Using multimodal strategies to challenge early years children's essentialist beliefs

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Abstract

The work reported here forms one element of a wider study across the 4-11 age range funded by the Nuffield Foundation. The research was more broadly concerned with the development of ideas about evolution, an area of science introduced to the National Curriculum for England in September 2014. Within the study of evolution, one essential foundational idea is that of variation, as it is within-species variation that enables advantageous features to confer greater survival and breeding success on living things, whether driven by natural selection or selective breeding. This paper reports on the process and outcomes relevant to variation in living things generally, drawing on evidence from the participating children and teachers in the early years (4-7) age range. Young children tend to hold essentialist views of living things that lead them to regard all individuals within a species as identical – a view at odds with biological reality. Children's consideration of within-species variation was explored in their enquiries relating to themselves, other animals and plants. We describe how a range of tailored formative interventions, including the use of mathematical tools, proved to be helpful in supporting and developing children's understanding of variation in living things.

Keywords

Early years, variation, evolution

Introduction

The work reported here forms one element of a broader study funded by the Nuffield Foundation that examined teaching and learning of 'Evolution and Inheritance,' an area of science introduced to the National Curriculum for England in September 2014. The authors worked collaboratively with teachers and children across the primary age range to explore teaching and learning processes within this important biological domain. The domain was clustered into five interrelated themes, defined as 'Variation', 'Fossils', 'Deep time', 'Natural selection and selective breeding' and 'Evolution'. These themes were believed to have conceptual coherence, form manageable work packages and provide sufficient breadth to ensure access for children across the primary age range. Here we report some reflections and findings within the study of 'Variation' from the sub-set of early years settings (children aged 4-7 years) included in the project. The research questions of particular relevance to this paper are:

- What ideas do young children bring with them to their study of 'Variation'?
- What multimodal formative interventions can be developed in early years teachers' practices?
- How can evidence from practice be used to define optimal teaching and learning sequences?

Within-species variation is what makes changes over generations possible, so is fundamental to evolution by natural selection; without it, evolution by natural selection or by selective breeding could not occur. Yet children tend to believe all living things within a species are the same; all frogs, rabbits, oak trees, dandelions, etc. are deemed to be identical. This recurring, so-called 'essentialist', view of living things is one in which the belief is that all individuals within a species share some essential nature that makes them identical (Evans, 2001; Gelman & Rhodes, 2012). Appreciating how living things within the same species vary represents an important step along the developmental journey towards understanding of evolution. Children tend to focus on similarities between living things of the same species, as it is these that endow them with their identity. What child wouldn't believe that the tadpoles in Figure 1 are all the same? To combat this essentialist thinking, Lehrer and Schauble (2012) suggest that children (grades K - 6) can be encouraged to engage in enquiries in which they observe and measure differences in living things of the same kind.

The research sought to bring to children's attention variation in general, whether in plants, animals or parts of animals or plants and including variations in behaviour or morphology. In short, the interest was in variation in living things generally, with no particular bias of interest towards animals or plants. The choice of living things was in fact explored by prioritising organisms (or parts thereof) that practitioners or teachers found to be manageable or viable in their classroom and wider resource environment. The spectrum included, as well as farm animals (accessible through out of school visits), stick insects and tadpoles and various plants grown from seed. The exploration of children's ideas about variation thus was framed in terms of variation in living things generally, with no special priority or bias in mind favouring either plants or animals. The actual organism selected was determined by teachers' preferences and children's interests. Some of those choices made measurement possible.

Figure 1: Observing tadpoles.

