Chapter 11
Using Object-Based Learning to Understand Animal Evolution

Paul Davies and Joanne Nicholl

In London in 1828 in Bloomsbury, then, as now, a fashionable district of central London, home to the British Museum and Library and University College London (UCL), Robert Edmund Grant established the Grant Museum of Zoology at UCL (see Fig. 11.1), a collection designed to support students of zoology in understanding comparative anatomy and dissection. Prior to moving to London, Grant has lectured at Edinburgh University, during which time he tutored Charles Darwin, assisting him collecting specimens and encouraged his early thinking about evolution. Grant's interests then moved further towards zoology and, in 1827, he was appointed Professor of Comparative Anatomy at University College London. He was the first Professor of Zoology in England and campaigned for the development of a zoological collection, the first in the U.K., the fruits of which we see in the Grant Museum of Zoology, UCL.

This chapter explores why places like the Grant Museum are important, not just for specialist, learned activities, but also for their role in fostering cultural awareness of the natural world and how influential they can be in helping people understand what it means to be human and our relationship with other animals. By considering the rise of natural history collections and the special place that objects play in teaching and learning about animals, we examine a project designed to support pre-service teachers in their thinking about how animal material can help them, and their students learn about biological evolution and argue for a renewed analysis of how we think about collections and their meaning to society.

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Fig. 11.1 The Grant Museum of Zoology, UCL

11.1 What Are Natural History Collections?

The early incarnations of natural history collections were not designed for rigorous academic study. Rather, they were used to either begin making sense of the natural world, as in the collections of Aristotle, or as a way to better understand God's great design, as in the collections of Albertus Magnus (Ashworth 1996). The contrast here is stark. For Aristole, it was for humans to describe and order nature, for Albertus, the 'natural law' of nature displays the omnificence of God and help him argue for cases of design and creation. These collections evolved slowly to become, by the mid seventeenth century, celebrated 'cabinets of curiosities'. One of the earliest and most important of these collections was established by Ferrante Imperato, who made it famous through his *Dell'Historia Naturale* (Fig. 11.2). Established in Renaissance Naples, this collection of gems, rocks, plants and animal materials, plus published catalogues, was the first to organize and use specimens to try and better understand how nature itself is arranged in the natural world.

Cataloguing and making sense of the living world was epitomized in collections of Linnaeus, both through his personal collections and the natural history collection he established at the University of Uppsala, Sweden (Koerner 1996). The collections of Linnaeus were developed to reflect his notion that 'the earth is then nothing else but a museum of the all-wise creator's masterpieces, divided into three chambers' (Linnaeus 1754). And through this we are left with a powerful effort to organize the natural world in Linnaeus classification, as revealed in his *Philosophia botanica* in 1751. Of course, the Linnaean classification systems does not come about through

Fig. 11.2 Engraving from Ferrante Imperato. The Cabinet of Curiosities. (Image from Wiki: "RitrattoMuseoFerranteImperato" by (Anonymous, for Ferrante Imperato). Original uploader was Wetman at en.wikipedia – Transferred from en.wikipedia; transferred to Commons by User:Shakko using CommonsHelper.(Original text: http://www.ausgepackt.uni-erlangen.de/presse/download/index.shtml). Licensed under Public Domain via Commons

chance. Using his collections, Linnaeus worked hard with his students in Uppsala, struggling between using folk and common species names, towards a universal and highly organized system which recognized relationships and gave a common language to classification (Koerner 1996).

At about the same time, in England, Hans Sloane was establishing his collection of anthropological and biological objects. As a cabinet of curiosity, this collection was housed in his London home, which was something of a spectacle in eighteenth century London. Upon his death, Sloane bequeathed his vast collection of over 71,000 manuscripts, drawings, objects, gems, minerals and animal and plant material to the nation – an event which ultimately resulted in the founding of the British Museum, the world's first 'universal museum' (De Beer 1953). Continuing to expand its collection, in 1887, almost 60 years after Grant had established his collection, the British Museum moved its natural history collections to a new site in South Kensington, thus establishing the Natural History Museum. At the Natural History Museum, the general public was given access to 'rare materials' – objects that are not commonly seen in everyday life (Braund and Reiss 2006). These objects opened the eyes of many people to the wonders of the natural world. It is here, too, that a shift occurred in the focus and purpose of natural history collections. On one hand, the Grant Museum, and others like it, such as the Ashmolean in Oxford, were largely ‘teaching’ collections, with specimens displayed in taxonomic groups or dioramas. Such displays were designed to recreate nature in its natural form and were used many by academics. On the other hand, the Natural History Museum was designed to entertain and teach the public about science. About when major museums were shifting towards engaging with the general public, a marked change occurred in the focus of collections, from solely taxonomic to understanding physiological systems: museums started dividing their collections into galleries of physiology and paleonotology (Outram 1996). This change was coupled with a move away from seeing collections as having links with theology and moving, instead, towards viewing natural history as an expert science. Good examples of where this occurred are collections such as the Natural History museums in London and Philadelphia and the Museum of Zoology and Geology in Berlin. Perhaps the best example of this trend was that of the Museum national d’Histoire Naturelle in Paris. Here natural history academicians, such as Cuvier and Lamarck, amassed and studied collections to support their emerging ideas about the relationships between living things and how the natural world works, even as they were building a collection that was open to the public, designed to immerse them in the living world through a botanical garden, a zoological garden, and a specimen collection (Limoges et al. 1980).

