Chapter 12
Learning in Physical Science Opportunities at Natural History Dioramas

Sue Dale Tunnicliffe, Rebecca Gazey, and Eirini Gkouskou

12.1 Learning Everyday About Science

Children begin formal school already having experienced some everyday science in their lives. In countries such as England, many children attend preschool from 3 years of age. Increasingly, places for families offer sessions for an adult and child aged 2 years old to 'Stay and Play' (Lloyd et al. 2016) where the activities offer science learning experiences. If you observe young children at play, they are purposeful in their 'work'. They investigate, ask themselves questions and try out strategies, apparently to 'see what happens' and they try to explain what they observe in their own terms from their existing knowledge.

Psychologists assert that aspects of science are learnt in different domains; one for biology and one for physical science. Moreover, the ideas of a child about what scientists identify as physical science are different from those of scientists, hence being children's science (Hadzigeorgiou 2015). Children of different ages, and thus different stages of cognitive understanding, interpret phenomena differently. Their 'common sense' ideas are modified as they acquire new experiences and make their own observations. Additionally, they integrate information and explanations, received from a variety of sources such as teachers, into their mental model. Driver et al. (1985) suggested that the claims of young science learners are similar to those

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of earlier societies, in particular those in western Europe. Present ideas developed in the advent of scientists who made their pronouncements based on evidence and often suffered for it, for example *Galileo Galilei* in the Renaissance in Western Europe. Whilst developmental psychologists discuss the process of learning sciences, biological science appears to be an exception to the accepted idea of how children learn; biology is different because we are members of the biological domain and are in agreement that conceptual development is a specific construction of the physical world (Inagaki and Hatano 2008). As the learner interacts with their environment they find patterns and develop a store of knowledge as past ideas are modified and developed in the light of further understanding.

Ideas are modified as fresh understanding and are assimilated. These mental models are applied regularly and some do not change even in adulthood, particularly if they have not encountered any further information. For example, a group of mothers at Sreepur Village, Bangladesh, who had not received schooling and were attending a session of 'everyday science' were adamant about their explanation of shadows and explained thus *"Sunray comes from the sun but sometime the sun swallowed the earth. Because sun is grateful to the moon. That's why earth become dark sometimes*" (translated from the Bangla by Angshuman Sarkar science facilitator). Children of different ages and thus different stages of cognitive understanding, interpret phenomena differently. Their 'common sense' ideas are modified as they acquire new experiences and observations. Thus, the same question asked to say a 6-year-old, an 8-year-old and a 10-year-old is likely to be answered differently.

Is there a place for developing physical science awareness? The ideas of early learners are not 'misconceptions', as defined by teachers well versed in the school and scientists science. This is children's science, referred to by some researchers as 'naive theories', or alternative conceptions (Driver et al. 1985). Such concepts aid the understanding of 'school science" which may lead to a 'scientists' science' (Osborne et al. 1983). It is argued that young children have the ability to acquire viable realistic concepts of the living world when involved in relevant activities where they are instructed. We argue as teachers that children, through their own observations, construct an understanding from their own experiences. Children make acute observations and explain phenomena through applying 'such personalization'.

The more similar the target for interpretation is to the human (that is themselves), the easier it is to explain biological phenomena in personal terms. Such use of the self as a template was explored extensively by researchers such as Susan Carey (1985). Hence, the use of anthropomorphic explanations or examples when visitors of all ages interpret animal structures and actions, whilst looking at animal exhibits is not surprising (Patrick and Tunnicliffe 2013). However, whilst children have some everyday knowledge of everyday animals and plants (Patrick and Tunnicliffe 2013), and know of some non-endemic animals such as lions and rhinos from media sources they have more restricted knowledge of plants (Gatt et al. 2007). Cacti, for example, were not recognised as plants, a term that is used frequently by young children synonymous with flowering plants. It follows that when looking at natural history dioramas too, visitors interpret that which is noticed in a similar way. Cognitive psychologists however, regard Scientists' science as belonging to a different domain. However, the viewers of natural history dioramas do not appear to spontaneously notice physical science in action.

