Embodied Learning for early and primary science: Key implications from the Move2Learn project

● Andrew Manches ● Euan Mitchell

Abstract

When teachers or children explain science ideas, they often gesture, typically with little awareness of doing so. Over the last twenty years, research has demonstrated the significance of these gestures in revealing the embodied nature of how we think, and the potential to encourage body-based experiences to support learning – Embodied Learning. Drawing upon research in this field, including the international Move2Learn project, which worked with children aged 3-8 in informal science centres, this paper presents three key implications of Embodied Learning for early and primary science: 1) Recognise children's understanding in ways beyond words, especially gestures; 2) Encourage meaningful sensory and movement experiences; and 3) Communicate in ways beyond words, especially gesture. These tentative implications require further research leading to a further key message: the need for research-practice collaboration in this emerging field that draws upon educators' insight from everyday practice.

Keywords: Embodied Learning, Embodied Cognition, gestures, informal science centres

Introduction

The importance of science learning in children's early years is well documented (e.g. Gelman & Brenneman, 2004). However, as children are increasingly introduced to science concepts in school, there is a risk that some struggle to relate these more abstract ideas and language to their everyday experiences in the world. Embodied Learning seeks to address this challenge by proposing approaches to learning that draw on the research field of Embodied Cognition.

Embodied Cognition

Embodied Cognition is a research paradigm in the cognitive sciences that claims that our bodies and our bodies' interaction with the world are inseparably linked to our cognitive processes, challenging the mind-body distinction (Wilson, 2002; Barsalou, 2010). Although this can feel obvious to practitioners who recognise the importance of experience, Embodied Cognition is quite a radical challenge to dominant theories of cognition, which can influence how we consider knowledge, assessment and educational goals.

Traditional theories have tended to separate mind from body: cognitive development is presented as graduation away from concrete to more abstract ways of thinking. A bit like a robot, our *sensory* (e.g. visual, touch, hearing) and *movement* experiences ('*sensorimotoric*') are perceived as important as, but ultimately distinct from, cognitive processing (thinking) that happens in our brain. In contrast, Embodied Cognition argues that cognition is a dynamic activity involving our brain, body and the world around us. We not only interact with the environment to 'offload' cognitive tasks (e.g. writing notes, raising fingers to count) but, even when we think '*in our heads*', we are activating internalised body-based (sensorimotoric) experiences – cognition is embodied.

Gestures – a window into our embodied cognition

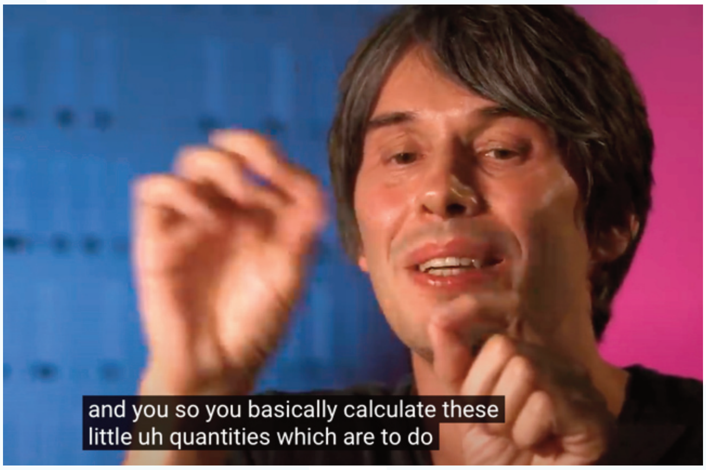
Whilst evidence for Embodied Cognition comes from various sources (e.g. brain studies), in the last two decades a more accessible source of evidence has emerged: gestures (see Goldin-Meadow, 2005).

Gestures refer to spontaneous hand movements typically co-produced with speech when explaining or problem-solving. Many factors influence if and how we gesture – from cultural norms to content of speech. We are often unaware of our gestures and gesture even when the listener cannot see us (e.g. on the phone). Teachers naturally gesture, changing their gestures depending on factors such as learner understanding (Alibali & Nathan, 2012).

Some gestures emphasise words ('beat' gestures). Others connect our speech to the environment by pointing ('deictic' gestures). But the most revealing gestures are representational, where our hands trace, interact with, or even stand for an imagined object. Because gestures are simulated or representational actions (Hostetter & Alibali, 2008; Novack & Goldin-Meadow, 2017), they support the claim that thinking is embodied.