Museums and collections continued to evolve and change, sometimes driving public opinion of their use. A significant moment for this came through the rise of ‘Science Centers’ with a more ‘hands on’ experiential design. The first of these was the Exploratorium in San Francisco. Founded by Frank Oppenhiemer, this museum allowed the public to interact with materials and explore the galleries with less focus on guided learning and with greater reliance on curiosity and exploration (1972). It was at this time, too, that many curators of natural history collections began to shift their focus from one of learning about taxonomy, evolution and physiology, to one where the central message was one of conservation (Millar et al. 2004). This new message was conveyed both through the research associated with the collections and also redirection ofthe the income they generated from admission charges and public donation towards conservation activities. This ‘new’ message for collections initially conflicted with the specimen acquisition processes of many collections – it is difficult to drive home a message about conserving species when many of those in the collection bear the hunting scars (Fig. 11.3). However, the new message slowly has taken hold, and the ‘public’ now largely recognizes conservation as a key justifier of collections; this message now helps justify public money funding many of these institutions (Turnhout et al. 2012).

Fig. 11.3 Rhinoceros skeleton at the Grant Museum of Zoology, with a bullet hole in left scapula (shoulder blade)

11.2 Learning About Natural History Through Objects

Serving a range of purposes, the use of natural history collections has changed in response to public opinion, funding and research foci, but at their heart they are places of objects. Whether they are preserved in jars, mounted skeletons, fossils or intricately arranged dioramic scenes, specimens remain at the very center of museum design and experience. The Grant Museum of Zoology contains a large number of 'wet' specimens, fossils and taxidermy animals. Among these are some very rare specimens, including the quagga (an extinct species of zebra), the dodo and the Tasmanian tiger (Chatterjee 2009). The objects of the museum are key to learning and interaction, but an object-based pedagogy is a more recent development in thinking (Chatterjee 2011).

Object-Based Learning (OBL) offers a range of experiences and supports learning and skill development across subject specific content, communication and teamwork, and observation and 'noticing', and it promotes curiosity and inquiry (Were 2008). Central to OBL is the role of touch. This means that OBL needs to be interactive. That is, the learner and the object need to exist in a dynamic relationship, with the learner having access to the object and receiving tactile feedback from touching it. Christos Giachritsis (2008 p. 75) argues that touch is the "ultimate sense which allows use to build a complete representation of the world." Certainly, touch plays a significant role in human development; the importance of touch is evident in watching infants explore their physical world through hand-on interaction (Paulus and Hauf 2011).

Touch is more than just a method of learning about the physicality of an object: it also islinked to an emotive response – the so called 'touch emotion'. As Solway et al. (2015) explains in detail, when holding something, the brain receives information about the object's weight, texture, size and temperature, which helps 'build a picture' of what the object is like. These sensations parallel affective responses, such as feelings of pleasure or excitement, and can evoke memories, much in way that smells can (Critchley 2008). These preliminary findings in OBL have suggestive, important therapeutic implications, and early work shows that interaction with objects can help with both physical and mental health problems. For example, Martin and Jones (2009) showed that using objects can help young people convey their emotions and identify the emotional states and needs of others. A key feature of the success of OBL comes in its role in multisensory experience. Clearly, for most people touch is accompanied by visual, auditory, verbal, and in some cases, olfactory interactions. This multimodal approach is potentially beneficial, for itprovides alternative approaches to interaction for learning and the development of mental models and memory (Baddeley et al. 2009). Alberto Gallace and Charles Spence (2008) provide a useful overview of the mechanisms of 'tactile memory systems' and show how sensory inputs from touch lead to long term, possibly even lifetime, changes that take place within a dynamic relationship between tactile stimulation and the brain. An important finding of their work is that the three-dimensional nature of an object affects learning. When presented with two-dimensional, or even 'raised' objects, learners struggle much more with visualizing the object, as well as with carrying out spatial manipulations in their brain. It seems that touching, holding and manipulating objects can help maximize learning. This outcome can be enhanced when the experiences take place in a social environment where talk, exchange of ideas and discussion can take place.