12.2 Physical Science and Primary Schools

An important issue in considering physical science in particular is that in many early years settings the educators, be they carers, primary/elementary teachers or chaperones on school field trips, are not confident in their own science understanding. In particular it seems in the area of physical science and the nature of science. Indeed, in a sample of primary schools by the Wellcome Trust, only 6% of science subject leaders were found to have a degree containing any science (Wellcome Trust 2013). Furthermore, it was also stated in the UK Parliament in 2014 that only 8.3% of teachers in primary schools had science degrees (Outlined in answer to House of Commons written question 218,919, Parliament UK 2014). Thus, it is not surprising that primary teachers often feel uncomfortable teaching physical science. However, offering workshops in professional development on physical science and animals can interest teachers and provide them with more confidence to tackle simple physics, such as forces, with their classes and look for applications. Hence, looking at animals in zoos and museums is a different way of assisting children to understand some aspects of physical science in action. Furthermore, it is increasingly recognised that there are 'Big Ideas' of science knowledge and that the curriculum should be narrowed from a broad, uncoordinated content, to one of greater in-depth learning. Moreover, it is also recognised that science teaching of whatever kind should be in applied to an everyday context (Harlen 2015).

Physical science concepts are acquired in different psychological domain and hence are different to biological concepts (Inagaki and Hatano 2008). A domain is identified as a set of phenomena. So, children make sense of what they see from what they know, which can be termed 'children's science'. Some physical phenomena are given biological explanations. For instance, young children assume moving objects are endowed with biological powers such as movement at will. The possession of life is often attributed to physical phenomena such as clouds and fire. Tomkins and Tunnicliffe (2007) noticed this use of biological attribute of movement to inanimate objects in pre-secondary school aged children's responses to items on a nature table.

12.3 Recognising Physics in Action

People rely on the content of their mental models to name or identify that which they are observing. The following work described here, is a preliminary attempt to find if children can identify any manifestation of physical science in action in

Fig. 12.1 Primate diorama in Gallery 1 where these reported workshops were conducted. The collection of primates is in the diorama at the end wall. Copyright Nikhilesh Havel. (Reproduced courtesy of the Trustees of the Powell-Cotton Museum)

natural history dioramas. Of particular interest is the topic of forces, which is shown in movement or balance by the way the animals are displayed; bending their heads down to drink from a water hole for instance, or to graze on ground covering vegetation. Balance is also particularly shown in arboreal animals, such as the primates in the Primate Diorama in Gallery 1 at the Powell-Cotton Museum (Fig. 12.1). Position of eyes and ears, light and sound receptors, as well as movements and adaptations to the environment which the featured organism naturally inhabits, can also be identified.

Observing natural history dioramas spontaneously and then cued provide opportunities to identify physics in action, *albeit* at ‘a moment frozen in time’ as Reiss and Tunnicliffe (2011) describe in a Museum of Scotland diorama, which shows a pair of wolves frozen in their chase of a wild boar in a Caledonian pine forest.

Most animals, when alive, can make some observable movement and most possess the power of locomotion – being able to move from one place to another. Balance and centres of mass are phenomena which can be observed in natural history dioramas, as well as structures to bear the mass of the animals. Appendages, particularly legs in land-living animals, such as those of the elephant, and inquiring why the legs of these animals are much bigger in diameter than those of the antelopes or indeed of the giraffe in the diorama. Such observations can lead to the understanding of surface volume ratio and the needs associated with being warm blooded and maintaining body temperature. Observations of basic physics in action such as the optimum position for the legs, in quadrupeds then bipeds, can be developed through using modelling clay and matchsticks to try out varied positions of legs on a modelling clay ‘body’.

At the Kashmir diorama in Gallery 2 (Fig. 12.2) of the Powell-Cotton Museum a boy exclaimed, *“Look, See! At that animal, he’s fallen off. The wolf’s made him fall off*’. A goat is depicted falling from the top of a cliff where there is a wolf as well. An observation such as this would provide an opportunity to discuss further gravity and forces.

Fig. 12.2 Kashmir Diorama in Gallery 2. Copyright Nikhilesh Havel. (Reproduced courtesy of the Trustees of the Powell-Cotton Museum)

12.4 The Galleries of the Powell-Cotton Museum and Opportunities to Develop Physical Science Understanding

The dioramas and galleries are described in detail, there is thus repetition of such in the companion book (Natural History Dioramas – Traditional Exhibits for Current Educational Themes: Socio-cultural Aspects) where a different topic is discussed but referring to the same dioramas. Gallery 1 is displaying the animals of north and west Africa, and India (shown in Fig. 12.1).

Today, Gallery 1 is the first gallery visitors see on entering the museum. However, it was actually the last gallery built by Percy Powell-Cotton himself, being completed in 1939 the year before his death. The large diorama to the left presents many species from across northern Nigeria and Chad.