Various works have examined how gestures reveal the embodied nature of concepts. Manches and Ainsworth (2022), for example, revealed some gestures in online videos explaining COVID-19. The Figure 1a[1]) speaker created a gesture of rotating a grasping hand to talk about the way in which viruses mutate. In this work, the authors show the potential to examine gestures in the many online videos of science explanations. For example, in Figure 1b[2], Brian Cox explains Quantum Mechanics – for a radio audience. Here he represents time, movement and quantum quantities by tracing lines with pinching gestures.

Figure 1. Gestures explaining a) COVID-19, b) Quantum Mechanics.



Embodied Learning

With increasing evidence that thinking is embodied, researchers (e.g. Shapiro & Stolz, 2019) have begun to explore ways to support learning by enhancing children's sensorimotoric experiences – Embodied Learning. It is claimed that Embodied Learning can make learning more *meaningful* by helping children connect more abstract forms of communication (e.g. science words or diagrams) with personal experiences (Nathan, 2021). Embodied technologies, concrete materials and gestures will be explored further below.

Embodied technologies

There have been various approaches to Embodied Learning. Much work has explored the potential of *Embodied Learning technologies* to link actions or gestures to digital representations. For example, in Figure 2a, children explore ratio by moving their hands at different relative distances from the tabletop and observing the resulting digital representation (Howison, Trninic, Reinholz & Abrahamson, 2011). In Figure 2b, children explore the movement of moons around planets through whole body actions mapped onto the floor (Lindgren, Tscholl & Moshell, 2013).

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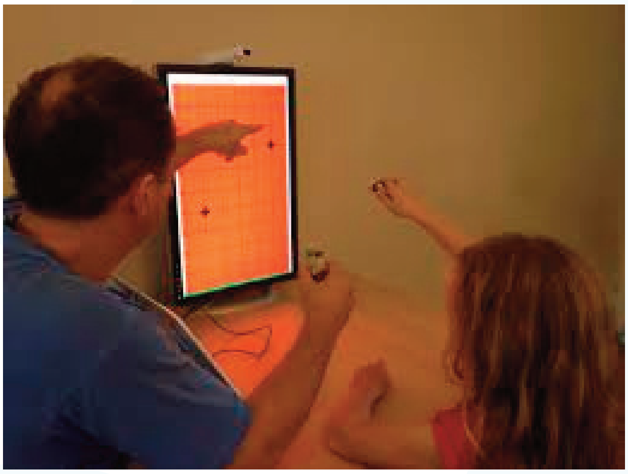
[1] https://www.youtube.com/watch?v=oMHacLHchl0

[2] https://www.youtube.com/watch?v=fcfQkxwz4Oo_

Figure 2. a) Mathematical Imagery Trainer, b) Meteor modelling.



Concrete materials

Other work has adopted an Embodied Learning lens to examine interaction with everyday concrete materials. Manches and Dragomir (2016), for example, investigated how physical materials may help children think and explain number relationships (e.g. why 1+7 makes the same as 2+6). Gesture analysis revealed how both adults and children communicate number concepts using metaphors of numbers being like collections of objects (e.g. grasping and swapping imaginary groups of objects – Figure 3a), or like points along a line (pointing to the far right of the body – Figure 3b). An implication of this research[3] is to consider how using materials (e.g. number line, blocks) and language (e.g. 'count up', 'split') can support metaphors across increasingly complex concepts, and challenge approaches that seek to graduate children away from concrete resources. The importance of sensorimotoric experience has also been demonstrated in early science. Thomas, Price, Nygren and Glauert (2021), for example, showed how young children's hands-on interaction at water tables shaped the type of gestures that they used to communicate their subsequent science explanations.

Figure 3. Gestures when talking about number concepts as a) collections of objects, b) points along a line.

Gestures

Other Embodied Learning research has focused more directly on how *gestures* can support learning. Some work has examined how teachers' gestures can support children's comprehension by revealing information beyond speech alone (Hostetter, 2011). Other research has shown how children's gestures offer teachers an additional means to assess and build upon understanding. Church and Goldin-Meadow (1986), for example, showed how young children were able to communicate understanding of conservation through gesture before they could do so verbally. Some studies have shown how encouraging children's gestures can make learning last (Cook, Mitchell & Goldin-Meadow, 2008).

