Understanding of evolution and inheritance at KS1 and KS2: Formative assessment probes

Terry Russell and Linda McGuigan, Centre for Lifelong Learning, University of Liverpool.

Introduction

This report on formative assessment probes is one aspect of a project designed to develop practical guidance for teaching Evolution and Inheritance at KS1 and KS2. Some findings are presented in a series of articles in the Association for Science Education's journal, *Primary Science*. In addition, the authors have produced a full report and project summary, a review of literature and resources and a report on feedback from KS3-KS4 biology teachers. All of these are available at www.nuffieldfoundation.org/primary-pupils-understanding-evolution-and-inheritance

This document describes a set of formative assessment procedures or 'probes' for each of the five themes defined. The five themes are i) Fossils, ii), Variation, iii) Inheritance, iv) Deep Time and v) Evolution.

Each of the five themes has a number of probes associated with it together with suggestions for follow-up questions.

(Note that two of the probes are suggested to support further research and the wider exploration of children's developing understandings of DNA and Cladograms. While these are significant and important areas for the understanding of inheritance and evolution, their study is not expected currently within the primary national curriculum for science. Some primary pupils have gained awareness through their out-of-school experiences so further research in this area will be of interest.)

The basic function of these formative assessment probes is to establish the quality and extent of children's current ideas. Insight into children's thinking provides essential information to teachers (and to the children themselves) as to the current state of their understanding: what they know and don't know, and the needs for further learning. Once these baselines are established, focused interventions are a more realistic possibility. It is also the case that the act of encouraging children to express their science ideas is in itself a form of intervention that encourages the development of thinking. This happens in two ways. Firstly, the act of articulating what were previously unformed ideas causes reflection and consequently, self-awareness of one's own ideas. Secondly, pupils hear other points of view expressed by other children that may be novel, insightful or in conflict with their own current beliefs. These experiences impact on their conceptual development.

Children should be invited to express their thoughts about Evolution and Inheritance and listen to, critique and reflect upon their own and one another's and ideas. They can make their thinking public in a variety of ways: through speech, drawings, and actions or in 3-D models. These ideas can be developed through science discourse or 'working scientifically': reasoned dialogue or argument in which the evidence and reasons for ideas are examined. The skills required to explore and critique each other's ideas and reasoning are consistent with the requirements of the 'speaking and listening' curriculum but the pattern of dialogue required in science may be novel. With planned opportunities, practice and support, teachers can help children to acquire the necessary skills to engage in science discourse. Children establish the habits of taking turns, listening carefully, expressing ideas and giving reasoned explanations; they should also critique, challenge and reflect upon their own and other's ideas. By these means, children and adults become resources for the development of

understandings in arguments that draw on evidence gained from experience, secondary sources, educational visits, field trips and empirical enquiries.

Fossils Formative Assessment Probes

Typical ideas	Formative Assessment Probe	Follow-up Questions
Children tend to focus on animal fossils and rarely mentioned plant fossils. Fossils tended to be almost exclusively linked with dinosaurs.	**Probe 1: Ideas about fossils** Children handle and observe real fossils. They think about and discuss their own and others' ideas, making their reasoning explicit.	How would you know that something is a fossil? What do you think fossils are? What do you think they were before they became fossils? How old might fossils be?
Children may suggest that the rock is responsible for the organism's death by falling on and burying it. They may express the view that the solid animal sinks into the rock.	**Probe 2: Sequenced drawings of how fossils are formed:** Sequenced drawings encourage recording of ideas about what the organism was like as a living creature, where it lived and ideas about how it changed. The time and cause of change can be added as annotations.	How do you think fossils are formed? Draw pictures that go back in time to show the steps in the process of a fossil forming. Why do you think it has changed in the ways you suggest? How long do you think it takes to change in the way you suggest?
Children tend to think of the fossil as the entire original organism. They tend to be thought of as found randomly on beaches, caves, etc., difficult to find and very valuable. Thinking about the structure of the organism may lead to consideration of the habitat where the organism was likely to survive and the places where fossils might be found.	**Probe 3: Making a 3D model to show how the fossil looked when it was a living organism** Making a 3D model encourages new ideas about how the animal or plant might have looked before it became a fossil that may not be shown in 2-D drawings or speech. The shape, relative position and relative size of different parts of the organism may be shown in a model. The ideas communicated in models are claims that can be compared, explained, critiqued, challenged and reflected upon.	What did the thing that became fossilised look like when it was alive? How did the pattern and shape of the fossil help you to decide how to make your model? What part of what it was previously has become a fossil? How would the living thing have lived previously?