This framework for thinking about OBL is useful only if applied in real situations and, for the natural history collection, real situations take different forms. The Grant Museum of Zoology has a long history of using objects for education. For example, one aspect of the undergraduate biology degree program taught at the Grant Museum of Zoology involves students working with a 'mystery' object, which could be an entire specimen or part of a specimen. Taking an inquiry approach, through handling and drawing the specimen, and comparing it to other material in the museum, the students develop a hypothesis about its identity. The hypothesis then is written up with additional context, in the style of a scientific article, with the intent being to explore the evidence students think supports their conclusions. Another example, aimed at school students, involves students examining and handling a series of animal skulls and complete specimens to try and categorize them into feeding adaptations (Fig. 11.4). By touching the teeth, manipulating the jaws and comparing the specimens to others in the museum, the students develop insights into how biologists build up and use evidence to develop scientific theory. Such experiences scarcely resemble those of visitors staring at specimens behind glass doors, or looking at articulated skeletons devoid from any biological context! And it is one such experience that we now go onto explore.

Fig. 11.4 Skull adaptation activity at the Grant Museum of Zoology, UCL

11.3 Using OBL at the Grant Museum of Zoology

> Learning through argumentation at a place like this is really powerful, especially when you can imagine naturalists actually arguing it out in this building years ago. Peter, PGCE Science Secondary student (Biology)

Peter's impromptu comment was music to the museum curator's ears. Peter was at the museum, taking part in a project aimed at improving pre-service teachers' understanding and teaching of evolution. But here was the 'special' part. Not only was Peter at the only remaining university zoological museum in London, in an area not much bigger than a large living room – it was home to over 68,000 specimens representing the entire animal kingdom. Further, the participants were allowed to touch some of the specimens. They were able to pick them up, take them apart (where possible) and connect with them in ways that go far beyond simple observations.

Peter wasn't accurate in his statement regarding the use of argumentation[1], but his statement did showcase how the nature of the space influences people's ideas and enthusiasm for learning. He was not the only one that began this journey of realization; many of the pre-service teachers (PSTs) demonstrated a change in their perspective towards evolution and learning, some of which will be discussed later in this chapter.

[1] Rather than using argumentation, the workshops had an exploratory nature to them, and thus model 'inquiry science' rather than specifically argumentation.

All participants taking part in the project were trainee teachers, near the end of their one-year training on the UK post-graduate certificate of education (PGCE) course. The project attracted many different personalities and varied expertise; some of the trainees were training to be biology teachers, including Katerina who specialized in palaeontology, and Peter – a trainee physics teacher with a basic knowledge of biology but a passion to learn. The PSTs attended three workshops during the project, and each workshop encouraged them to engage in some way with the animal specimens. The main activities involved studying animal skulls, exploring the evidence for evolution using anatomical structures; and constructing phylogenetic trees – a branching diagram showing the relationship between various species based on their physical or genetic characteristics.

The workshop activities deliberately shifted from the passive transmission of knowledge, towards a more active approach in acquiring knowledge. This 'exploratory' nature of the workshops at first made many of the students feel uncomfortable. Vanessa, for example, kept repeating, 'but what animal skull actually is it?' Selima confirmed her facial expressions by stating 'I feel frustrated that I don't know this,' and Anna portrayed the anxieties of many science teachers; 'I am just pleased that I wasn't wrong *all* the time.' These conversations initially led to a tense atmosphere in the museum. The students were attempting to learn *about* the objects rather than learn *from* the objects. However, as time went on, their goals changed. The PSTs began to explore ideas more openly and they began to consider connections between the different animals and the stories the specimens could tell about the natural world.

Observing anatomical structures is one way that scientists review evidence for evolution. This approach was one that Charles Darwin used when he proposed his idea of natural selection. Homologous structures are those that appear in different animals that have similar anatomical characteristics that have derived from the same evolutionary origin. The homologous structures may not perform the same function (such as a dolphin's flipper and a human arm), but they have a common ancestral origin. Conversely, analogous structures are those that are not closely related, but do perform similar functions, or look as if they are similar in origin. The typical examples are the wings of bats, birds and insects. Structures that have lost most, if not indeed all, of their original functions, but still remain a structure on the species (such as the human little toe or the appendix), are referred to as vestigial structures. Allowing the PSTs to explore these structures through the specimens at the museum was a particularly effective way of getting them to recognise the concept of common ancestry. The PSTs became engrossed in comparing different structures such as a manatee and human's appendage. There was even debate surrounding the use of vestigial structures in providing evidence for evolution, where Karl highlighted:

> I disagree with what you guys are saying. With the coccyx, it shows there was some link to our evolutionary history. There is an element there that shows a hint of what we used to look like.