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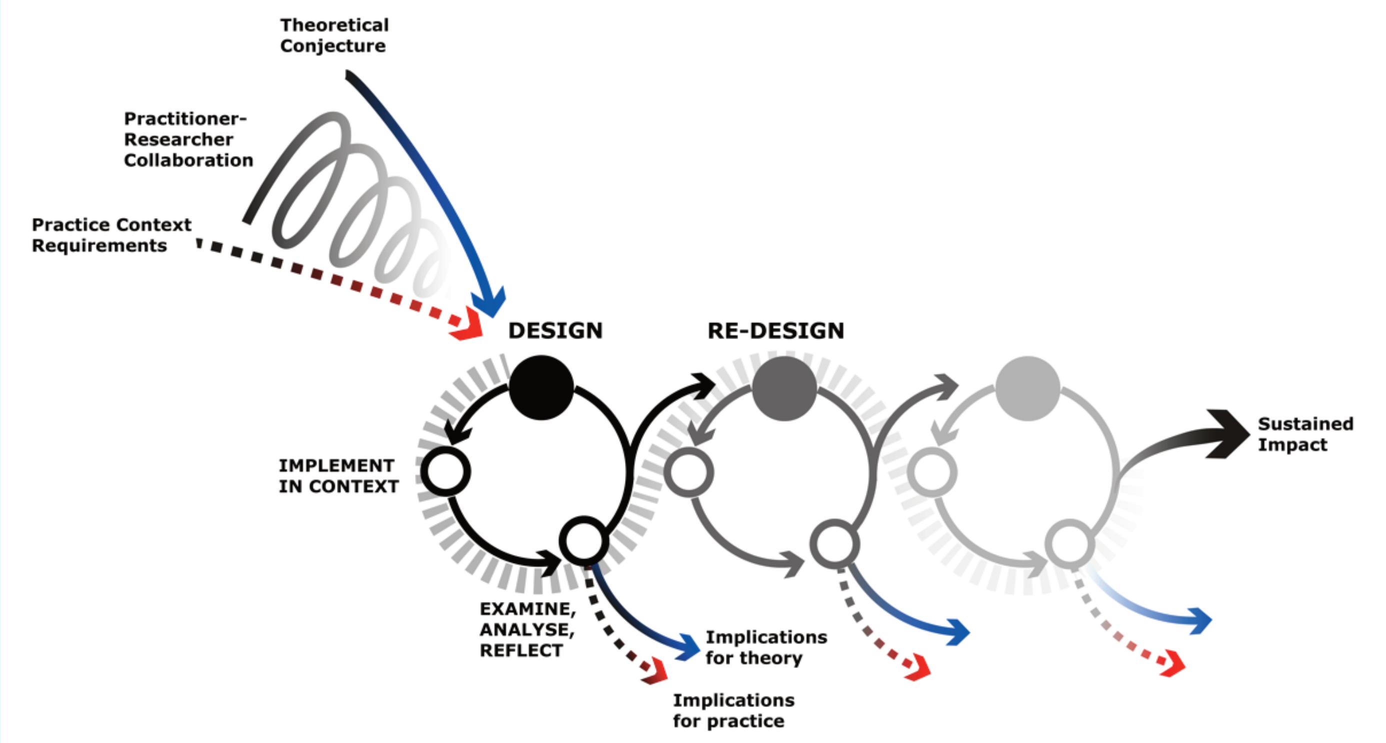
[3] See https://vimeo.com/160639180 for an animated summary of this research.

Move2Learn

Despite the educational implications of Embodied Learning research, studies are often carried out in quite controlled settings and the broader implications for practice are unclear. The Move2Learn research project sought to address these challenges.

Move2Learn (2017-2020)[4] was an international collaborative project (three academic partners; six science centres from UK/US), to explore Embodied Learning in early years science (aged 3-8). The context was informal science centres, where there is demand for knowledge to inform hands-on exhibits and capture the educational value of interactive experiences and design of digital experiences. The project adopted a design-based methodology (Figure 4), that derived implications for theory and practice through several iterations of examining, evaluating and informing designs (which may be physical and/or pedagogical). The UK partnership was led by the first author, who was previously an Infant/Special Education teacher.

Figure 4. Design-based methodological approach of Move2Learn.



