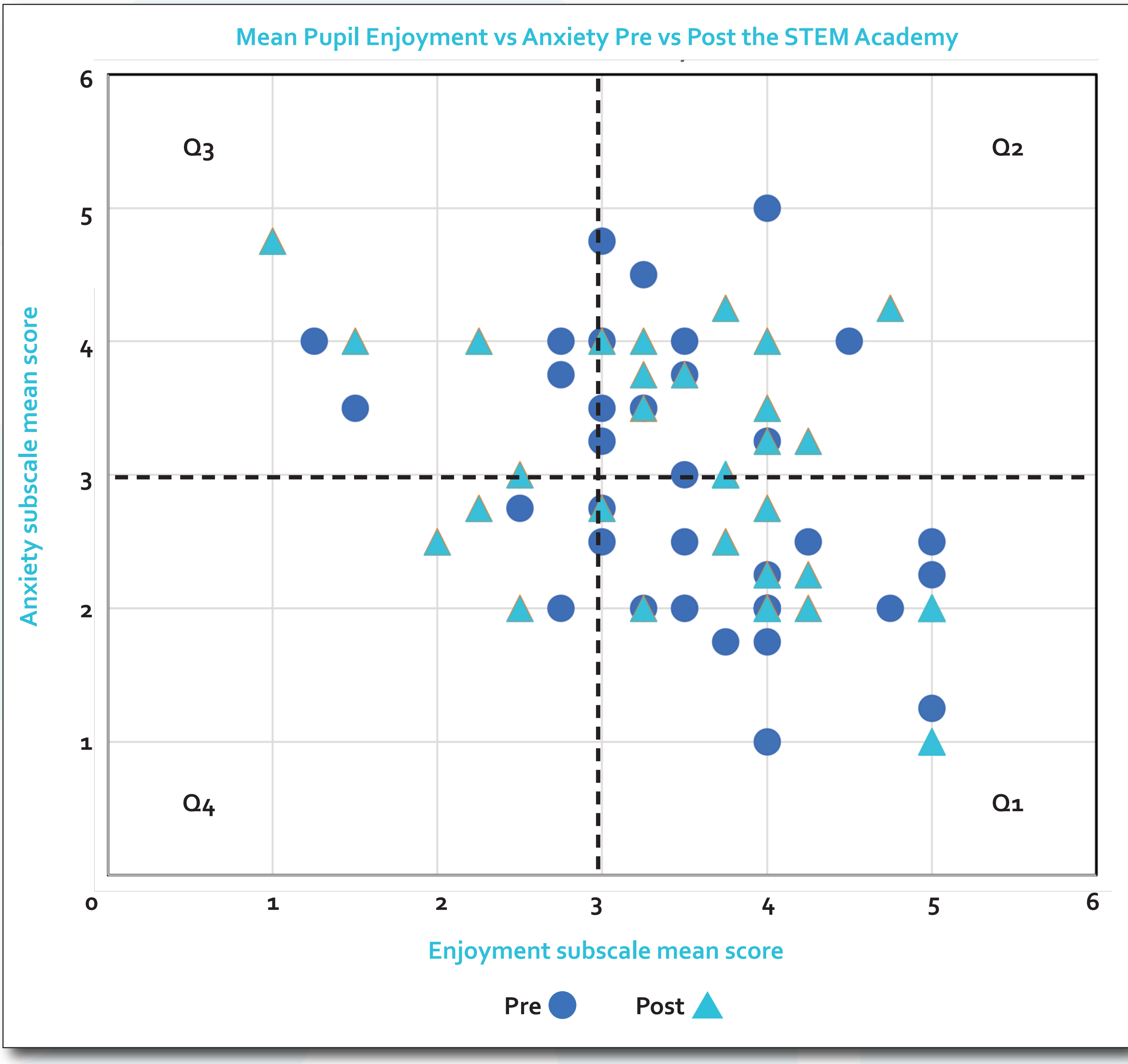
Summary table for ANOVA results (Key* – highly significant)

Descriptor (teachers %)	**Affective Control** Self-efficacy vs Anxiety		**Affective State** Enjoyment vs Anxiety		**Perceived Control** Self-efficacy vs Context Dependency	
	Pre	Post	Pre	Post	Pre	Post
High Potential (Q1)	22.6	74.2 p<0.01*	35.5	68.8 p<0.01*	32.3	45.2 p<0.05**
Promising (Q2)	22.6	12.9 p<0.01*	32.3	15.6 p<0.01*	12.9	41.9 p<0.01*
Reluctant (Q3)	35.5	9.7 p<0.01*	25.8	6.3 p<0.01*	48.4	12.9 p<0.01*
Indifferent (Q4)	19.4	3.2 p<0.01*	6.5	6.3	6.5	0 p<0.01*



Self-efficacy vs Anxiety quadrant allocation – pupils (n=39).

Quadrant	Pre-STEM Academy	Percent of total Pre-STEM Academy	Post-STEM Academy	Percent of total Post-STEM Academy
1	**19**	48.7	**20**	51.3
2	**12**	30.8	**13**	33.3
3	**5**	12.8	**4**	10.3
4	**3**	7.7	**2**	5.1



Enjoyment vs Anxiety quadrant allocation – pupils (n=39).

Quadrant	Pre-STEM Academy	Percent of total Pre-STEM Academy	Post-STEM Academy	Percent of total Post-STEM Academy
1	**18**	46.15385	**18**	46.15385
2	**9**	23.07692	**12**	30.76923
3	**8**	20.51282	**5**	12.82051
4	**4**	10.25641	**4**	10.25641

Self Efficacy vs Anxiety quadrant allocation – pupils (n=39).

Quadrant	Pre-STEM Academy	Percent of total Pre-STEM Academy	Post-STEM Academy	Percent of total Post-STEM Academy
1	**19**	48.7	**20**	51.3
2	**12**	30.8	**13**	33.3
3	**5**	12.8	**4**	10.3
4	**3**	7.7	**2**	5.1

The results above indicate an increase in the number of teachers and pupils being recorded in quadrant 1 and quadrant 2 and a reduction in the numbers recorded in quadrants 3 and 4 post-participation in the STEM Academy. This is indicative of the positive impact of the STEM Academy on teachers' and pupils' attitudes towards STEM. Quadrant 1 is indicative of teachers with a high potential in the aspect of engaging in STEM. Quadrant 2 is indicative of teachers showing a promising attitude in engaging in STEM. Quadrant 3 is indicative of teachers who are reluctant to engage in STEM and Quadrant 4 is indicative of teachers who are indifferent in their attitude towards engaging in STEM.

Samples of pupil and teacher comments post-STEM Academy

Pupil A: *'It helped my confidence in meeting new people. Everyone running events were very enthusiastic and knowledgeable so the activities were more engaging. The activities were practical which made them easier to remember.'*

Pupil B: '*The event had lots of different workshops which were interesting. I learned a lot and got a good overall view in how science is applied in the world of work.'*

Pupil C: *'Really brilliant having different groups working in the same room working together.'*

Pupil D: *'Possibly make the event a little longer, so as to spend more time in each workshop.'*

Pupil E: *'Could maybe identify specific interests in STEM and base group tasks on these so that people engage with their own personal STEM area.'*

Teacher A: *'I enjoyed and gained a lot from the 2-day programme, meeting many engaging and inspirational people. It really highlights the importance of making links between research, secondaries, primaries and grass roots and inspiring young children and making the science world accessible as a successful career path.'*

Data analysis and discussion

Data were analysed using SPSS and the 'R' programme.

A Two-way Friedman ANOVA test was applied to data related to pre-service probationary primary teachers. The resulting analysis of data pre- and post- the STEM Academy demonstrates significant differences in five key components of confidence, namely: self-efficacy, anxiety, difficulty, relevance, and enjoyment.

During analysis of data relating to pupils' attitudes towards science and technology using a Two-way Friedman ANOVA, Wilcoxon Sign Rank test taking into account statements about their relevance in contributing to society and supporting the development of a country, there were significant differences between pre- and post- responses.

Pupil enjoyment versus Anxiety in engagement in STEM showed a positive trend pre- versus post-participation in the STEM Academy. A similar trend was observed in pupil Self-efficacy versus Anxiety pre- versus post-participation in the STEM Academy.

Analysis of the results demonstrate that this multi-level partnership approach to working has a significant impact on teacher confidence in and attitudes towards STEM subjects. For teachers, key components of confidence such as self-efficacy, relevance, anxiety and enjoyment improved significantly.

Overall analysis of the data demonstrated a significant increase in the number of teachers identified as having high potential towards the teaching of science in primary schools. They were also shown to engage more positively in STEM-based activities and their delivery.

The reduction in anxiety and increase in self-efficacy in both teachers and pupils indicate the positive mental health impact (and future application) of this model and approach to improving mental health in teachers and pupils through multi-level partnership working. A recent study reported that making the science more relevant (exactly the aim of the STEM Academy) and more of an adventure had a significant impact on senior pupils' engagement in science (Morgan *et al*, 2022).

Our findings highlight the STEM Academy model of multi-level partnership working as a successful programme for probationer and pre-probationer teachers, especially primary practitioners. It provides primary practitioners with the opportunity to work with secondary pupils and gain an insight into the secondary curriculum and how sciences progress in the secondary school. It also enables primary practitioners to experience working with industry and academia and learn about current developments in both. In doing so, it helps to contextualise STEM learning for teachers and therefore their pupils, in this case primary, and aligns the input of academia and industry with the curriculum to support skills development, inspire learning and demonstrate the relevance of the learning.

Overall, this 'new to the field' approach in co-creation, resulting in the development of workshops involving primary student teachers and, ultimately, primary pupils during the follow-up period is a novel approach to improving primary STEM. Primary pupils would have the opportunity to present their workshop at a future STEM Academy, parents' evening or within a community setting, or using social media. Another strength of the STEM Academy was the emphasis on highlighting the relevance of STEM. The importance of this is discussed by Morgan *et al* (2022).

Conclusion

The STEM Academy builds partnerships between primary and secondary schools and between primary schools, academia and industry. During follow-up to the STEM Academy, primary probationer teachers will be supported by academic and industrial partners and senior pupils to deliver co-created activities in their primary/secondary school and across the cluster of primaries and local secondaries. Senior pupils will work with academic and industrial partners and deliver co-created activities in secondary schools and modify the activities for delivery in primaries, and to youth groups, at parents' evenings, science festivals, community and fundraising events.