Variation Formative Assessment Probes

Typical ideas	Formative Assessment Probe	Follow-up Questions
Young children tend to believe that all seeds will grow into identical plants and grow to the same height; also that they will germinate at the same time and produce the same number of flowers or fruit as long as they have the same amount of water, temperature and light. Fruits such as apples will be expected to be the same size. Differences between plants may by differences in the age of plants or by different conditions for growth.	**Probe 1: Thinking about how plants might differ** Ask children to observe and measure common plants (e.g., dandelions) that they can handle or measure, or to think abut the growth of seeds that children can sow.	How would you check whether the plants of the same kind (e.g. dandelions, or seeds that have grown) are all the exactly the same? Are there any differences between them? Explain why you think so. Do you think seeds you sow will grow into plants that are exactly the same or will there be any differences between them? Explain why you think so. How would you compare or measure the plants?
Children tend to believe that animals within a species are identical so 'all sheep are white', or 'all ducks have yellow beaks'.	**Probe 2: Children think about how animals might vary** Invite children to think about and explore the variability in animals they are familiar with, such as frogs, tadpoles and snails. These animals tend to be readily observable in the classroom or outdoors.	Do you think all the animals of the same kind (e.g. frogs) are all exactly the same? Explain why you think so. How could you check if animals of the same kind are exactly the same or different? What would you compare or measure to find out if they are all exactly the same? How can you explain any differences you see?
Differences between people need to be treated sensitively although differences in hand span, foot length and height, or running & jumping prowess are more likely to be safely accessible. Children tend to express surprise that there are differences in measurements of their hand spans, etc. As they describe the patterns in their results, some describe the extremes; the low frequencies of the largest and the smallest measurements. Some may focus on the most common outcome. A few might describe the shape of the distribution as 'hill' shaped.	**Probe 3: Children consider how they may differ from their friends.** Ask children to observe, measure and record their handspans, foot length and height and compare and describe the pattern of variability across the class**.**	How could you compare and measure the heights or handspans of everyone in your class? How could you record your results? Explain your reasons. What do your results show about the features you measured? How would you describe the shape of your chart or graph? If you collected the same data for another class what would the shape of the pattern in the results look like? Why do you think it might be that shape?

Inheritance Formative Assessment Probes

Typical ideas	Formative Assessment Probes	Follow-up Questions
Children recognise that seedlings and young plants look like their parent plants. They tend not to be aware that the characteristics are inherited from one generation to another. Plant life cycles may be an interim step towards a fuller understanding of inheritance.	**Probe 1: How do young plants come to look like their parent plants?** Children can observe some of the familiar plants around school (dandelions, etc.) As they talk about the features that a young plant might get from the parent encourage them to sort their ideas into groups showing 'features that a plant gets from its parent plant', 'features that are brought about by its environment (how and where it grows)' and a third group of 'unsure' ideas. Ask for their reasoning.	How are growing seedlings like their parent plants? What features do the new plants get from the parent plants? Explain your reasons. What features are brought about by where it grows and growing conditions? Explain your reasoning. Why is it important that plants inherit characteristics from the parent plant? Which characteristics in young plants help them to survive and in turn help offspring of the same species to survive?
Children may be aware of resemblances in appearance, and temperament etc. between parents and their offspring. They tend not be aware of heritable traits and how information is passed between one and more generations. Commonly expressed ideas include the view that offspring are an average of mum and dad or that particular resemblances are from the mother, others from the father.	**Probe 2: How do animals come to look like their parents** Children should observe a selection of local animals or pictures or animals. As they talk about the features that a young animal might get from its parent encourage them to sort their ideas into groups showing 'features that an animal gets from its parent' and 'features that are brought about by its environment and a third group of 'unsure' ideas. Encourage them to explain their reasoning.	How is the young animal like its parents? How do you think it happens that young animals come to look like one or both of their parents? Why is it important that animals inherit characteristics from the parents? Which characteristics in the young animals help them to survive and in turn help further offspring of the same species to survive?
In the context of selective breeding, children tend not to appreciate the need to control which animals breed. Many are likely to suggest that animals lacking preferred traits might be trained to develop these characteristics. Children's beliefs in fairness and equity tend to lead them to find value in animals lacking preferred traits.	**Probe 3: How could you 'design' and breed an assistance dog?** Encouraging children to imagine they are dog breeders taps into their enthusiasm for imaginative role-play. Posing the challenge of breeding a particular kind of dog gives a purpose to the selection process. Children have to bear in mind how the animal is to be used as well as the variety of possible traits: for assistance, for racing, for herding other animals, etc.	What characteristics would you want in your assistance dog? How would you try to make sure you bred puppies with these characteristics? Where have you heard the term DNA? What do you think DNA means? How do you think DNA might affect the way offspring resemble their parents?