Method

A collaborative Design Based Research approach (DBR, Anderson & Shattuck, 2012) was adopted for the study. DBR combines science education research and theory with educational design and development intentions to generate evidence-based and ecologically valid recommendations for practice. The enquiry and this report are qualitative in nature. It is understood and accepted that practical and applied project outcomes are more likely from the use of DBR methodology than measurable effect sizes. Because DBR deals with complex interacting variables, discrete measured outcomes tend to be relatively insignificant in the bigger picture. More weight is attached to the validation by the practitioners involved in the research and construction of support materials than to measured outcomes of pupils' assessed understanding. A core principle of DBR is to assume complementarity between the skills of researchers and practitioners, recognising teachers' existing proficiencies with the age group. The classroom relevance of outcomes also enables informed support to be offered for professional development where there is a lack of confidence. The broader enquiry across the 4-11 years age range was conducted with a group of twelve practitioners selected on the basis of their curiosity to explore the ideas that children bring to their learning. Specialist biological knowledge was not essential. Four of the twelve practitioners contributed to the evidence collected in respect of children aged 4-7 years reported here. Fourteen researcher visits were made in total to the project's four early years settings. The research followed ESRC (Economic and Social Research Council) ethical guidelines.

Year	25 Feb 2014	Feb-Apr 2014	Apr 30 2014	May-Jun 2014	Jun 30 2014	Sep-Dec 2014	Jan-Jun 2015
Activity	First core group meeting	Classroom based research, review & analysis	Second core group meeting	Classroom based research, review & analysis	Third core group meeting	Classroom based research, review & analysis	Review Validate Consult

Table 1: Project scedule.

All teachers attended three project meetings and engaged in cycles of activity that involved finding out children's ideas and developing formative, targeted interventions. Table 1 outlines the DBR schedule.

Research activities comprised: a) classroom activities managed by teachers; b) researchers' observations of practice; c) teachers' insights and practices communicated via an online (SharePoint) facility and their (Evernote) digital research diaries; and d) group meetings. Data were drawn from researchers' observations of practice, children's classroom outputs and teachers' records of their involvement. Significant information-gathering activity took place during researchers' visits to schools, including video recording, photography and collection of children's products.

The DBR approach was one in which the researchers took responsibility for setting out the general conceptual agenda. The importance of a formative approach to teaching and learning was emphasised, implying that teachers should accept the need to identify children's current understanding in order to support progression in their developing ideas. The teachers were deemed to be the early years experts and the judges of the needs and capabilities of the children they taught. Our intention was and is to build on existing confidence rather than to inadvertently disempower practitioners by the imposition of top-down views of science practices (Russell & McGuigan, 2015). Emerging practices were exchanged, critiqued and developed across the group. In this way, it was ensured that all activities were viable and appropriate for the early years age group and sat easily with generic practices.

Results

Evidence of children's expectations of within-species similarities were revealed and confirmed in their initial explorations of animals, plants and features of themselves. Reception children (4-5 years) visiting farm animals tended not to recognise the black sheep that they were observing and discussing as a sheep. Their exclamations made explicit their essentialist reasoning: *'They're not sheep! Sheep are white'.* For these children, one essential feature of sheep was a white woolly coat. Similar essentialist biases were revealed as the young children closely observed ducks. A widespread view of ducks having yellow beaks led to children failing to identify the animals that were the object of their attention as ducks (Russell & McGuigan, 2015). The wider research agenda had sensitised teachers to the essentialist issue. So it was that, in response to expressed ideas, the interactions during the visit encouraged children to observe directly some of the differences within collections of sheep, ducks and rabbits. Later and back at school, collections of hens were brought into some settings for children to observe directly.

Children initially viewed all tadpoles as homogeneous and undifferentiated. Observation using magnification brought home to them that the unhatched tadpoles showed variation and this was a surprise to them. Children's descriptions of the tadpoles' diversity included: *'That is a different shape, not round'*; *'That's got a white dot in it and the others are black'*; *'Some are brown and some are black.'* Amongst the ideas discussed for the measurement and observation of variation was plotting the number of tadpoles that hatched day by day (or by number of days after egg-laying or collection of frog spawn). This was expected to reveal a pattern (normal distribution), with a few hatching early followed by an increase in rate and then a tailing-off. Another measurement possibility was to count the emergence of legs and absorption of tails. Unfortunately, half-term breaks and fatalities intervened.