The central diorama showcases the amazing diversity of Africa's primates and the different landscapes in which they live. The diorama to the back right of the gallery depicts animals from the Indian state of Madya Pradesh (which translates as 'Central Province'). The final diorama, to the right of the gallery, incorporates a

Fig. 12.3 Diorama in Gallery 3. Copyright Nikhlesh Havel. (Reproduced by courtesy of the Trustees of the Powell-Cotton Museum)

variety of landscapes and animal habitats. The far left represents the lusher woodlands around the Mkuze River, in northern KwaZulu-Natal, South Africa. The central part of the diorama, formed of a high rocky crag, represents the Ethiopian Highlands, an area where land levels rarely fall below 1500 m. The Mountain Nyala are only found in this region and have become a rare and endangered species. Finally, the desert habitat at the front of the case showcases the diversity of species found in the Sahara Desert (Powell Cotton Museum 2015a).

Gallery 2, called 'The Pavilion', was the first gallery designed and built by Percy Powell-Cotton and the starting point for his relationship with the taxidermist Rowland Ward, who helped build and design the museum's famous natural history dioramas (Powell-Cotton Museum 2015b; Fig. 12.2).

Gallery 3 was the second gallery to be built, added on to the 'Pavilion' in 1909 (Powell-Cotton Museum 2015c). The dioramas in this gallery focus on species from equatorial Africa and the plains at the edge of these forested areas. Galleries 2 (Fig. 12.2) and 3 (Fig. 12.3) equally have the science potential to explore physical concepts but they were not used in this present pilot study.

The following table (see Table 12.1) is a summary of some of the physics concepts that are illustrated in the dioramas of the Powell-Cotton Museum. For example, gravity and forces maintaining the balance of animals and the position of the legs, especially when the neck is bent toward a water source. Linking biology with physics, for example zebra and antelope are ungulates (Artiodactyls). They are two toed hoofed animals. Their weight is distributed between two toes, and the third and fourth, which form the hooves. The one toed, or odd toed, ungulates, for example rhino (Perissodactyls), have their weight carried through by the one hoof. The various physics principles, which are manifest in the animals, are listed below. They can be identified in looking at any animals, live or taxidermy specimens, but are particularly effective to notice in a natural history diorama where the animals are exhibited in action in a realistic context (Tables 12.2 and 12.3).

Table 12.1 The Watering Hole and the Indian Forest dioramas in the Primate Gallery, Gallery 1

Diorama	Physics ideas	Animals
The watering hole (long full wall diorama on left in Fig. 12.1)		
	Camouflage	Bongo (stripes), Zebra
	Stripes	Mongoose
	Countershading	Oribi
	Pattern/sunlight	Giraffe
	Colour blending	Antelope
	Flight (forces)	Butterflies
	Reflection	Oribi
	Centre of gravity, spreading load	Giraffe
	Stray legs/heavy animal	Buffalo split hoof wider surface area sand
	Thin legs light animal	Gerenuk (on 2 legs)
	Position of legs	Quadrupeds
	Heat loss	Fur
Indian Forest (right hand side in Fig. 12.1, adjacent to the all primate end wall diorama)		
	Stripes	Tiger
	Forces (pull, pushes)	Sloth bear claws
	Forces (gravity)	Leopard & antelope in the tree
	Push	Porcupine spines (also adaption of fur/hair)
	Gravity	4 horned antelope off ground (leap up and down)

Table 12.2 Primates (Gallery 1 in Fig. 12.1, middle)

Diorama	Physics ideas	Animals
Primates		
Balancing	**Balancing:** Walking on branch	Central African red colobus, monkey
	Balancing: Sitting on the branch	Black and white colobus
	Balancing: Standing by tailing	Chimpanzee
	Communication	Gelada baboon, *Theropithecus gelada*

Table 12.3 The North Africa diorama in Gallery 1, on the right hand side nearest entrance (Fig. 12.1)

Dioramas	Physics Ideas	Animals
Gallery 1		
	Camouflage	Addax
	Camouflage (different version)	Red neck gazelle
	Balance	Addax
	Colour blending	Antelope

12.4.1 An Exemplary Guide to the Potential Physics Concepts in Gallery 1 of the Powell-Cotton Museum

Some museums have made an active effort to involve visitors with the content of their dioramas by providing artefacts related to the narrative in front of the dioramas, so visitors can not only mentally interact and interpret the narrative but also physically. The Panorama at the University of Kansas Natural History Museum, a 120-year-old, nearly 360-degree-view diorama that embodies a historic first, in the representation of nature to the public, has introduced such physical action interpretative items. This iconic exhibit represents ecological regions extending from the Arctic coast through North America into tropical rainforest. These include two interactive stations with touchable objects and activities in museum discovery guides.