What do you know about DNA?

You have probably heard experts talking or writing about 'DNA'. This may have been in newspapers, on TV, perhaps the Internet, or maybe in conversations.

1. Describe some of the situations or contexts in which you have heard people referring to DNA – as many different situations as you are aware of.

2. Even though you might not yet have learned about DNA in your science lessons, you have probably picked up some ideas about it. We are not looking for 'right answers' because this is not a science test. It is about pupils' everyday knowledge, so we would like you to write what you have picked up about:
    a. Where in the human body is DNA found?
    b. What does it look like?
    c. What does it do?
    d. What could a scientist tell you about yourself from an analysis of your DNA?
    e. Any ideas about how medical people use DNA?
    f. Any ideas about how the police use DNA?
    g. Any ideas about how biologists who study evolution (palaeontologists) use DNA?
    h. Anything else you can add about your knowledge and understanding of DNA?
    i. Some companies can offer you an analysis of your DNA. What sort of things do you think they would be able to tell you about yourself?
    j. Have you heard any concerns expressed about scientists' research with DNA? Do you have any concerns or views about this line of research?

In 2003, the successful completion of the Human Genome Project was announced.

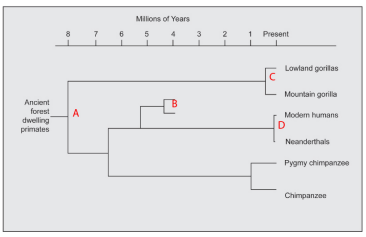
Have you heard of the Human Genome project? Write what you know about the human genome, the project, and how it might be useful to individuals and society.

3. 'Three-parent' babies have been in the news.
    a. What do you understand about 'three-parent' babies?
    b. How are they produced? Why should parents want to have such babies?