By targeting pupils from deprived areas, with a focus on girls, many children from disadvantaged backgrounds will experience industry for the first time. Through engaging with industry and academia, learning is contextualised and multi-level working will provide an insight into the variety of opportunities that STEM provides. Senior pupils who complete the PRAiSE Award, an award that promotes citizenship and is mapped into teaching standards and professionalism, and primaries who implement co-created activities, will be invited to deliver a workshop at the STEM Academy the following year, therefore assuring the sustainability of the programme. This is a key aspect of the STEM Academy.

The recommendation for primary practitioners is that they should take the opportunity to participate in a STEM Academy. In this way, they will gain more confidence in delivering STEM-based activities within a primary school. They will also develop partnerships with secondary schools where secondary pupils can deliver STEM-based activities within a primary setting. This can support the primary practitioner, as well as excite and motivate primary pupils in STEM. This approach of senior pupils leading STEM workshops in a primary setting has already been used and has been shown to be highly effective in motivating primary pupils in STEM.

The long term aims of the Summer STEM Academy programme are to:

- Build on the success of the STEM Academy and develop the STEM Academy model across more UK ITE institutions;
- Assess impact on teachers and pupils (primary and secondary) during a 6-month and 12-month follow-up regarding engagement in STEM and key components of confidence relating to mental health and transition;
- Extend access to qualified teachers (primary and secondary); and
- Assess the impact of the model on diversity and inclusion. Results of initial data analysis are very promising.

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Clinton Jackson, Community Learning and Development Officer, who assisted with the running of the workshops.

Note: Readers who wish for further information about schools that participated in the STEM Academy programme or the workshop programme are welcome to contact Dr. Margaret Ritchie directly at Glasgow University on Margaret.Ritchie@Glasgow.ac.uk

Head, Hearts and Hands for the environment

● Ravina Winch

Abstract

As a teacher of science in a middle school serving children with diverse needs, I was keen to explore whether an embodied approach might be fruitful in supporting learners to engage with environment education. Embodied cognition (an example of which is the practice of Making) is an emerging idea that has foundations in established pedagogies such as those of Dewey, and involves placing tangible materials at the centre of the learning experience to promote deeper cognitive understanding. I therefore turned to the theory of embodied cognition and designed a lunchtime club that encouraged learning with hearts (learning through passion and values promoting a change in behaviour), heads (becoming cognitively involved in the learning and showing engagement), and hands (engaging with and manipulating tangible objects to engage with real-world issues). By engaging in embodied approaches to test the optimal growing conditions for different vegetables, pupils also developed STEM skills (science, technology, engineering, and mathematics), for example, critical thinking and teamwork. Embodied cognition can, therefore, be seen as a way to embed STEM skills and develop affective interest in the environment.

That is, when pupils are shown how to care for their environment, then embodied acts such as upcycling or planting seeds could be become an act of self-expression and potentially shared with the wider community.

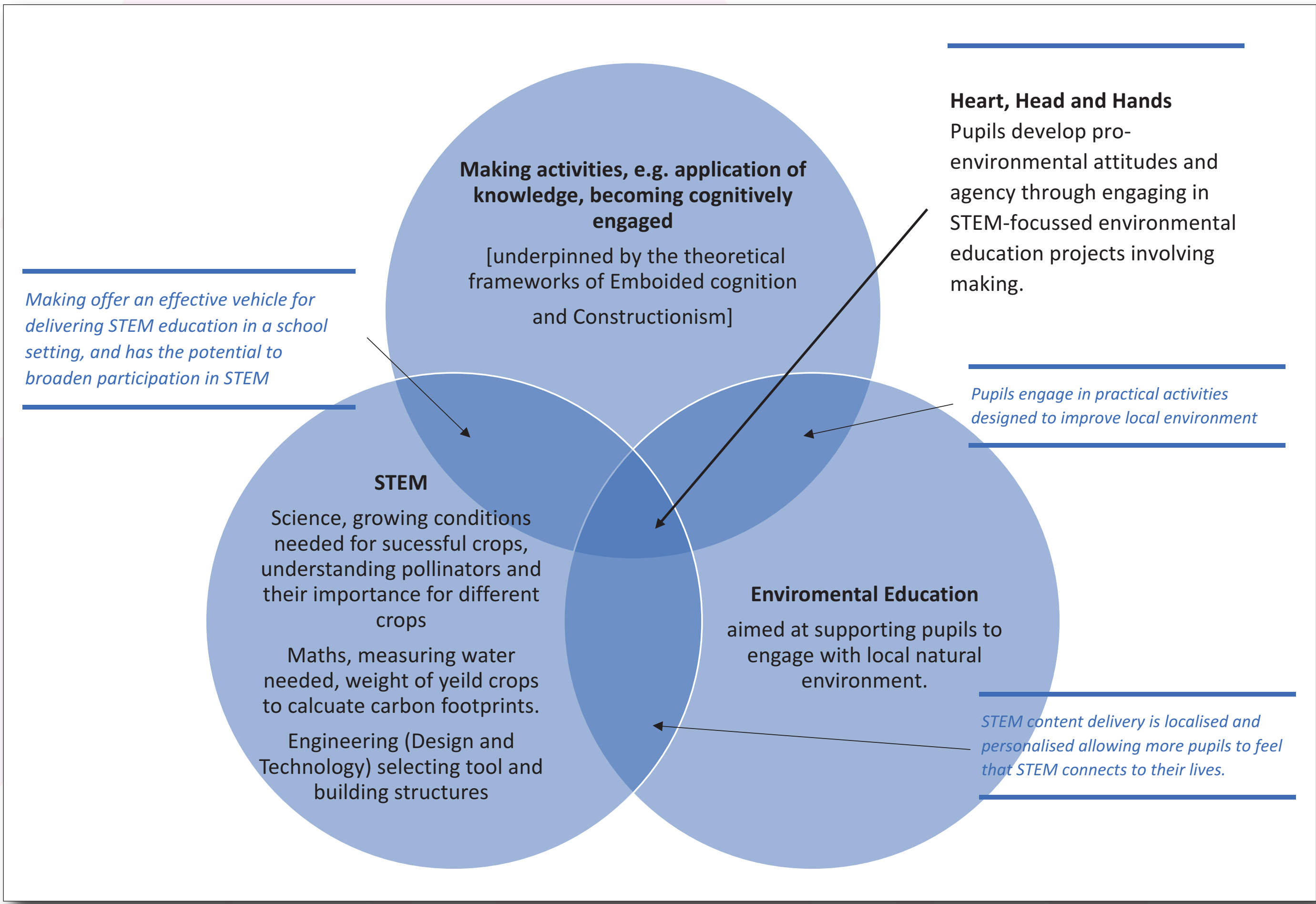
Introduction

Environmental Education (EE) was included in the formal education system in England in 1989 when the National Curriculum was launched. Glackin and King's (2020) analysis of how EE is delivered in secondary schools in England found that pupils are exposed to issues relating to the environment in science, and geography. However, their findings suggest that pupils are mostly taught *about* the environment rather than learning *for* the environment. That is, pupils learn facts about the environment such as deforestation and climate change, but rarely engage in critical analysis of these issues. Glackin and King go on to discuss that learning *for* the environment could be achieved by the pupils being *in* the environment. For example, to help a pupil to really make a connection with the environment and act to protect it, they should have the opportunity to physically interact with their natural surroundings.

Academics have viewed STEM education as having connections with EE. For example, Bybee (2020) addresses the need for pupils to understand and develop the skills that they will need to overcome challenges, such as over-population and climate change, as active and concerned citizens. He suggests that grounding these global challenges into a context that pupils can understand could enable them to see the role that they can play; and how, through innovation, STEM can help to resolve these issues.

Furthermore, it has been widely viewed in the literature that there is a need to challenge the dominant forms of STEM education as being masculine, about robotics, or excluding some social demographic groups (Archer *et al*, 2020; DeWitt *et al*, 2011; Halverson & Peppler, 2018). Projects such as ASPIRES (Archer *et al*, 2020) suggest that widening participation in STEM is necessary and calls for a systemic shift to change the perceptions of who can do STEM.

Figure 1. VENN diagram representing the connections between STEM, EE and Making.



The learning theories that are associated with the embodied approach of Making, where pupils are constructing new knowledge using their hands, is accredited to Papert's theory of Constructionism (Bevan, 2017; Kafai, 2005). His theory marked a new era in understanding how pupils learn; providing practical learning environments allowed pupils to construct their own knowledge and grasp abstract concepts through purposeful manipulation and interactions.

Above is a VENN diagram (Figure 1) drawing together my findings from academic literature. I noticed that the research suggested that there was an opportunity to deliver a STEM-focused environmental education programme using the embodied approach of Making.

Wilson's (2002) review of embodied cognition emphasises that we must understand the role of the mind and body when interacting with tools in learning situations. Her work includes two tentative views of embodied cognition that are relevant to this study, stating that cognition is situated, and that cognition is for action. The first view highlights the importance of learning in the environment and that we can learn best when we are actively placed in the situation – a claim that Wilson feels is well researched. The second claim underlines the importance of the mind to guide action. For example, our minds can develop episodic and implicit memory through our experiences and interactions and that, over time, difficult tasks become familiar and easier to comprehend. That is, our bodies can store information to help them to carry out actions, thus reducing the cognitive load for actions such as walking and using tools.

However, there is, as yet, little research examining the use of embodied approaches in the context of EE. I thus sought to explore the impact of using an embodied approach for engagement with the environment, emphasising head, hands and heart, through the implementation of a STEM-focused lunchtime environmental education club.

Research study

To explore the impact of an embodied approach to learning about the environment, I applied the work of Bevan *et al* (2020), in which they propose a framework of learning dimensions that can be observed during embodied activities.