Such action labels lead to the pilot studies conducted at the Powell-Cotton Museum in England to explore the spontaneous recognition of physical science in action in the dioramas and whether this could be increased by trigger workshops to refresh primary school children of science concepts they had studied.

12.4.2 Primate Diorama in Gallery 1 (Shown in Fig. 12.1)

Two pilot studies were undertaken; one with two 11-year-old boys who had studied science at their state school and were frequent visitors to this museum. The other group was of 15 mixed gender and ability 8-year-old children, half of whom had visited the museum previously. Museums in the United Kingdom run courses for parties of school children, as do zoos and botanical gardens. The majority of these courses are linked to the topics required to be studied in state schools relevant to the national curriculum of the country of residence.

The two boys were invited, each with a researcher, to look at the African diorama (on the left in Fig. 12.2) and to tell us whilst looking at the diorama, "what is it about?" Their response was of observations made with some inferences. Boy 2 replied, *"Desert. Wild variety of animals doing all kinds of things. A giraffe reaching to eat. Different species of animals. Different zebra animals, doing different things as a group"*. Boy 1 was interested in that, *"this diorama puts together animals in the same space. The diorama is like it combines different animals in arrangement for the visitor."*

His response to "Where are the things you notice?" was about the effect of the dioramas. He commented, "*It's a freeze framework of the wild, a short image, very impressive, they also have created the background representation of the wild.*" Whereas Boy 2 replied, "*leaves and animals and it really seems I am there and this makes the difference (to learning science at school)"*. The responses to what the animals were doing were factual and descriptive. Interest was expressed by Boy 1 in the movement of animals portrayed but with sensitive interpretation of positions; he highlighted one antelope that was looking back over its shoulder "*as if she's lost something and she looks round to spot it. The antelope's attitude is like a tourist's attitude in a new place when confused.*"

12.5 Workshop in Middle of a Visit

In another gallery, kept for activities, the boys were introduced to the 'equipment' for a workshop, namely modeling clay and some small sticks (cocktail sticks) to represent legs. They were asked to make an animal that could stand upright and be stable with 4 legs. One boy immediately made a horizontal rectangle shape and fixed 4 legs, one at each corner of the body. The other boy decided to make a 4-legged animal with a vertical cylindrical body. This was resistant to standing up! He eventually decided to reorient his 'body' so he had a rectangular one lying horizontally. Then he fixed the legs together in the middle of the underside of the 'body'. Eventually he decided to try positioning the legs at corners and was pleased that this produced a stable model. The boys were invited to stand their 'animal' on a piece of card which acted as a 'wobble' board and to investigate how long their animal could stand for as they increased the backward and forward movements of the board. They found that by having the legs not coming down vertically from the body but at an obtuse angle (slanted) the model animals were more stable. The boys were asked to add a neck and head onto their model 'body' and then show how the giraffe-like model animal could drink by simulating the visit to the water hole, as modeled by a giraffe in the waterhole dioramas in this Gallery. They found that the animal toppled over until they had made the area between the legs wider and shallower. They remembered they had learnt about forces in school science but said it had not related to anything in their everyday world, like animal movement.

On returning to the dioramas in Gallery 1 the boys added these inherent science ideas of balance, stability and centre of gravity to their interpretation of the diorama. Boy 1 reported that *"the giraffe starts bending her legs to get her head closer to the ground. I can see stability in the animals. The legs support the position of the head. Each part of the body supports because, for example, one leg of the giraffe cannot work without the other legs."* He noticed the information provided by the body of the animal; the spreading of legs increasing the surface area underneath, spreading their weight on their legs and nobody standing on one leg.

Boy 1 used his own body to show how an animal altered the position of its legs in order to bend down to drink and not overbalance. He was intrigued and continued identifying animals that were bending down. Boy 2 also noted that the buffalo had wide legs and the antelopes had thin stick legs. He postulated as well that animals with big ears, such as the Bongo, could hear better and needed to because it was dark in the rain forest.

The boys had also been asked to balance on one leg as a starting activity and were intrigued, particularly looking at the Gallery 1 primate diorama, to now notice that animals sitting on branches must be balanced and had to walk one leg in front of the other along a huge branch. Moreover, the study shows that children can identify science in action in animals. Thus, in addition to the usual workshops on biodiversity and conservation, basic physical science has its place in natural history museum education.