The possibility of children measuring and comparing the length of caterpillars was also discussed. In relation to stick insects, it was discussed whether it might have been possible to time and quantify skin moults. Keeping track of individuals proved extremely difficult for the age group and under the conditions in which they were kept, so that the criterion of classroom viability dictated that other foci of interest were pursued.

While planting seeds and growing plants is a ubiquitous and frequent experience in Reception and Key Stage 1 (4-7 year-olds), project children revealed an unequivocal essentialist expectation that, if the seeds they were to plant received the same amount of water and sunlight and were planted at the same time, they would all grow to the same height and produce the same number of leaves, flowers, etc. Figure 2 shows a child's drawing of how the sunflower seeds might be expected to look when the seeds grew into 'adult' plants. In conversation with a practitioner, the child explained that each plant would have two leaves and a flower. While there is a hint of variability in the height of the drawn plants, the child was of the view that the plants of the same age would all be the same. Pointing to one of the shorter plants, she explained that this plant was '*the baby*' and would therefore be smaller.

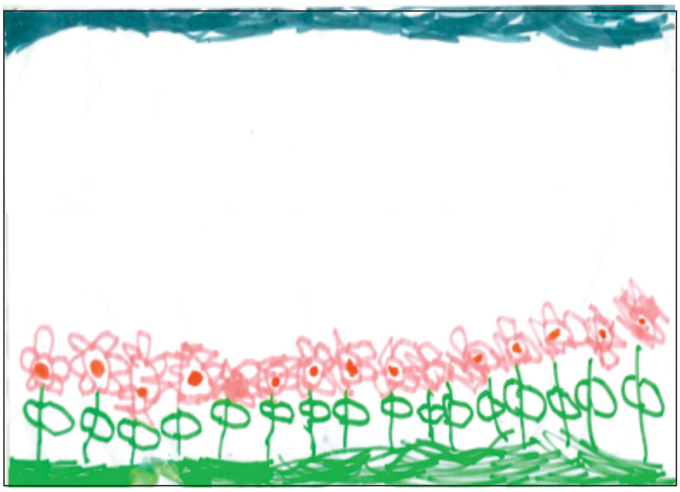

Figure 2: Child's (50 months) drawing of ideas about how sunflower seeds will grow.

Figure 3: Observing differences in the growth of pea seedlings.

A number of formative interventions were developed as the result of discussions between the project teachers and researchers. Several teachers found children engaged with a non-fiction story, *The Tiny Seed*, by Eric Carle. The narrative explores how the germination and subsequent growth of seeds is affected by environmental factors, providing a low-key and implicit introduction to the notion of survival probability – a key idea in evolutionary thinking. Reception children seemed to take the demise of the majority of the story's seeds in their stride and described some of their own experiences of neighbours' pets and birds eating seeds in their own outdoor areas.

From this starting point, children from Reception to Year 2 (ages 4-7) were encouraged to observe and compare the growth of their seeds. Across the year groups, children grew a variety of plants including carrots, peas, cress, beans, tomatoes and sunflowers. Their teachers shaped activities so that children were encouraged to look closely to observe not just similarities but also differences between collections of plants of the same kind.

In one class (aged 4-6 years), children grew peas in a wormery so that they might be enabled to observe and compare the differences not only in the shoots and leaves of the peas but also to compare root growth (Figure 3). The transparent sides provided novel opportunities for children to observe and measure differences in the individual plants' root systems. Sticky labels and marker pens were used to record length, while also taking standard measures of length in centimetres. Once a measurement strategy had been invented and agreed for one of the plant's roots, it could easily be used by children to compare each of the plants growing in the wormery.