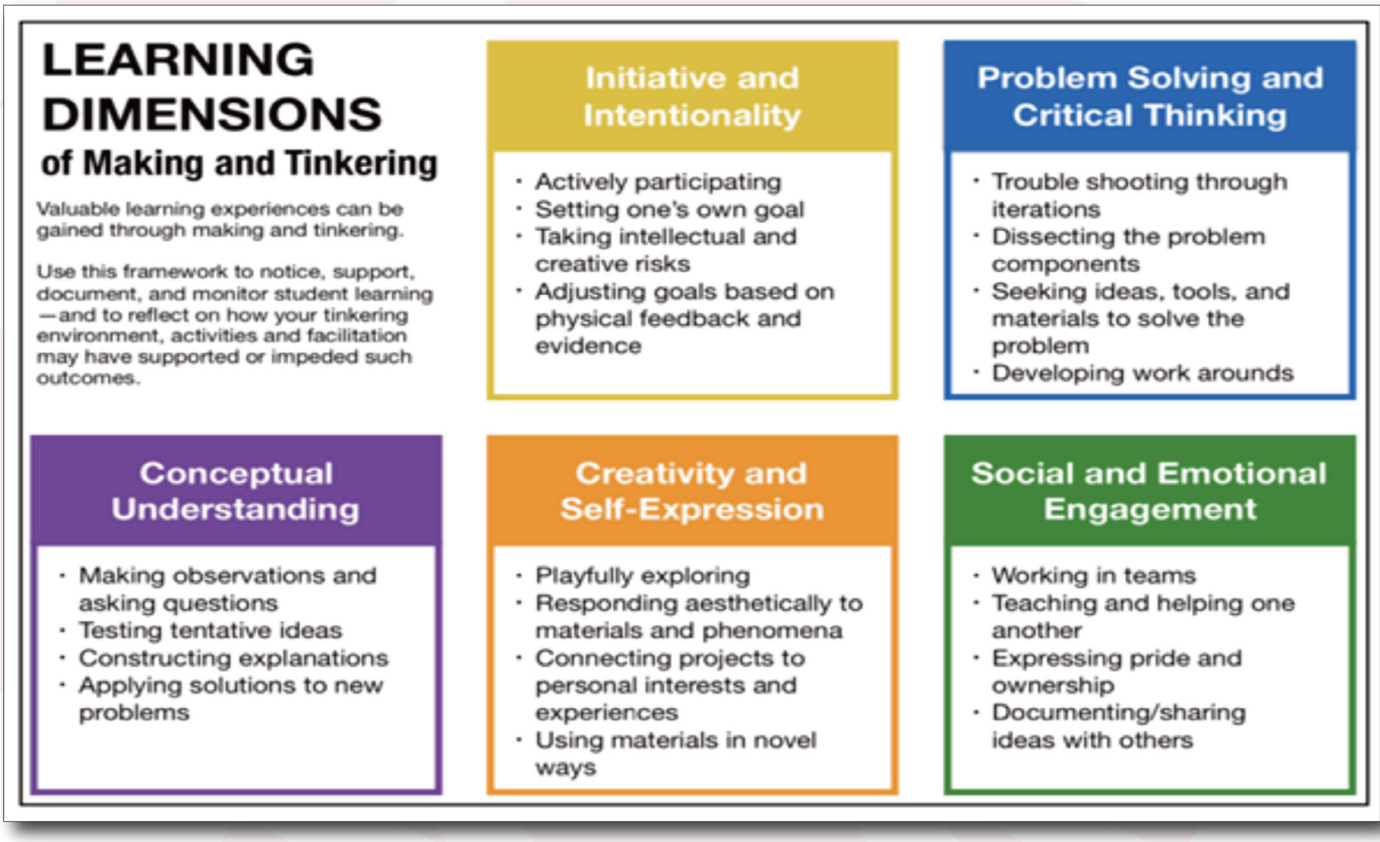


Figure 2. Learning dimensions of an embodied approach to STEM education.
Learning dimensions of an embodied approach to STEM education, © 2020 Bevan, Ryoo, Vanderwerff, Wilkinson & Petrich, reproduced under Creative Commons Attribution License (CC BY) (Bevan *et al*, 2020, p.4).

Method and data collection

To ensure that this study was conducted in an ethical manner, I made sure that all stakeholders were aware of the research objective and given opportunities to ask questions. I sought ethical approval from King's College University; this study was the dissertation module for my Master's degree.

Fifteen pupils aged 11-12 years returned the permission forms; hence, this was the size of the sample group. I recorded my data from April to June, spanning a school term. The pupils planted seeds from an organic seed library, which included runner beans, peas, tomatoes and other root vegetables. The pupils also made structures to support their plants and investigated factors that affect the yield of their crops. More specifically, plants were placed under different conditions and the yield recorded. For example, some were in raised beds, some were placed under a cloche (polytunnel) or in plant pots, with some being planted in direct sunlight and others in more sheltered spots. These data were shared with an external STEM partner who used the figures to calculate the carbon footprint of the pupils' produce; pupils were then able to make comparisons with fruit and vegetables that they buy from the supermarket.

For this project, I gathered empirical data using a reflective ethnographic journal along with a focus group meeting at the end of the project. This triangulation of qualitative data allowed for a deeper understanding of the impact that the intervention had on the pupils; I was able to cross-reference my perspectives with those of the pupils and make new discoveries from the focus group.

Notes were recorded each week and set out chronologically; they contained photos and brief descriptions of my observations in each session. The notes began as general observations and became more focused over time. For example, I would set up an activity with the learning dimensions (Figure 2) in mind and document evidence of pupils displaying those skills. This helped to keep the sessions focused and allowed me to collect data that could suggest pupils engaging in a STEM-focused EE.

Findings

The data gathered showed that pupils were developing an appreciation for the school environment. Additionally, the learning dimensions (Figure 2), such as displaying social and emotional engagement, were shown in this intervention. It was apparent during the seven weeks that the pupils could use the STEM disciplines to make structures to support their plants to grow. Once they could see how the pea plants were supported, they applied this to all other plants that looked as if they would fall, such as tomatoes and runner beans. Through iteration, they could select tools that were needed to carry out tasks without seeking guidance from me.

This intervention found that an embodied approach is a complementary way of learning that could be used in conjunction with formal education activities. For example, during the focus group discussion, pupils reported that learning whilst in the garden helped them gain a better understanding about what they were asked to do than merely writing notes in their books. The concept of cognition being situated is well researched (Wilson, 2002). Dewey (Bodzin *et al,* 2010) advocates that embodied learning should be with purpose, and the purpose here, as the pupils describe it, was to allow them to act in line with their environmental concerns. For example, during the focus group, pupils explained that they had chosen to attend the club because they wanted to learn how to grow their own food and be self-sufficient. Pupils growing their own vegetables, saving the seeds, and returning them to the library can be viewed as acts in line with global issue solutions: food shortages for a growing population. Further, by pitching global issues at a local level – that of being self-sufficient in vegetables – allowed pupils to take ownership of their actions and contribute to addressing environmental issues in ways that were feasible for them. For example, the pupils enjoyed sharing their crops with the Design and Technology department, as well as taking some of their produce home. This allowed pupils to see that what they were doing was having a direct impact: they enjoyed being part of a positive drive to reduce the carbon footprint of the food that they consume.

The focus group responses as to why they continued to attend the club were that they had developed an affective interest in environmental issues, and that the activities were motivating and helping them to learn. For example, they expressed their desire to learn new skills to *'save the planet'* and, more prosaically, they liked getting muddy. The focus groups also stated that they were applying the skills they had learned in the club to their communities, for example, in their parents' gardens. This was encouraging, as these acts can be viewed as promoting pro-environmental behaviour such as an awareness of their local environment and acting to preserve it. They were also promoting the club and generating interest amongst their peers, and had encouraged others to join in.

From my perspective, I found that an embodied approach to EE was impactful and especially effective for pupils aged 11-12 years. The pupils were also developing their STEM skills and their agency. For example, it was evident that, to begin with, they were apprehensive and sought guidance from me each time that they were assigned a task. Over the course of the term, pupils began to ask me if they could lead on a job and took ownership of their learning: they wanted to test their ideas, they sought specific tools, and they used their initiative in nurturing their plants. They enjoyed working as a team and assigned jobs to each other, with a shared goal of providing suitable conditions for their crops. They were also observed mentoring new recruits, thus demonstrating to me that they had gained new knowledge and skills and were able to convey them to others.

Figure 3. Pupils growing plants from organic seeds.

Figure 4. Pupils putting their plants into raised beds.

Figure 5. Peas growing around the structures that pupils made.

What was apparent through this intervention was the building of pupils' mindsets to engage in activities that had a purpose and meaning; they came along to the club as they wanted to *'do their bit'* to help the environment. They displayed cognitive, social and emotional engagement in environmental issues and conceptual understanding, hence reinforcing the ideas of hands-on and heads-on learning that is guided by the heart.

Pupils arrived with great enthusiasm, and I was able to nurture this to expand their environmental competencies. To help me see the relevance of my findings, I turned to Birmingham and Calabrese's (2014) study, in which pupils put on a carnival to help them understand green energies.

These authors reported that pupils who are traditionally excluded from science learning were given a voice and felt that they could participate. Further, the authors argued that connecting the mind and the body, by contextualising the science content that pupils could then physically use, helped provide meaning to the scientific knowledge. The data from my intervention suggest a similar conclusion. By providing an opportunity to develop skills, environmental awareness and agency, pupils were beginning to see that their voices were having a positive impact on the school. The club situated the global, abstract idea of reducing one's carbon footprint into a context that pupils could not only understand, but also one in which they felt that they could actively participate. Finally, the pupils reported better epistemic returns (building knowledge) when the learning was contextualised into something that was meaningful to them. That is, enabling pupils to pursue their interests in the environment helped them to see how STEM can be part of their lives, thus encouraging them to develop their skills.

Conclusion

My objective was to understand the impact of an embodied approach implemented within a STEM-focused environmental lunchtime club. The findings indicate that an embodied approach was impactful and that pupils exhibited pro-environmental attitudes and behaviours as a result of their participation in the club. Data collected at the end of the term indicated that participating pupils demonstrated many of the competencies outlined by Bevan *et al* (2020), such as teamwork and application of knowledge (Figure 2). The results from this study found that allowing pupils to see a broader view of what STEM is helped them to engage with STEM and foster environmental attitudes and agency. The adoption of a head, hands and heart pedagogy, where pupils were encouraged to develop their skills and not just focus on abstract knowledge, helped pupils to have a better understanding of tasks in which they were engaging.

The literature highlighted the limited research on the development of pupils' pro-environmental behaviours and a need to understand the pedagogies that teachers deploy to encourage engagement in EE. Here, I have offered my perspective and have suggested a way forward to help shape pupils' environmental attitudes. This small-scale study reports the perspectives of both the researcher and the pupils involved. As I work at the school where the data were collected, I am aware that the findings are situated within this school's context and may not be transferable to other settings. However, I hope that these findings demonstrate how an embodied cognition approach can be a useful vehicle for delivering a STEM-focused environmental education that could, potentially, help pupils to see how STEM connects to their lives. That is, schools could encourage pupils to identify local environmental concerns that they feel connect to their lives and with which they could engage with hands, head and heart. From this, schools could support pupils to find small-scale solutions that could have an impact, thus promoting a local and contextualised approach to global environmental issues. The framework from Bevan *et al* (2020) (Figure 2) would provide the academic justification for this project, as pupils will be observed developing their skills specifically related to STEM.