Move2Learn involved multiple studies with over 500 children across a range of exhibits at different sites, from fully immersive digital interactive exhibits to more familiar water tables, and variations of participants: children on their own, with peers, with a practitioner (science facilitator/ teacher), or parent. However, the structure for studies was similar: first, children were encouraged to play with an exhibit, and then they were 'interviewed' away from the exhibit and asked to communicate their experience and understanding of relevant concepts. Many sessions were video-recorded to analyse in detail how children and adults interacted and communicated: their speech, actions, gestures, body position, facial expression, or eye gaze. In particular, the research examined how children's actions with the exhibit helped structure their subsequent speech and gestures in interviews.

Move2Learn4Teachers

In response to interest, a follow-on project (Move2Learn4Teachers, 2021-2022) was funded to develop messages and resources from Move2Learn for primary teachers. This was achieved through a series of

[4] See https://www.youtube.com/watch?v=PLYw69l_q5g. for 3-min animated summary of Move2Learn project.

three workshops, with 10 teachers from across the UK, delivered online due to the pandemic. As well as the original science centre practitioner leads, the project collaborated closely with the primary and Early Years lead of SSERC, a leading STEM education organisation and co-author of this paper. From this work, three implications for practice were co-developed and described below:

***1. Recognise** children's understanding in ways beyond words, especially gestures*

Educators already recognise the diverse ways in which children communicate their understanding (although such diversity is often challenged by formal assessments). However, both traditional paradigms of cognition and practice privilege more abstract forms of communication, notably speech and writing (Flewitt, 2005). By arguing that knowledge is intrinsically linked to internalised experience, Embodied Learning emphasises the importance of recognising more body-based modes of communication, notably gestures, which offer a unique window into children's science understanding (e.g. Thomas *et al*, 2021). Attending more to children's gestures may particularly benefit children who struggle to communicate their thinking through words.

In Move2Learn, children tended not to gesture whilst interacting with exhibits, unless pointing to direct others' attention. In contrast, many (>50%) gestured in interviews, although it was unclear what influenced the likelihood of gesturing (beyond rapport with interviewer). Whilst younger children's gestures were typically not succinct or easy to interpret, they often preceded speech and appeared to help prompt verbal explanation. It was also clear from videos how adults attended to children's gestures and often used them as a springboard for continuing dialogue with children. In some instances (see Figure 5, for example), children would watch and emulate each other's gestures when explaining in pairs/groups.

Figure 5. Children emulating other children's gestures.

The variation in the way that children gestured similar ideas was insightful. Some children re-enacted their actions from a first point of view (e.g. simulating moving blocks on a balance board); others' gestures were more representational of underlying scientific processes, for example how balance was affected by distance from the pivot. Such '3rd person' gestures arguably reflect more developed thinking, representing scientific processes in more abstract ways that can generalise to other balancing contexts.

It is worth noting that, in Move2Learn, children were asked to *explain*, which generally implies speaking – gestures were coincidental. In Move2Learn4Teachers, we developed a game to encourage practitioners and children to focus on gestures by having to explain concept words just through gestures – STEM Charades[5]. This game raises the interesting possibility that we might sometimes help children to express ideas by explicitly *showing* (i.e. gesturing) their thinking.

***2. Encourage** meaningful sensory and movement experiences*

Children's and adults' gestures demonstrate the importance of experiences in shaping conceptual development. Some concepts have a clearer mapping to experiences: for example, the feel of friction on different surfaces or the force pulling you out from the centre of a roundabout. For other concepts, experiences can act as metaphors (Núñez, 2000): for example, concepts of time drawing on experience of moving forwards and backwards, the flow of water for electricity, running around colliding with others for how gas molecules behave, or balloons to think about the expanding universe. Many science concepts, such as 'energy' (Lancor, 2015), draw upon multiple metaphors.