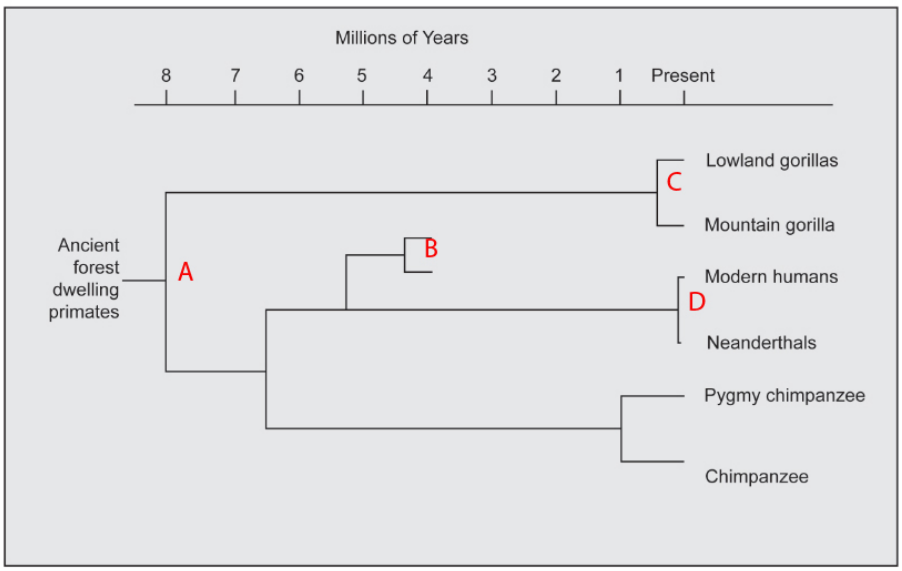
Deep time Formative Assessment Probes

Children's science ideas collected in the research	Description of each 'Thinking Allowed' probe	Questions to be posed to elicit and develop thinking
Ideas about the overall duration of geological time tend to be hugely underestimated. The scale of Deep Time compared to familiar markers of the passage of time is likely to be unfamiliar. Time lines used in the history curriculum may be familiar, but the scale of evolutionary time (aka 'geological' or 'Deep' time) needs a bespoke approach.	**Probe 1: Children construct their timeline to represent Deep Time** Children construct a time line walk of 450 metres in which one metre represents 10 million years and one cm stands for one million years, one mm for one hundred thousand years.	What overall time scale will you need to show evolution? Explain your reasoning. What landmark events in evolution do you think should be included in your timeline? Explain why you think these are important and should be included. What time do you think each of these events happened? How would you write these numbers so that you can add the events to your time line?
Children may have difficulty representing the large numbers associated with deep geological time as numbers.	**Probe 2** Children write down the numbers associated with some key geological events**.**	How would you write four and a half billion? How would you write four thousand five hundred million?
As well as overall magnitude of the scale of evolutionary time, ideas about the sequence and duration of events can also be probed. For example, the time of the dinosaurs, the first plants, animal life emerging from the oceans, can all be discussed.	**Probe 3.** Using a ream (or half ream used double-sided) of paper, children make their own book of important events in Deep Time. Their decisions about the events to be included, the sequential order of events and how many years might be represented by a single page reveal understandings that can form the basis for children's further research.	How many pages will you need to show all of evolution? How many years will each page stand for? How will you work it out? When did each of these events happen? Why do you think the events you have selected are important to be included in your book?

Evolution Formative Assessment Probes

Typical ideas	Formative assessment probe	Follow-up questions
Children tend to think of evolution as change happening to individuals as they grow (maturation) or as change due to metamorphosis. They rarely suggest examples of plant evolution. Those thinking of human evolution tend to think of a single straight-line sequence of change from apes to humans. They may think of evolution as involving a trait acquired in a lifetime and transmitted to offspring (Lamarckism).	**Probe 1: Thinking about evolution** Children draw and write to show their ideas about evolution.	What do you think is meant by 'evolution'? Draw and write with examples that help you to explain your reasoning. How do you think evolution happens? How long do you think it takes? Why do you think living things evolve?
Children can be introduced to cladograms (branching diagrams). Their attempts to interpret simplified Trees of life and Cladograms may show a basic understanding of some features such as the direction of time, how extinction and speciation are shown. Increasing recognition of evolution as happening along different routes rather than along a linear sequence might be expected.	**Probe 2: What do you think is shown on this 'cladogram'?** Introduce the simplified Cladogram to children. Explain that the diagram shows primate evolution. Encourage a class debate as a way of eliciting ideas about how humans evolved.  The diagram shows some of the different lines of descent, time in millions of years, some of the organisms currently alive and some branches ending with extinction.	'What do you think is happening or happened at A? Why? What do you think is happening or happened at B? How would you tell the story of the living things at B? What do you think is happening or happened at C? What do you think is happening now to the two living things at C? What do you think is happening or happened at D? How would you describe the story of the two living things at D?
Children tend to be aware of examples of animals that have become extinct but rarely mention plants. Overwhelmingly, they mention the extinction of dinosaurs. Some of the causes of extinction that are suggested include environmental changes, climate change, predators and competition.	**Probe 3 How do you think extinction happens?** Encouraging a debate about the different living things that have become extinct provides opportunities for children to express their understanding of the different species that have become or are becoming extinct and the reasons for their extinction.	What do you think 'extinct' means? What animals or plants do you know of that have become extinct? Why do you think some species of animals and plants become extinct? Can you think of species of animals and plants that might be in danger of becoming extinct?

Simplified cladogram of primate evolution



Possible questions

Explain with reasons what you think happened at A.

Explain with reasons what you think happened at B. How would you tell the story of the living things at B?

Explain with reasons what you think happened at C. What do you think is happening now to the two kinds of gorilla at C?

Explain with reasons what you think happened at D. How would you describe the story of Modern Humans and Neanderthals at D?

Acknowledgement
The Nuffield Foundation is an endowed charitable trust that aims to improve social well-being in the widest sense. It funds research and innovation in education and social policy and also works to build capacity in education, science and social science research. The Nuffield Foundation has funded this project, but the views expressed are those of the authors and not necessarily those of the Foundation. More information is available at www.nuffieldfoundation.org