Lastly, the literature acknowledges the need to challenge dominant views of what STEM is and widen participation from some demographic groups that feel excluded from STEM. I believe that a STEM-focused environmental club, which employs the pedagogical approach of embodied cognition, can be seen as one way to channel pupils' affective interests in the environment, successfully motivating them to learn. The greater hope here is that pupils can leave school with the skills to contribute to and participate in society as environmentally aware and pro-active citizens.

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Can a science storybook enhance children's science vocabulary and understanding?

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● Jo Guillon ● Chris Wemyss

Abstract

Our experience in the classroom and in previous projects led us to consider whether a specially created picture book could stimulate discussion and learning about a topic such as gravity. Children's use of vocabulary was considered in Year 3 (age 7-8) classes in three schools in Stoke-on-Trent in England. A comparison was made between use of a factsheet and a storybook as a teaching stimulus.
The study found that children who had discussed the storybook rather than the factsheet used scientific vocabulary accurately and meaningfully more often in their explanations.

Keywords: Picture books, gravity, vocabulary, story

Introduction: The power of stories

From our experiences as teachers and trainers, we have found that stories are very engaging. We tell stories in assembly and two hundred children fall silent, eyes fixed on the storyteller. Two hundred faces react as the bird dies or the treasure is found. In training sessions full of teachers, who are constantly multi-tasking, the diaries are closed, their phones tucked away, and their bodies relax when told a story. There are important cognitive consequences of using the story format. Psychologists have referred to stories as 'psychologically privileged', meaning that our minds treat stories differently from other types of material (Willingham, 2011). People can find the story format engaging, easy to understand and easy to remember.

Bower (1978) says that our minds pay attention to stories in a different way from information presented in the absence of an emotional narrative. The emotional connection is what makes stories different from non-narrative texts. He says that we are hard-wired to engage with stories and our minds give psychological privilege to information presented in this form. Stories help us to empathise with others. Empathy with others is essential when maintaining one's place in a social group. Therefore, listening to stories, engaging with and empathising with others, may have been subject to natural selection. People who engage with stories remain in the social group, which is safer than living alone, so Bower suggests that it may be a trait that is positively selected in the evolutionary process.

Our journey into writing science picture books began when we were teaching the topic of evolution. Evolution is a complex theory that is often distilled into an overly simplistic definition: animals adapt to a changed environment, e.g. the brown bears that went north in search of food 'became' polar bears. Children whom one of the authors encountered believed that this meant that the brown bears stopped at the edge of the snow, aged and their fur went white (as human hair does) and that this white hair 'stuck' for all future generations. When children do not have all the facts, they tend to fill in the gaps with their own ideas, which are often incomplete ideas (preconceptions) or more fully developed incorrect ideas (misconceptions). We wanted to bring these preconceptions (and misconceptions) to light in the classroom and use stories to provoke discussion.

Teaching approaches that focus on purposeful 'dialogic' classroom interactions (Alexander, 2005) highlight the need for open discussion, for teachers to be prepared to allow children to question evidence. Mercer *et al* (2004), for example, have shown that teaching interventions designed to promote 'exploratory' talk can enhance children's thinking, reasoning and understanding in science. A move towards more dialogic practice can be facilitated by the use of activities that enable groups of children to engage in discussion autonomously without constant intervention (Simon & Maloney, 2007).

Jules Pottle reflects on previous development of stories for science

In 2018, Rufus Cooper (R. Thomas) and I began toying with the idea of writing a picture book that demonstrated natural selection. We aimed to write a science-based book with sufficient ambiguity to promote dialogic talk in the classroom, where children could work through their ideas and also allow the teacher to hear their changing ideas as they reconsidered what others had said. I had previously found that the more ambiguous the evidence, the better the conversation, as they would all fix on different bits of evidence and argue it out from there: in this way, explicitly discussing their ideas including any misconceptions, leading towards the development of more scientific conceptions. We trialled a prototype in schools to see if we had hit the mark in terms of the level of ambiguity (enough to create discussion, but not too much to cause confusion), the level of vocabulary and the emotional hooks in the story. Where it was too open, we added pages of extra pictures to clarify the story, together with teacher notes on possible pre/misconceptions. This led us to the creation of *The Molliebird* (Pottle & Thomas, 2018).

When trialling this text, we considered: Can the children *learn* a concept by reading and discussing a story? This informal research was challenging to analyse, as the children's answers were so varied. The teachers' answers were much clearer, however, with teachers reporting that the children talked more and were more engaged in the lesson than in other science lessons.

Our next project was with teachers in Stoke (through Science Across the City), working with Year 2 (age 6-7) classes on classification. We wrote a story called *Jasper the Spider* (Pottle & Thomas, 2019) and, in partnership with the teachers, devised some techniques to gather data on the following questions: Do children learn and retain information presented in a fictional story as well as information presented as a factsheet? These included a 'before and after' quiz, with questions that showed their understanding of the differences between spiders and insects. It also included some forest school/art activities, where the children constructed and described their own models of spiders and insects. We found that, generally, the learning appeared to be similar – both groups learned that spiders were not insects (Pottle, 2021). Teachers also reported that the children using the book were much more engaged with the topic: they talked about spiders in the classroom spontaneously, they brought in research that they had done at home (on which spiders eat their own mates), and they used the vocabulary learned from the book, correctly and with purpose, to talk about insects and spiders encountered in the rest of the topic and beyond.

We found with *The Molliebird* and *Jasper the Spider* that these stories stimulated engagement and discussion (see Box 1). For this next study, our research question was designed to consider any improvement in vocabulary more closely:

Do children accurately use scientific vocabulary more after reading a science picture book or after reading a fact file on the same topic? (NB: In both cases, the teacher read the text out loud).

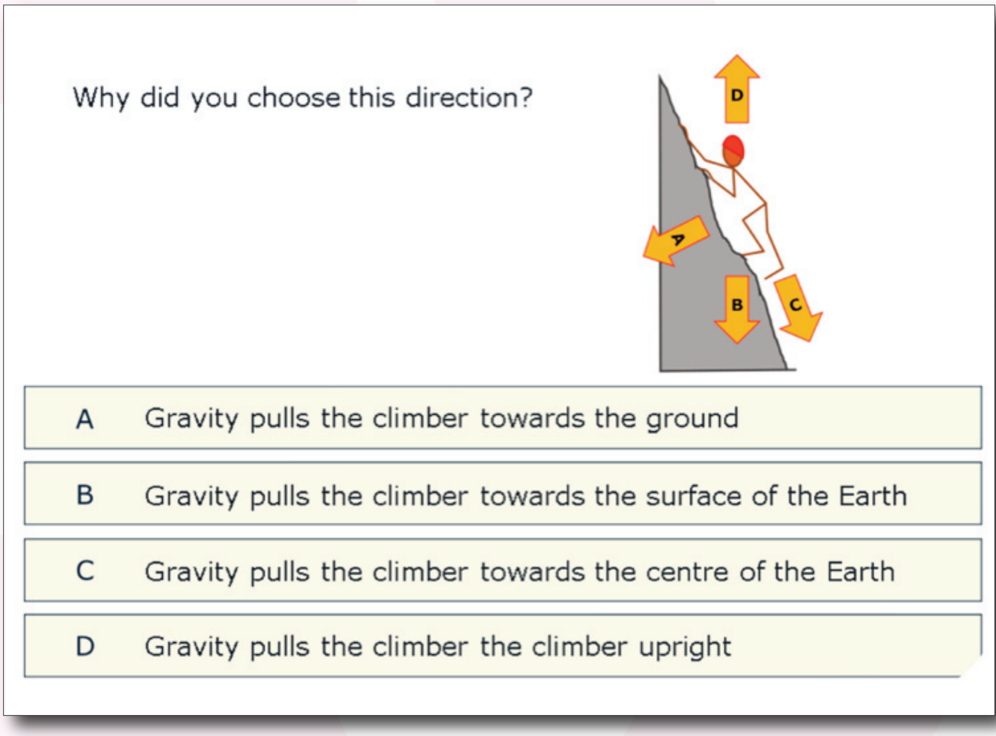
In order to answer this question, we created a new science picture book on the topic of gravity.

Why did we write a book on gravity?

In 2021, the data available to secondary schools at transition were limited due to the COVID-19 pandemic pause on reportable Key Stage 2 (KS2, ages 7-11) attainment data. As an interim solution across all primary schools in Stoke-on-Trent, every Year 6 (age 10-11) child completed diagnostic assessments for English, mathematics and science. The pupil question data were analysed centrally within the local authority, to inform secondary schools of curriculum gaps for their upcoming Year 7 (ages 11-12).

Furthermore, having question data from over 3000 children from 70 schools enabled an understanding of themes that were causing the greatest challenge in primary science (Price, 2021). The diagnostic assessment was built from BEST questions (see BEST weblink below) that were relevant to the KS2 Teacher Assessment Framework (STA, 2018). More children gave incorrect responses to the question about gravity than to any other, with only 32% of respondents stating that gravity pulls the climber towards the centre of the Earth (Figure 1). Most children recognised a link between gravity and the Earth, but there was confusion about the ground. 32% selected 'Gravity pulls a climber to the ground', and 28% selected 'towards the surface'. Primary teachers in the city reflected upon the findings and pondered whether their teaching approaches were resulting in simple vocabulary recall rather than development of conceptual understanding. This resulted in a desire to find a new strategy that would be more supportive of children's learning in the future.

Figure 1. Diagnostic question for gravity from BEST.