In a Reception class (aged 4-5 years), differences between sunflower seedlings were recorded qualitatively, in drawings and paintings. As children made drawings of the changes in their sunflower seedlings, they were encouraged to observe closely, to 'look again' to check their observations and draw the leaves accurately. One child drew leaves as green lines. When asked to look closely again at the leaves, he self-corrected, changing his leaves to a curved shape. It is noteworthy that this adult's comments on drawing did not simply tell the child how the leaf *should* be drawn, or point to *a fault* or *shortcoming.* More simply, it was a matter of suggesting that further observation might prompt a change of mind or a more careful examination. Once prompted in this manner, children 'adjust their sights', perhaps even raise their standard, in line with external expectation. While each child had their own potted sunflower seedling, they were encouraged from time to time to make observations of differences across the collection of pots. Developing these careful observations and recordings helped children to identify and describe qualitative differences across the collection.

Children also recorded the number of leaves on each plant. Some looked across the data and noticed that the number of leaves on the sunflowers' stems differed. Similar observations helped children to notice that some stems varied in height while other seeds had not germinated at all. They employed their mathematics vocabulary to describe the heights of sunflower plants and used ordinal relations to sequence seedlings from shortest to tallest. With adult help, they were able to transform this row of plants ordered by height into something resembling a pictogram, putting live plants of similar height into columns. Each child added their plantlet to the 'living chart' of seedlings, observing carefully and judging where they thought each seedling should go. Typically, a child might put her plant in one column and then, following

Figure 4: Making a 'living pictogram' of plants by height (60 months).

discussion of the plant's height, move it to a different column that she thought more accurately matched the height of the plants in that set.

One child had a seed that was just showing signs of growth. He demonstrated what was happening to the seedling by his actions, curling up his body as if to show the seedling coiled up inside the seed. He put his seed pot at the very far left of the group, indicating that his plant was the smallest.

These interactions helped children to carefully compare height across the seedlings. It is from such early interactions that we might expect children to develop an awareness of the need for more systematic measures that will support judgements about variations in height.

Children were able to identify the tallest and shortest and referred to all those in the middle as 'middle-sized'. They traced around the shape of the chart with their fingers to describe the curve (Figure 4), also attempting to make the outline shape of the chart in the air when invited to do so. The child's curling up and unravelling of his body modelled the germination of the seed, while tracing the shape of the heights of the plants with a finger through the air may be the first form of recognition of the curved shape of the normal distribution or 'bell-shaped' curve. Both of these forms of representation use partial or whole body gesturing.

The activities in the Reception class reveal children using a variety of representations, e.g. drawings, paintings, speech, actions, miming, lists and charts to share their understandings. Different representational formats offer different affordances for revealing and communicating understandings. Each of the representations highlights different aspects of children's observations of variation in the sunflower seedlings. The drawings enable children to reveal ideas about differences in the colour, shape and number of leaves. Relative height can be shown in drawings, while measured height can be added in written annotations. Shape and movement might be shown in actions. Moving between (or 're-describing') representations in different ways is a metacognitive strategy that helps children to construct new understandings. The 'living chart' could not show the detail that is possible through the use of additional notations in children's drawings, but it did succeed in showing the differences in the number of seedlings at different heights. In doing so, children were introduced to the overall shape of the distribution of height of all the plants being grown by the class.

Year 2 children (6 and 7 year-olds) recorded their observations of bean seeds in individual diaries. To reflect the formative focus on children's developing ideas and to encourage observation of differences within the collection of bean seedlings, this relatively familiar experience was shaped in the following ways:

- Their teacher encouraged children to invent and decide for themselves the observations to be made and how any measurements might be taken.

- Children were encouraged to share their data with one another and to make comparisons across the collection of growing bean seeds.

Some children focused on the number of leaves, others the height of plants or the length of roots. Their drawings and writings included qualitative, semi-quantitative and quantitative observations. For example, the height of plants was compared directly, side-by-side, using non-standard (finger widths) as well as standard measures. They were eager to discuss and compare other children's seedlings with their own (Figure 5) and used the accumulating data to highlight differences between the plants. Using measurement helped children to recognise, describe and compare their