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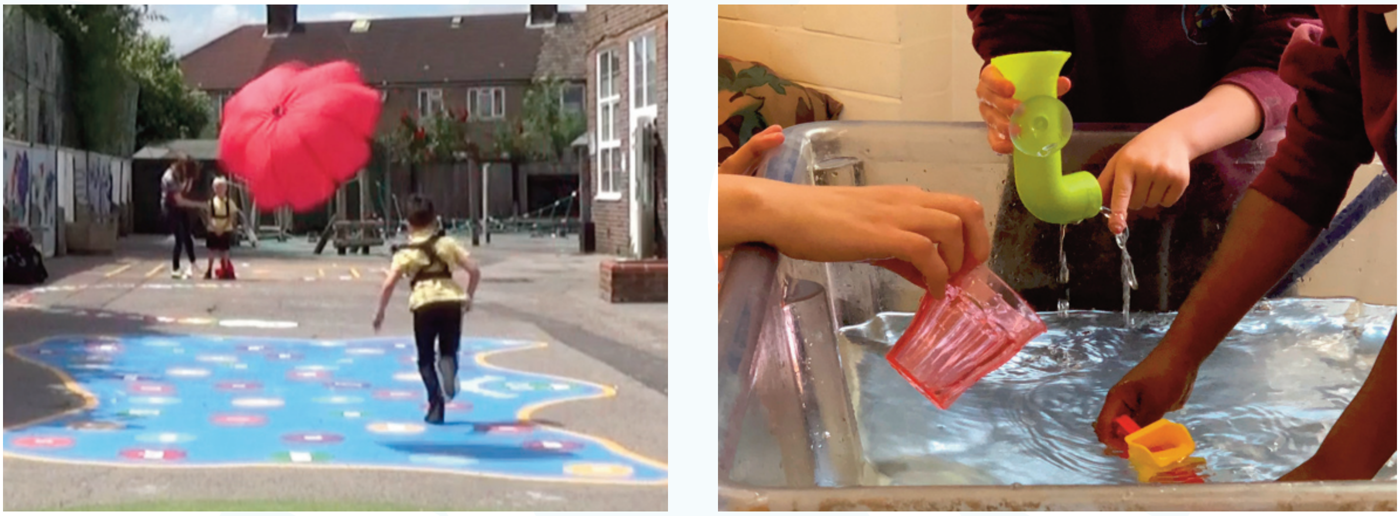
[5] STEM Charades video https://youtu.be/J39Ezk1J79E

Many experiences, such as those exemplified above, are gained from everyday interaction in the world (although this does raise questions about whether children have equal access to such 'everyday' experiences). But some experiences can be encouraged in education – through activities (e.g. nature walks) or designs (e.g. educational materials, exhibits). Everyday technologies offer immersive experiences, although they also raise questions about whether forms of interface (e.g. mouse, touchscreen) can sometimes limit sensorimotor interaction.

In Move2Learn, we observed the range and frequency of sensorimotoric experiences that children encountered through engagement with exhibits and activities, from designs encouraging movement (e.g. attachable kites to explore resistance – Figure 6a) to more tactile experiences, (e.g. feeling flowing water or submerging objects – Figure 6b).

Figure 6. Experiences offering meaningful sensorimotoric experiences: a) attachable kites, b) water table.



The importance of active engagement is well documented in education; the more specific contribution of Embodied Learning is to draw attention to the relationship between sensory and movement experience and conceptual thinking – how these experiences help generate cognitive resources for children. The question of which experiences are meaningful for specific ideas is challenging and ongoing. Whilst gesture studies can help reveal the role of some visual and movement experiences, revealing the cognitive significance of other sensory experiences, such as auditory or tactile (e.g. the sound of the wind, the feel of tree bark). remains challenging.

3. Communicate in ways beyond words, especially gestures

Educators employ diverse ways of communicating ideas with children, both through resources around them (e.g. manipulatives, diagrams) and how they communicate directly (e.g. speech, gesture, facial expression). Whilst there has been increased recognition of the importance of multimodal communication in science learning (Kress, Charalampos, Jewitt & Ogborn, 2006), Embodied Learning emphasises the cognitive significance of more body-based communication, notably, the potential to represent sensorimotoric experience through gesture.

Through detailed video observation, Move2Learn revealed the nuanced ways that adults communicate with children in science learning contexts, both when children interact with exhibits and afterwards in interviews. For example, in Figure 7, a science facilitator is supporting children's interaction with a balance board. The practitioner spoke little, but scaffolded children's interaction throughout the session, particularly by drawing children's attention to important features of the exhibit using gesture (pointing), eye gaze or body position (e.g. crouching down to encourage children to notice under the board – Figure 7a). Body position was also important in signalling intention to intervene or encourage children's independence simply through stepping/leaning forward and backwards. Facial expressions were often exaggerated to guide interaction, from intentionally puzzled (to encourage reflection), to happily surprised expressions (to help children recognise significance of actions).