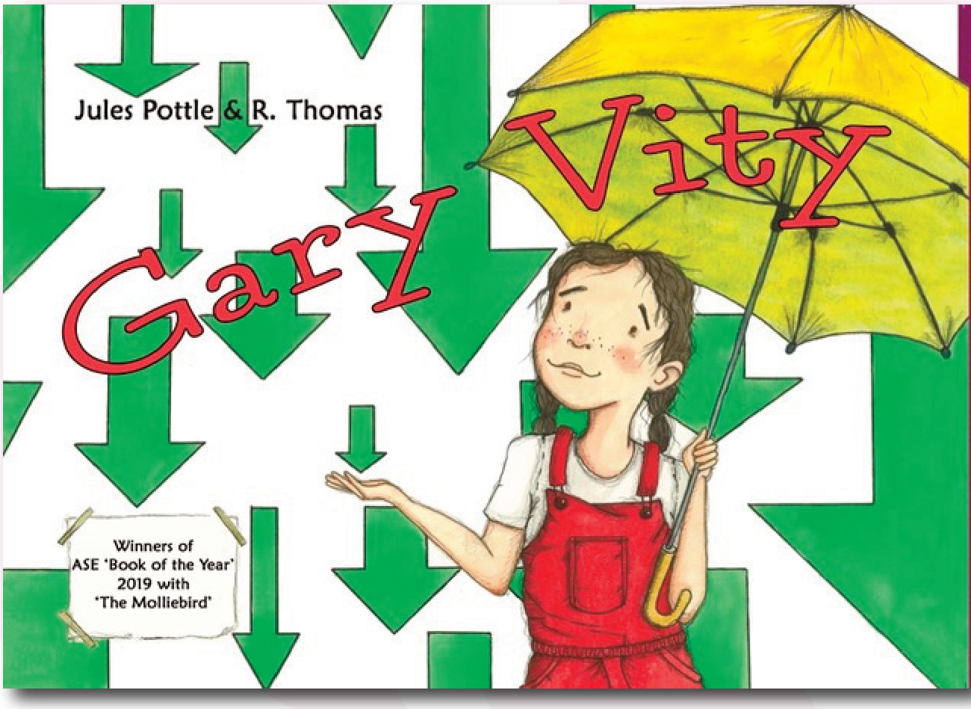


Professional learning model

Having recognised a city-wide issue regarding the understanding of gravity, a practitioner research forum was set up. Jules Pottle was invited to lead on the development of the new resource in response to the identified learning gap, and teachers reviewed, tweaked and trialled the resource as it emerged from concept to final publication reality. This peer joint-practice model for professional learning is sustained, collaborative across schools and enables authentic enquiry, with evidence of impact on pupil outcomes at the heart of the professional dialogue (DfE, 2016; Earley & Porritt, 2010). Engagement in this CPD approach was reported by those involved to have a lasting effect beyond the publication of the book, with other teaching approaches now more likely to be justified and evaluated rather than selected simply for novelty.

Method

The Year 3 classes from three schools from across the city took part in this research project. We were interested to see if class discussions and vocabulary use differed depending on the stimulus resource used for teaching. The stimulus resource was either a factsheet or a story, the latter being a trial PowerPoint version of the new story of the character 'Gary Vity', which was read to the children.



To compare responses to the two teaching methods, two comparative groups were set up in each of the Year 3 classes. We selected a cross-section of the class to include boys and girls and all abilities with respect to science. Both groups were taught about gravity, but used either a factsheet or the story of Gary Vity. A cross-section of children were selected by the class teacher to create groups with mixed prior attainment (low attainment, middle attainment and higher attainment). The research project was discussed with the children and parents, to ensure informed consent. Data were stored securely on the school system and anonymised before sharing beyond the school.

The children were filmed before and after learning about gravity using the book or the factsheet. Both groups were asked to explain gravity through two different scenarios:

- *Can you explain scientifically what will happen when a pencil is dropped on the floor?*
- *Can you explain scientifically what will happen when a toy car goes down a ramp?*

The class teacher watched the video recordings back and analysed vocabulary use by counting the frequency of accurately-used specific scientific vocabulary.

Results

After the group discussions, the following vocabulary use was tallied from the video recordings: *gravity, push/pull, pull to centre of Earth*, *speed/power*, *straight down* and *force.* A tally (x) was recorded for each time that a word was used by each child (xx = twice) in the group table (e.g. Figures 2 and 3). (HA = high attainment in science, MA = Middle attainment in science, LA = Low attainment in science.) We only counted words that the children used. We did not pre-select the vocabulary.

Figure 2. Vocabulary use in factsheet group.

Information sheet group

Child	Gravity correctly	Gravity incorrectly	Push and pull correctly	Push and pull incorrectly	Pull down to centre of earth correctly	Pull down to centre of earth incorrectly	Speed and Power used correctly	Speed and Power used incorrectly	Straight Down correctly	Straight Down Incorrectly (side to side)	Force correctly
HA Boy	xx		Xxx		X Plummeted down	X			xx		xxx
HA Girl	xx		xxx		x						
MA Boy	xxx		x		x				xx		x
MA Girl	xxxx								x		x
MA Boy	xxx		xx				xx		xx		
MA Girl	xxx						x		xx		x
LA Boy	xxx		x		xxx			x			x
LA Girl	xxx		xx								x

Figure 3. Vocabulary use in story group.

Story Group/PPT

Child	Gravity correctly	Gravity incorrectly	Push and pull correctly	Push and pull incorrectly	Pull down to centre of earth correctly	Pull down to centre of earth incorrectly	Speed and Power used correctly	Speed and Power used incorrectly	Straight Down correctly	Straight Down Incorrectly (side to side)	Force correctly
HA Boy	Xxxx invisible		xxx		Xx core		xxx		xxx		xxx
HA Girl	Xxxx Invisible force		xxx		Xxx Middle of earth		Xxx Aerodyna mics xx		xxx		xx
MA Boy	x xx		x						x		
MA Girl	xxxx		x						x		
MA Boy	xxx		x								x
MA Girl	xxx		xx		xx		xx		xxx		xx
LA Boy	xx	xx	x	xx					xxx	x	xx
LA Girl		x	x	xx							

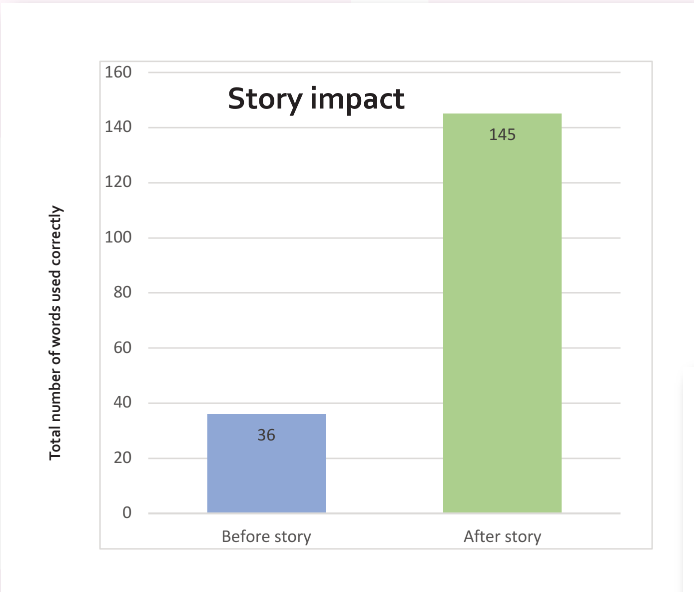
Figure 3 contd.. Vocabulary use in story group.

MA girl talked extensively about the steep slope making the car go faster. The force at the top will make it go slower and as it gets to the bottom of the slope it goes faster. It stops at the carpet because of gravity. It is mixed speed.

HA had a similar discussion but used the word 'gravity' in context more frequently. HA girl also talked about aerodynamics and could explain it. ("A shape of an object that can affect how something goes through the air – wind too")

When comparing the impact of the non-fiction sheet versus the story, the results show that the story had a greater impact on the vocabulary that the children were using. This can be seen in the greater number of Xs in Figure 3 than in Figure 2. The pupils who had read the story showed improvements in the correct use of scientific vocabulary linked to gravity. While the children who read the factsheet did make improvements, these were not as large as in those who had read the Gary Vity story. Those who read the story used 109 correct words, compared to 44 words for those who read the factsheet (Figure 4).

Figure 4. Bar charts to compare vocabulary use in the factsheet and story groups.

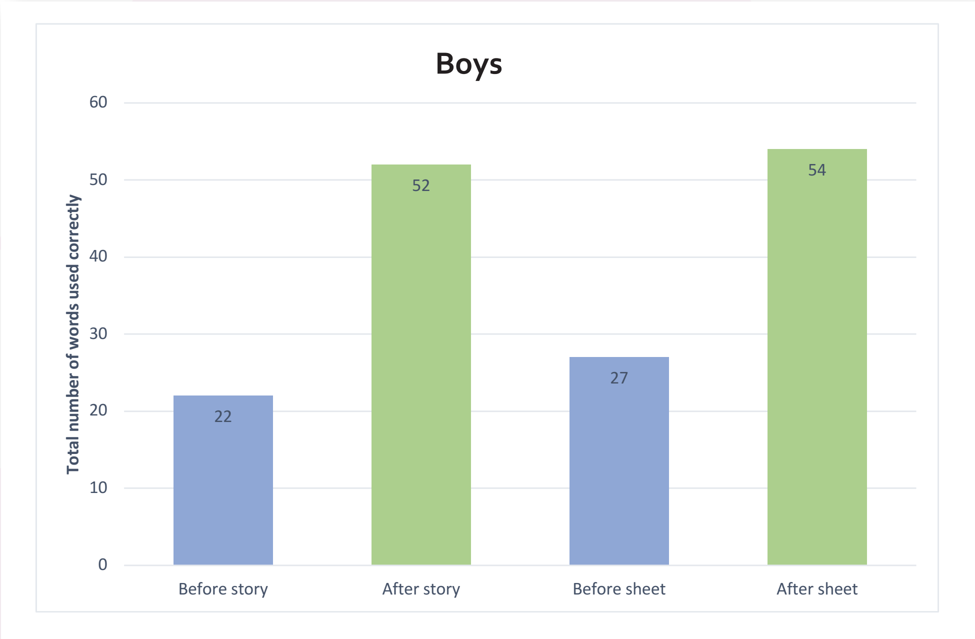


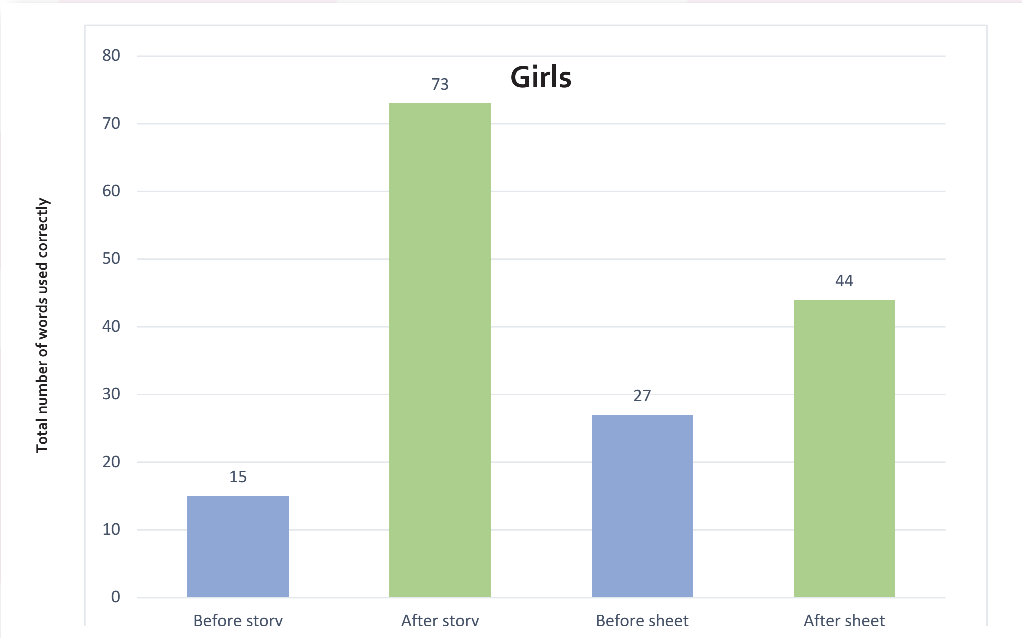
Gender comparison

The results show an interesting comparison between the effects of the story versus the factsheet between boys and girls. Whilst boys have shown a good amount of improvement using both the story and the non-fiction sheet, the girls' data reveal something interesting: girls who read the story made a greater improvement in the use of their scientific vocabulary compared to the girls who read the factsheet text (Figure 5).