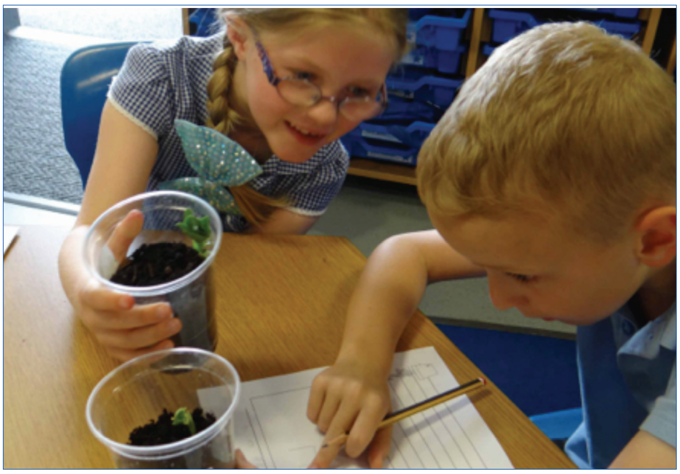

Figure 5: Comparing bean seedlings (6 & 7 year-olds).

observations of the differences within collections of plants of the same species.

In order to encourage an overview of the number of leaves on each seedling across the collection of plants grown by the class as a whole, one of the practitioners drew chalk lines as the axes of a large chart in the playground. Each child placed their growing bean seedling on the chart according to its number of leaves. Their teacher spotted some 'exaggerated' counting due to an initial desire of some children to have grown the plant with the most leaves and reminded them to count accurately, so that they could trust the results! The numbers of leaves were re-counted and plants were placed in columns according to the number of leaves grown. Children appreciated that there were fewer plants at either end and a lot more in the middle. Drawing around the assemblage of plants helped to make the shape of the distribution of number of leaves more visible and evident to children (Figure 6).

Recording measurements in 3-D charts using real plants led children to describe the shape of the distribution as *'like a volcano'* and *'like a hill'*. The term *'hill shape'* emerged as useful in helping children recognise similar patterns in their charts of measurements of their hands and feet. This provided the research group with a useful vocabulary to use in place of the more formal and obscure (to young children) 'normal distribution' – the correct term to which children might be expected to be introduced later in their learning. This shape cannot be seen by looking at individual drawings or by

Figure 6: Drawing around the assembled plants helps make the shape of the distribution more visible (6 & 7 year-olds).

comparing one plant with another. It emerged only when children aggregated the data for one attribute across the collection of plants. The early years teachers seem to have found an innovative and accessible way to introduce children to a recurring pattern in the distribution of continuous variation across a population.

Children observed and measured variability in a number of contexts, enabling them to appreciate the recurring 'hill-shaped' pattern. While encouraging children to compare physical characteristics of themselves and their peers (especially non-continuous traits such as eye or hair colour) tends to be avoided to protect children from potential sensitivities, measurements of hand and foot size tend to be acceptable and were explored in parallel in several Year 1 and 2 classes (age 5-7 years). Project teachers invited children to suggest measurement strategies and required them to explain to their peers why a particular approach should be used. Once agreement was reached, the preferred strategies were adopted by the class to provide a collection of data. While many creative measurement ideas were lost in the negotiations, a variety of measurement strategies were used across the early years sample:

- Measurements of hand span or hand length were made, along with measures of the length of foot from heel to toe.
- In some classes, string and strips of paper were matched to size of hand or foot and then measured in centimetres. In others, a ruler was used directly to make the measurement.
- Some classes drew around the hand or foot and then used rulers to measure the span or length represented in the drawing.

Children drawing around their hands and feet often added standard measurements in centimetres.

Year 2 children were surprised to find differences in their hand sizes. To help them think of these differences positively, they were encouraged to think of variations as making them 'special'. Children were encouraged to place their own cutout handprint onto a chart. In their discussions of the assembled information, some noticed that the overall shape of the chart was the same, both in their hand and foot measurements (Figure 7).

Figure 7: Measuring and describing the variability in hand span (6 & 7 year-olds).