Peer group response to dioramas and the effects of a series of simple workshop activities with the 8-year-old children resulted in a greater awareness of the science in action in the dioramas. The activities tried were: to make four legged animals from modeling clay, to look at balance and stability, and to match colour and shape cards to colours and shapes of the animals (see Table 12.4).

The responses of 3 groups of 8-year-old primary pupils to the colour matching activity and a shape matching activity are presented at the Tables 12.4 and 12.5 below.

Also, laminated cards of the outline of simple geometric shapes enabled the children to find the basic shape in the animals and name the animals (see Table 12.5).

Finally, the museum educator had constructed a long 'line' out of thick paper an inch wide, which was adhered to the floor. Children were asked to walk along it

Table 12.4 The response of boys, girls and mixed groups to the Colour activity, carried out in gallery 1

Colour	Animals		
	Boys group	Girls group	Mixed group
Pink	Giraffe tongue	Gelada Baboon, Gorilla's mouth.	
Red	Baboon	Gorilla's eyes	
Beige	Donkey, Addax, Dorcas Gazelle	Western Lowland Gorilla	Gazelle, Ass, Oryx.
Brown	Swayne's Hartebeest, Roan Antelope, Beetle	Porcupine, Mona Monkey, Bush Pig, Addax, Talapoin, Guenon, Zebra, Gorilla's teeth.	Suni, Lechwe, Wildebeest, Giraffe.
White	Black and white Colobus, stripes on the Nyala.	Colobus Monkey.	
Black	Sloth bear, Bush pig, Cape Buffalo, Monkey.	Bear, Gazelle's horns, Udad's horns, Colobus Monkey, Chimpanzee, Gorilla, Bush Pig, Cape Buffalo	Gorilla, Buffalo, Chimpanzee, Colobus, Bush Pig, Giant Forest Hog.
Orange	Crab	Tiger, Leopard	
Black and white stripes	Zebra, Beetle, black and white Colobus, Tiger's face	Zebra	Zebra, Colobus
Cream with brown splodges	Giraffe, Cheetah	Giraffe	

Table 12.5 The responses of boys, girls and mixed groups to the Shape activity carried out in Gallery 1

Shape	Animals		
	Boys group	Girls group	Mixed group
Circle	Eyes, pond, leaves, Mrs. Gray's Lechwe	Eyes, Sloth Bear's head, Hyena's nose, Buffalo's nostrils.	Monkey's faces, Monkey's noses, Tiger's feet, Nest.
Semi circle	Zebras, ears, bananas.	Gazelle's nose, Tiger's ears, Buffalo's legs.	Hooves, bananas, claws, Monkey's nose, Ass' nostrils, Animal's nostrils.
Oval	Leaves, Deer's body, eggs, Mongalla Gazelle.	Buffalo's ears.	Boar's nose, leaf, noses, bodies, ears, faces, eyes, Beetle, Tiger's tail.
Cylinder	Giraffe neck, tree branch, nest, legs, horns, Monkey torsos.	Buffalo's legs.	Animal's legs, feet, tree, horns, tails, paws, claws, bananas.
Rectangle	Monkey torso, head, rocks.	Edmi Gazelle's body, Sloth Bears claws, Baboon's foot, Bush Pig's leg.	Rocks, bodies, Ass' body.

normally, finding they had to put one foot in front of the other to stay on the line, and then on tip toe and keep their balance. Children found that when walking on tiptoe they needed to use their arms in order to maintain their balance.

The lesson that emerged for us from these preliminary workshops is that primary science is not taught within a meaningful context in primary schools. The children needed a preliminary view then a workshop or in situ activities and a second viewing of the same diorama when the children are able to identify science in action.

12.6 Conclusion

Physical science principles are implicit in observing the living world and these life-sized representations of a moment in time, whether a faithful representation of a known scene or a conceptual construction diorama illustrating biogeographic principles provide the opportunity. School science, in the primary school at least, is not taught within a familiar context for children and they do not use school-learnt knowledge when interpreting, in this case natural history dioramas, until they have been cued into the science concept with some 'hand-on' activities. The plants and animals included in natural history dioramas display physical science in action through the positions in which they are exhibited; upright, flying, swimming, camouflaged, bending or balancing for example, as well as providing clues for visitors to recognise the earth science element from the habitat portrayed. Biodiversity learning can be amplified by the recognition of manifestations of other sciences within any one diorama.

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