This led us to wonder if this significant finding was due to Gary Vity having a female main character, or whether the fictional story appealed more to girls.

Figure 5. Bar charts to compare vocabulary use for girls and boys in the story group.

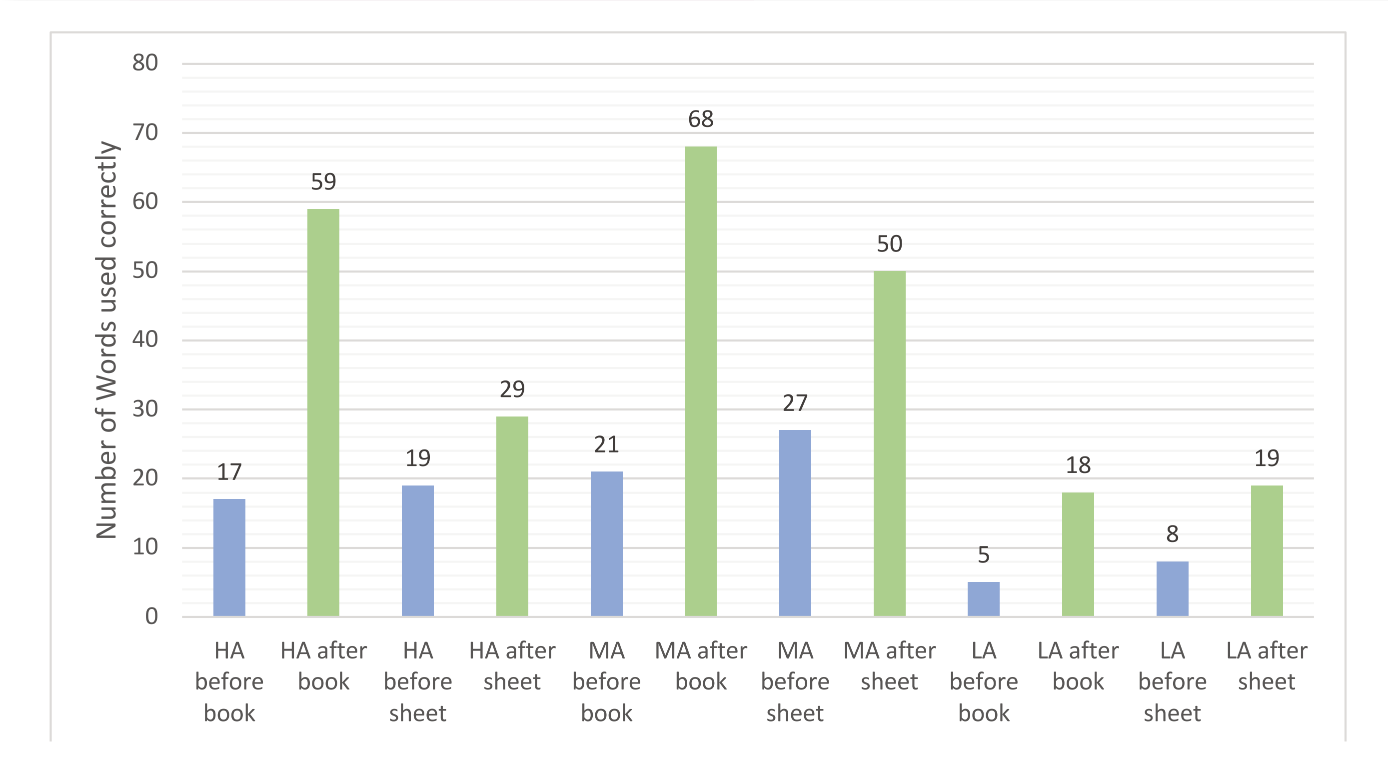




Prior attainment comparison

We also broke down the data to see whether prior attainment had an effect on the data. In the high and middle attaining groups, there was a clear improvement when reading the story: the group with higher prior attainment used the correct vocabulary 30 more times, whilst for those with middle prior attainment, vocabulary was used 18 more times than when reading the factsheet.

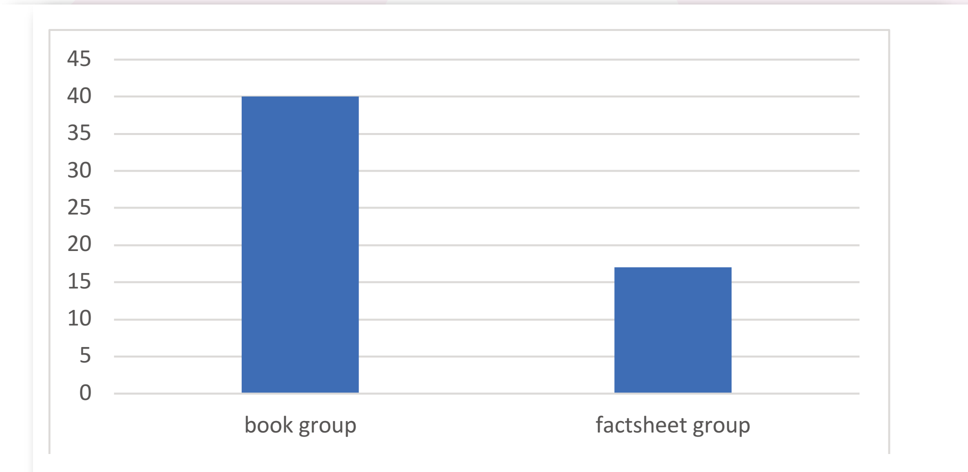
Figure 6. Graph to compare vocabulary use for high, middle and lower prior attainers in the story group.



Spontaneous mentions of gravity in the classroom

After the first session, where one group read the story and one group used the factsheet, both the teachers and teaching assistants in the classroom logged when gravity was discussed, spontaneously, by the children in the classroom (i.e not introduced by the teacher). This was mostly outside of science lesson time. The data were collected on a tally chart and, where possible, quotes were also noted down. From the average of the three schools, the book appeared to have had a stronger impact on the children compared to the factsheets.

Figure 7. Number of spontaneous mentions of gravity in later class time.



On average, the book was mentioned 14 times, compared to 4 times by the factsheet group. These mentions were not purely about the book, but referencing gravity correctly in everyday scenarios and lessons outside of science. References to gravity were varied and often playful: a pencil fell on the floor and a child said, 'Gravity!' and, when a pencil pot was knocked over, a child joked that it was 'Gary Vity up to no good!'.

The story had a big impact on the children and they were talking about gravity long after the those from the factsheet group. Anecdotal evidence from the factsheet group included comments that the factsheets were 'dull compared to the book' and, when they had read the book, 'the factsheets were boring'. The factsheets themselves were colourful and informative, but children repeating the poem from the story and the characters' comments had a bigger impact. Forces are difficult concepts for children to understand, but the story helped the children to retain and show a deeper understanding of gravity.

Conclusion and further questions

Returning to our research question:

Do children accurately use scientific vocabulary more after reading a science picture book or after reading a fact file on the same topic?

From this limited study, we found the answer in this context to be:

Children used more scientific vocabulary after reading a science picture book and this was more pronounced in the girls' usage compared to the boys'.

This is, of course, a very small study. It would need to be repeated on a much larger scale, with careful consideration of allocation to groupings and reading materials, etc., to increase confidence in the results. However, from our experience, we have found that story raises engagement in the topic; it acts as an effective prompt to increase the amount of discussion and often provides the link that helps children to remember their learning years later. Stories can often be more easily remembered. Learning associated with that story may be easily recalled too. It is as if the story becomes a peg upon which to hang that learning within our memories.

This study also raises other interesting questions. Do girls engage with the book because the protagonist and the wise helper are both female, or is it simply the narrative form that engages girls more? If we made another book with the same story but a male protagonist and a male wise helper, would it still have a greater effect on girls? Furthermore, if we put a child of colour at the centre of a story, would it have a positive effect on children of the race portrayed in the book? Stories are certainly powerful tools in education and have a strong link to long-term memory. If we can place familiar figures in the centre of emotive stories that also engage us in the science, then we may have the perfect way to help children to see themselves in scientific careers at the same time as giving them the vocabulary that they need to talk about science more confidently.

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Using Explorify for retrieval practice: consolidating prior learning and supporting new learning

● Rebecca Ellis ● Jo Moore

Abstract

This article draws on research and ideas from cognitive psychology and cognitive science and explores a rationale for using Explorify activities to support the building of long-term memory. It describes the outcomes and recommendations from a small trial that explored the extent to which Explorify activities, which promote science discussion and the development of higher order thinking skills, can also be used effectively to support retrieval practice. Working with a group of seven teachers over a six-week period, the Explorify team at the Primary Science Teaching Trust (PSTT) curated and trialled a set of activities relating to the science of teeth, digestion and food chains. The participating teachers were given guidance about which Explorify activities could be used for the engagement, elicitation and introduction of ideas, and which provided opportunities for children to practise retrieving their knowledge. The teachers reported that incorporating Explorify activities in these different ways had a positive impact on children's recall of their learning. Their various experiences are shared and key factors for success are drawn from these. Finally, guidance is offered about how Explorify activities can be used more widely to support the development of long-term memory.

Keywords: Long-term memory, retrieval practice, Explorify, higher order thinking, discussion

Introduction

As teachers, we have all experienced blank looks from children when we mention something in a science lesson that we know they have been taught. This issue has also been highlighted in the Ofsted (2023) report *Finding the optimum*, where it was noted that *'Across primary and secondary schools, some pupils did not have sufficient opportunities to practise and consolidate what they learned before moving on to new content. This meant they did not remember key content taught previously'* (Main findings, Ofsted, 2023).