Perhaps the most significant form of multimodal interaction from an embodiment perspective was the practitioner's use of representational gestures. For example, in Figure 7b, the practitioner tilted their forearm to represent the board balancing around a mid-pivot point. This gesture was significant because it offered children an abstracted representation of the complex naturalistic interaction context; it is also the gesture used later by children to describe their experiences.

Figure 7. Practitioner scaffolding through gesture: a) body position and eye gaze, b) representational gesture.

As well as gesturing, adults interacted with exhibits, often to draw children's attention to science relationships or help solve the exhibit task. In one study, we compared similarities and differences between practitioners (science facilitators and visiting teachers) and parents in how they scaffolded children's interaction. The findings revealed how practitioners tended to gesture more, whilst parents tended to act more – possibly because gestures have less impact on children's independent interaction and help provide a pedagogical bridge between children's actions and science language (e.g. 'balance', 'pivot').

In another part of the study, children were interviewed with parents who were told to support children as they might naturally. Here, parents used multiple representational gestures to support their children's recollection of interaction. Gestures often simulated children's actions with the exhibit (e.g. grabbing blocks – Figure 8a). Some gestures were more abstract, such as the balance gestures described previously (Figure 8b). Interestingly, the parent used the same gesture in the interview to link the balance exhibit to a recent seesaw experience. This example shows both how more abstract representational gesture can help connect multiple experiences and the way in which gestures help adults to extend dialogue from shared interaction experiences with children.

Figure 8. Parent scaffolding through gestures: a) simulating children's actions, b) representing concepts.

Conclusion

Embodied Learning is a relatively recent and growing research area promising exciting implications for education. Move2Learn contributes to this field by examining embodied interaction in a practice context, both how children (and adults) interact and subsequently how they communicate experiences and understanding.

Studies from Move2Learn are limited in many ways, not least the relatively unusual interview context after exhibits. Whilst Move2Learn4Teachers showed teachers' interest in and positive experiences of exploring embodied approaches in their classroom, more work is required to develop and evaluate research and practice in this context. The research also raised many new questions for future investigation, such as the relationship between gesture and sign language, or the extent to which practitioners should present gestures for concepts before or after encouraging children to create and reflect upon their own.

Move2Learn has highlighted the necessity of research-practice partnerships; hence the intention for this paper to help build interest in this field by presenting three broad messages, which are presented and summarised in Table 1.

Table 1. Summary of Embodied Learning key implications for practice.

Key implication	Practice notes
Recognise children's understanding in ways beyond words, especially gestures	Encourage children to express their knowledge in diverse ways
	Encourage gesture, perhaps asking children to 'show' you what they mean
	Continue dialogue by building upon meaning that children communicate through gesture
	Encourage children to reflect and discuss each other's meaning through gesture
Encourage meaningful sensory and movement experiences	Encourage where possible opportunities to gain sensory and movement experiences that are meaningful for science ideas from the everyday environment (e.g. nature trips/tables)
	Use/design materials/activities that provide sensory and movement experiences that are meaningful for science ideas
	Consider how materials may encourage different embodied metaphors for science concepts
Communicate in ways beyond words, especially gestures	Use multimodal communication as children interact to draw children's attention to meaningful actions (and results of these actions)
	Use gestures as children interact to help represent the scientific meaning in their actions
	Use gestures to help children draw upon previous experiences and to represent these experiences more abstractly
	Use gestures to help emphasise key words (beat gestures) and draw children's attention to key information (deictic/pointing gestures)

For the research and resources described here, the Move2Learn collaboration was awarded a Social Impact Award[6]; we are now working together to support science educators (formal and informal learning) through the development of an accredited online course on Embodied Learning for Early Years and primary educators. The shared goal is to realise the potential for Embodied Learning to make science meaningful for all children, notably for those who lack confidence or ability in communicating understanding verbally.

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Disclaimer

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of NSF, the Wellcome Trust, or ESRC.

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[6] https://edinburgh-innovations.ed.ac.uk/news/stem-education-collaboration-wins-scottish-knowledge-exchange-award

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Professor Andrew Manches, Professor of Children and Technology, University of Edinburgh.
E-mail: A.Manches@ed.ac.uk

Euan Mitchell, Head of Early Years and Primary, SSERC.
E-mail: Euan.Mitchell@sserc.scot