Conclusions

Formative targeted intervention experiences formulated within the research were designed to take account of young children's essentialist reasoning. This way of thinking tends to lead children to think of living things in the same species as sharing a common 'essence'. Ideas such as '*Sheep are white*' and '*Ducks have yellow beaks*' emerging in the course of our research may serve children well as they seek to name and classify animals. However, such reasoning fails to take account of variation within species and may lead children to fail to recognise black sheep and ducks with grey beaks as members of their respective family groups. Practical strategies used by teachers in this study, in which children compared the differences within groups of living things both qualitatively and quantitatively, helped children to appreciate variation. Taking a longer view of children's science education, awareness of variation within groups of living things is an important foundation upon which the mechanisms for understanding and accepting evolution have to be based.

Within the research, some familiar early years practices were shaped towards multimodal interventions to support children's understandings. The emphasis in practice was on children representing their ideas in different modes, including speech, drawings, writings, mime, measurement, lists and charts. Encouraging the development and use of mathematical tools such as counting and measurement extended children's observations, enabling them to recognise and compare differences that may not otherwise have been possible. The multimodal practices in combination were considered to have helped children develop an awareness of variation within groups of living things. In the course of the research, some insights were gained into how mathematical tools might help children shift from ordering data in linear sequences to preparing outcomes as charts comprising physical objects. Shifts from ordinal lists to charts helped children to show and describe a collection of measures gathered by the class. Children's descriptions of the (normally distributed) pattern in data as 'hill-shaped' provide a useful basis for generating later understandings of the relationships between distribution of attributes in populations and natural selection. These representational practices are likely to be foundational for children's development of 'thinking scientifically'. Rather than 'letting go' of drawing, mime, writing, etc. as they acquire more complex mathematical and symbolic capabilities, we see developing learners continuing to explore, use and make sense of the full range of representational possibilities as a critical aspect of their scientific reasoning. Just as scientists do!

The researchers' particular interest in children's ideas about variation included the prospect of formulating developmental trajectories that describe the kinds of understandings and practices in the early years that are important to support later understanding of 'Evolution and Inheritance'. Descriptions of conceptual progress are invaluable in supporting a formative assessment approach, but must be empirically checked in settings and classrooms. The longer-term practical aspiration of our work is the production of science curriculum support materials, validated and illustrated by those early years practitioners directly involved in their formulation and grounded in their expertise. Our DBR approach combines science education research and theory with educational design and development intentions to generate evidence-based and ecologically valid recommendations for practice.

References

Anderson, T. & Shattuck, J. (2012) 'Design-based research: A decade of progress in education research?', *Educational Researcher*, **41,** (1), 16–25. DOI: 10.3102/0013189X11428813

Carle, E. (1997) *The Tiny Seed*. London: Puffin

Evans, E.M. (2001) 'Cognitive and contextual factors in the emergence of diverse belief systems: Creation versus evolution', *Cognitive Psychology*, **42,** (3), 217–296

Gelman, S.A. & Rhodes, M. (2012) 'Two thousand years of stasis'. In Rosengren, K.S., Brem, S.K., Evans, E.M. & Sinatra, G.M. (Eds.), *Evolution Challenges: Integrating Research and Practice in Teaching and Learning about Evolution* (pps. 1–26). Oxford Scholarship Online. DOI: 10.1093/acprof:oso/9780199730421.001.0001

Lehrer, R. & Schauble, L. (2012) 'Supporting inquiry about the foundations of evolutionary thinking in the elementary grades'. In Carver, S.M. & Shrager, J. (Eds.), *The Journey from Child to Scientist* (pps. 171–205) APA

Russell, T. & McGuigan, L. (2015) 'Why clone a sheep when they all look the same anyway?', *Primary Science*, (137), 19–21

Russell, T. & McGuigan, L. (2015) 'Identifying and enhancing the science within early years holistic practice'. In Papadouris, N., Hadjigeorgiou, A. & Constantinou, C.P. (Eds.), *Insights from Research in Science Teaching and Learning.* Book of selected papers from the ESERA 2013 Conference, Springer

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