What can we do better to support the development of long-term memory in science? Earle and McMahon (2022) note that retrieval practice is one of the teaching and learning strategies to build long-term memory that is supported by cognitive science research. Coe (2019) provides an overview of this research; however, he points out that '*there is still a question mark about how effectively it can be incorporated by teachers into lessons*' (paragraph 1).

If we agree with Harlen (2010) that '*The goal of science education is not knowledge of a body of facts and theories but a progression towards key ideas which enable understanding of events and phenomena of relevance to students' lives*' (p.2), then fact-based quizzing should not be the only method that we use for retrieval practice. Indeed, Agarwal (2019) found that '*fact-based retrieval practice only increased fact learning, whereas higher order and mixed retrieval practice increased higher order learning*' (p.17). The results indicate that to consolidate learning for deeper knowledge, we need to provide opportunities for students to analyse and evaluate.

The Wellcome Trust report (CFE research, 2019) noted that over half of the primary-aged classes in their survey had under two hours of science curriculum time allocated per week. With this constraint on time, it is difficult for teachers to justify spending time on retrieval practice when they are already finding that they don't have enough time to cover the science curriculum. The development of a time-efficient method for teachers to provide retrieval practice opportunities, where children can elaborate, reflect and be creative, could enable Harlen's vision of networks of connected ideas in science: *'the "small" ideas developed from studying particular topics build to form gradually "bigger" ideas'* (Harlen, 2010, p.11).

Rationale: why consider Explorify for retrieval practice?

The online resource Explorify (Figure 1) is designed to stimulate curiosity, discussion and debate. The activities were based on the research findings of the *Thinking, Doing, Talking Science* project (see weblink in reference list), which encourages children to use their higher order thinking skills: applying their knowledge in unfamiliar contexts requires children to evaluate, reflect and reason (EEF, 2016). External evaluations of Explorify (CFE Research, 2019, 2020) showed that it encouraged higher levels of participation in science discussions, with many teachers reporting increases in children's confidence to express their ideas in science.

When children are actively participating in science discussions, this gives teachers rich opportunities to make formative assessments. Using Explorify to elicit pupils' prior knowledge is recommended as an effective device for responsive teaching in the Teacher Assessment in Primary Science (TAPS) Pyramid Tool (see weblink in reference list), as it enables the teacher to plan an appropriate sequence of learning. It is also possible that, by providing a safe space for deep discussion, Explorify activities could offer opportunities for retrieval practice and review of prior learning. This small study set out to explore this possibility.

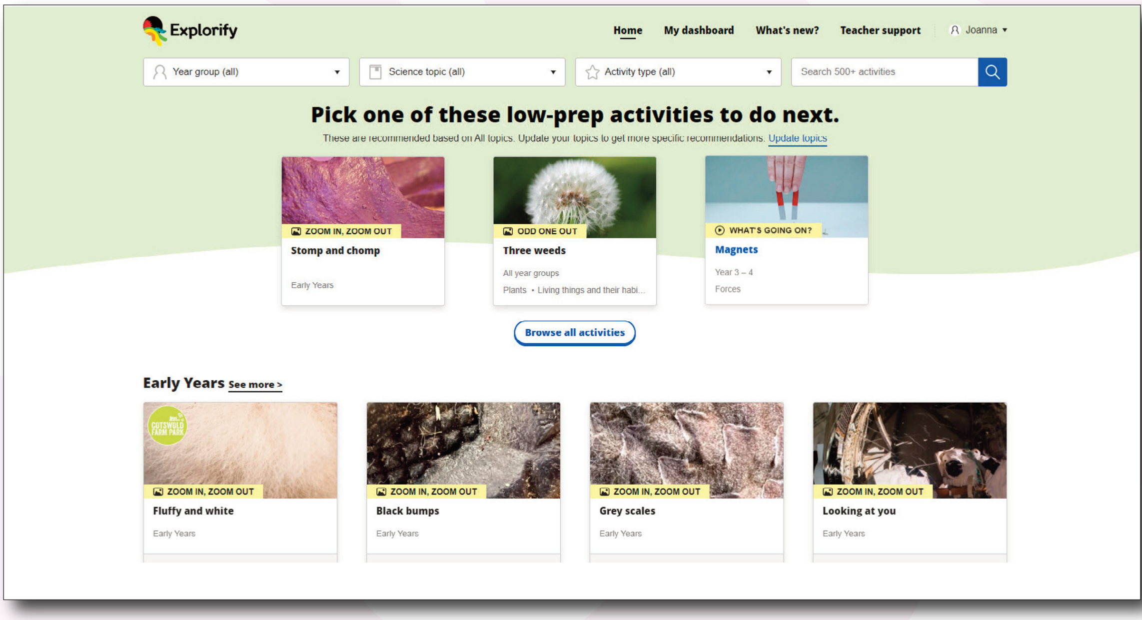


Figure 1. The web page for Explorify offers a completely free digital resource for teaching primary science: https://explorify.uk/

Applying cognitive psychology ideas to primary science

Shimamura's (2018) MARGE model suggests that important factors that promote the formation of long-term memories are **M**otivate, capture **A**ttention, **R**elate, **G**enerate and **E**valuate.

The Wellcome Trust (CFE Research, 2019, 2020) report that using Explorify positively affected children's **motivation** to learn by making science fun and engaging (Figure 2). The visuals, alongside the interactive nature of the activities, helped to capture and hold their **attention**.

Shimamura's third principle, **relate,** focuses on how *'learning is facilitated by finding similarities (comparing) and differences (contrasting) between new material and what you already know'* (p.23). Explorify's 'Odd One Out' activities clearly support this approach. By asking for similarities and differences between three images, they provide an opportunity for in-depth discussion and making connections between knowledge and ideas.

Shimamura explains: *'The generation effect is one of the most efficient ways of improving memory retention. When we **generate** information – such as telling someone about what we've heard or learned recently, we substantially improve our memory for that information'* (p.4). All Explorify activities are underpinned by partner/group talk where children talk about what they know and what they think. We suggest that this social construction of knowledge and opportunities for retelling supports the development of long-term memory, as well as children's science learning in general.

The final component, **evaluate**, requires higher order thinking. When using Explorify's 'Odd One Out' activities, after identifying similarities and differences, children are asked to use the differences to select their odd one out. The activities are designed so that there are good reasons for all the images to be selected. Because there is not only one correct answer, the stakes for children are lowered, increasing their **motivation** to participate.

Figure 2. Children need to be motivated and the activities must hold their attention.

McMahon *et al* (2021) have explored applying cognitive science principles to primary science teaching, and some of their conclusions about how to strengthen memory are pertinent to Explorify activities. They report that *'It seems that combining the two modes (speech and visuospatial) makes it easier to recall memories'* (p.9), which means that discussing pictures works well. The value of children thinking in science was also highlighted: *'We might think of retrieval practice as recapping or revisiting, but the crucial factor is that it is the pupil that does this and puts in the effort to retrieve the memory. It is not the same as the teacher repeating content or a pupil simply looking something up'* (p.7). In addition, they pointed out that children applying their knowledge in new contexts has value: *'There is something about the effort involved in retrieving the memory that strengthens it. Teachers can aim to provide many different contexts for retrieving memories to develop a range of connections with that memory, making it more useful and more meaningful'* (p.7). Explorify provides an easy way for teachers to deliver a variety of well thought-out contexts that are relevant to children's own lives.

Method to evaluate the impact of Explorify for retrieval practice

To assess the impact of the purposeful use of Explorify for retrieval practice, a group of teachers from across England, who were teaching the science unit 'Teeth, digestion and food chains' with children aged 8-9 years, volunteered to participate in a small-scale trial. They agreed to use at least 15 Explorify activities, eight of which were from a specified list, over six weeks in the autumn term 2022. The guide (Figure 3) allowed a flexible approach so that the Explorify activities could be fitted around the schools' existing schemes of work. Teachers who wanted support with subject knowledge, or guidance about activity ideas to underpin the key learning, were directed towards possible Explorify activities that provided help in the 'Background science' and 'Take it further' sections. To support the trial, thirteen new Explorify activities (mostly 'Odd One Out' activities) were designed and published.

Figure 3: Part of the guide for participating teachers (available on Explorify: https://explorify.uk/teacher-support/science-teaching-support/developing-long-term-memory).

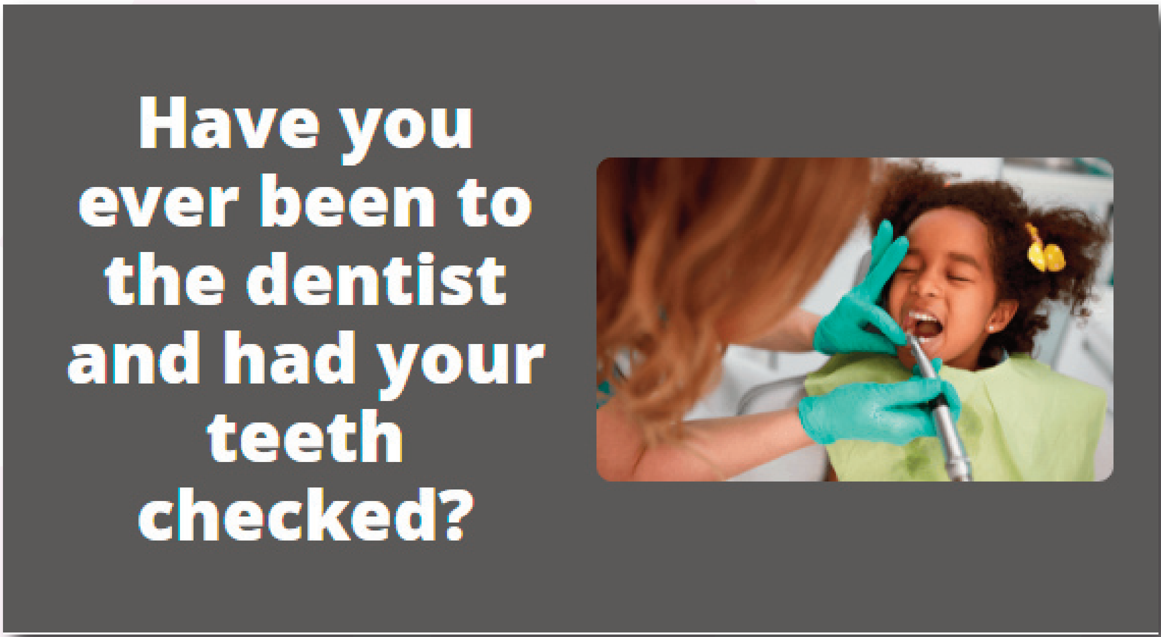
Explorify Guide: Improving long-term memory with embedded assessment and retrieval practice
Teeth, digestion and food chains

There is a guide to how to use this outline below the table.

Learning focus	Possible activities from Explorify (you can use your existing plans which cover the learning focus)	Elicit and engage	Deepening learning
Review previous learning	Assessment for learning techniques to help determine your starting point, generate displays of questions and review progress. You could include: Mind maps, vertical relay using body outlines, Explore, engage, extend activities, KWL grids. **Key questions:** *What do you already know about the digestive system?* *How should we care for our teeth?* *Can you sort these animals into carnivores, omnivores and herbivores?* *Can you complete a food chain?* *What's your favourite animal, is it a predator or prey (or both)?*	It takes more than guts Pearly tips Hot-steppers Say cheese Hunter and hunted	
Functions of different teeth	Big question Why do we have different teeth? Use the **activities in the Take it further and watch the videos.**	Have you ever been to the dentist and had your teeth checked?	**Bite, rip, mash** We had no teeth? You had teeth like a snake? Hidden away
Understanding tooth decay by carrying out an investigation	Use the **CIEC resources** recommended in **Take it further** of: What's going on? Disappearing eggshells	Sparkling smiles This is a mystery bag activity where you add objects linked to teeth hygiene.	What if toothbrushes didn't exist?
Plan and carry out a comparative test	Testing the impact of different drinks on our teeth. Disappearing eggshells has the		Healthy drinks

There was a clear distinction between the Explorify activities that could be used for the engagement, elicitation and introduction of ideas, and those that provided opportunities for children to practise retrieving their knowledge. Those in the first category supported Assessment for Learning (AfL), helping teachers to assess the children's knowledge and vocabulary, including what had been retained from previous science units (Figure 4).

Figure 4. An example of an Explorify activity suitable for engagement and elicitation of children's ideas.



It was suggested that the Explorify activities for retrieval practice could be used at a variety of times, including: at the beginning of the lesson after a new concept had been taught; later in the week; further into the unit; or even after the unit. Teachers could use them within their science lessons and/or whenever they had a spare 15 minutes during the school week.

The teachers were asked to complete a questionnaire at the end of the trial giving feedback on the impact that it had on their teaching and the children's learning. One of the questions that they were specifically asked was to compare the use of Explorify activities for retrieval practice with other strategies that they used.

Findings from the teacher trial

All the responding teachers agreed that increasing their use of Explorify had a positive effect on consolidating children's long-term memory. Even though all the teachers had already been using Explorify, 85% of them reported that participating in the trial had changed their practice. Teacher comments included:

'It has made me think more carefully about the activities I use and how effective they are in consolidating the facts.'

'I used them at more points within the unit of work and at different points within the lesson. In the past, I simply used them as discussion starters.'

'I now use it more as it is a good way to challenge/get children to start thinking and discussing.'

Teachers also valued that, because the Explorify activities only took 15 minutes, it helped deal with the challenge of the time constraints that they faced. The activities do not have to be done as part of the science lesson, but can be fitted in before lunch or at the end of the day, as well as during science lessons.

Common strategies that the teachers were often already using in the classroom to revisit and recap learning included questioning, discussion and information organisers. Less frequently, teachers also used quizzes, true/false statements or cloze texts. When asked to compare these strategies with using Explorify activities, teachers rated Explorify activities as either equally or more effective for building long-term memory.

Their comments provided further insights:

'It gives children a spark which then creates an interest and then the children remember more of their learning.'

'You delve deeper. The discussion allows a depth of knowledge to show.'

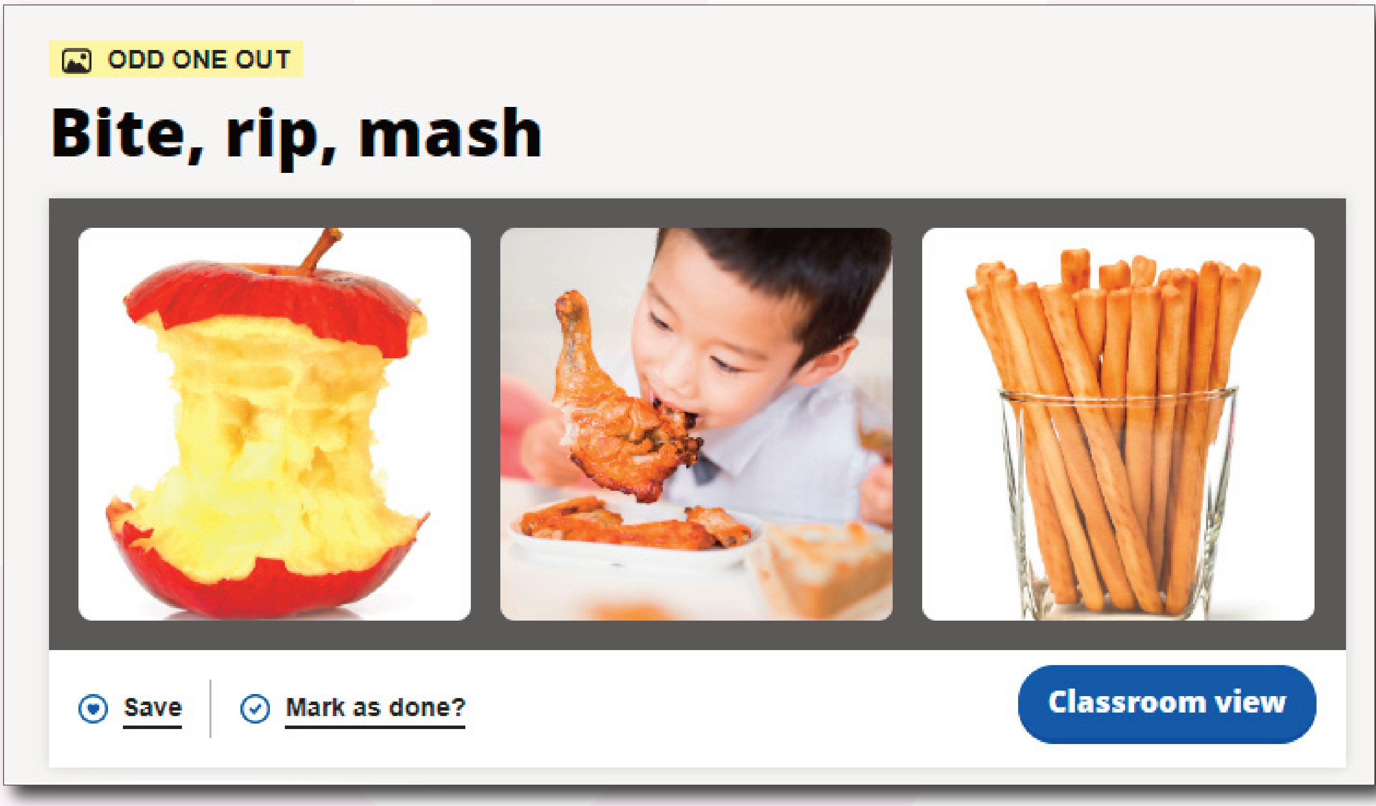
'The visual imagery is powerful and the lack of "words" makes it accessible to all.'

Which activities worked well for retrieval practice?

When asked to select the most useful activities for retrieval practice, a wide variety were mentioned. For example, 'Bite, rip, mash' (Figure 5) provoked this response:
'Children were discussing which type of teeth would be needed to eat the different foods…and also which groups of animals would eat them, herbivores, carnivores or omnivores.'

As anticipated, 'Odd One Out' activities in general were considered helpful:
'The odd one out activities really stuck in the children's mind as they helped to build knowledge, but the children were then also able to build on previous knowledge.'

Figure 5. An 'Odd One Out' activity that was created for retrieval practice.



'Hidden Depths', a 'Zoom In, Zoom Out' activity showing an X-ray of a child's jaw, was also identified as effective for consolidating children's knowledge about teeth. This unusual context '*hooked them straight away*' and stimulated rich discussion about the form and function of different tooth types. 'What if we had no teeth?' was another activity that *'really sparked a lot of conversation and discussion'* and got children thinking creatively, applying their knowledge of the functions of teeth as '*they discussed blending food, mushing it up or drinking through straws*'.

'Disappearing eggshells', a 'What's Going On?' video, models what happens when teeth come into contact with acid. Teachers explained that they were able to use it to provide scaffolding for children to design their own investigations: *'We tested the effect of different drinks'.* Links to real life were capitalised upon by asking children to give *'advice about what drinks a teacher should give to her child'*. Some teachers felt that this activity also helped consolidate children's understanding of tooth decay. One class conducted their investigations first and then *'used the activity to further explain the science behind it'.* Another teacher noted that *'the results of the experiment had been imprinted on their brains!'* These findings resonate with research by McMahon *et al* (2021), who describe how structured enquiry can provoke elaborations and stimulate children to ask meaningful questions.

Reflections on key factors to create activities suitable for retrieval practice

This trial only involved a small number of teachers and focused on one science unit, but it does suggest that Explorify-style activities can support teachers to deepen children's learning. If teachers want to select 'Odd One Out' activities, or make their own, to support retrieval practice across the science curriculum they need to ensure:

- that the images are relevant to the knowledge and understanding that you want the children to revisit and will stimulate recall;
- a low-stakes environment so that children can focus on their reasoning without fear of being wrong;
- that it is neither too obvious nor too hard for children to work out, and that it offers several reasons why each image could be the 'Odd One Out';
- that there is a new and interesting context;
- that there are opportunities to reinforce vocabulary; and
- that it is relevant to the real-world and/or their own experiences.

Ofsted (2023) states that *'In many schools, retrieval practice only went as far as asking pupils to remember facts in isolation, usually through short quizzes. It was rarely used to support pupils to develop interconnected knowledge, for example by asking them to compare their knowledge of related but different concepts'* (paragraph 111). Explorify activities encourage children to make connections between different areas of science precisely because of the quality and breadth of the discussion that they encourage.

There is a 30-minute professional development video (see reference list) on Explorify's website designed to introduce the approach to teachers and to make suggestions about how they can select Explorify activities to support deepening learning. Teachers have responded positively and requested similar guidance for other science topics. This is something that the Explorify team has added to their work programme.

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

Referencing examples:

Book

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

Chapter in book

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

Journal article

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

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