Using the museum to explore anatomical structures of different organisms brought to life the idea of divergent evolution. Being able to identify the similarities in animals set the tone to a more open and investigative atmosphere within the museum. Anna commented, upon returning:

> I liked looking at the snake. Even though it was completely different [to us], there is an echo of our ancestry in there and it is powerful.

The students had enlightening conversations about the paws of a wombat compared to the paws of a cat, and about a sea lion's skull compared to a lion's skull. They explored the size and similarities of a gibbon skull, and compared it compared to the skull of a chimpanzee, and they compared the skulls of a tiger and a lion. The opportunities seemed endless – but one aspect appeared to drive it: the 'knowledgeable other'. In retrospect, we under-estimated how little subject knowledge the PSTs were going to have on biological evolution. We expected the students to direct their own learning and understanding more than they actually did. Nevertheless, modelling to the students how to support them on their journey of discovery was useful, and it showed the PSTs what they would need to do later with their own high school students. It instilled the teachers with a drive to want to learn more, so they could evoke curiosity in others. The PST commented that being in a place such as the Grant Museum provided "proof of the similarities between animals," and they noted that "seeing the same bone on different species in the same position helped you see the links."

> I have never really been exposed to animal biology, I have just been immersed in human biology. Give me an alveoli any day and there would be no problem! Outside of school has really been my only experience of this type of biology rather than in school, which is pretty bad. Selima, PGCE science secondary student (Biologist)

A story such as Selima's is unfortunately common among biologists, especially when it comes to considering the concepts of evolution (Crawford et al. 2004). The problem continues for trainee biology teachers (Nehm et al. 2009). Those that study undergraduate degrees such as molecular biology, biochemistry and genetics sometimes may feel far removed from the natural world and the animals that live and have lived within it. I say this as a person speaking from experience: specialising in such topics as an undergraduate and then working as an editor for a drug-related journal meant that I was slowly detaching from the natural world. However, fortunately for me, that was true only until I became a Biology teacher.

Subject knowledge often has been identified as a crucial component of effective inquiry-based learning (Capps and Crawford 2013). When the PSTs were considering how to use the space and objects around them for future visits, they kept coming back to needing a 'knowledgeable other' or an 'information pack' which they could read before their visit. Discussing their subject knowledge led to a reflection by the PSTs on how much they really knew about evolution. The workshops taught some of the PSTs a few of the basic ideas spanning animal biology, such that turtles are vertebrates and snakes have ribcages. The workshops also evoked an enthusiasm from the PSTs in wanting to deepen their knowledge about animal biology and evolution. Interestingly, most of the PSTs did not know what homologous, analogous or vestigial structures were, and some were still struggling with these concepts at the end. For example, two of the PSTs identified a worm and a snake as analogous structures, even after the third workshop.

Evolution is a complex topic and harbours many misconceptions (Pazza et al. 2009). Research shows that an active approach to learning results in fewer misconceptions in students, but the results of active learning still can have limited gains (Nehm and Reilly 2007). However, active-infused learning, such as inquiry instruction, has a much more positive impact on student engagement and performance (Veall 2015). Evolution is now introduced to students in the UK primary curriculum, at age 9 years. Thus, many teachers, not just those specializing in Biology, need to understand the basics of evolution. Further, given the structure of many science departments at secondary school, many physics and chemistry teachers also will be expected to teach core concepts in evolution, with an aim of inspiring children to understand their connection to the natural world. And if this doesn't sound challenging enough, various philosophical and social issues create additional barriers for teachers who teach evolution. Added resistance stem from some religions, and in some parts of the world a large fraction of the population thinks that creationism should be taught alongside the theory of evolution (Coyne 2009). This situations can place teachers in difficult positions, where the subject turns from an exciting theory towards a more sensitive and awkward subject.

Motivating teachers in ways such as visiting the Grant Museum to encourage them to delve further into this complex notion, allowing them to develop a better appreciation of our connections to other animals. This type of activity does not just seem an added bonus: rather, it seems a necessity. Exploring novel approaches such as using and touching animal specimens provides opportunities for teachers and students alike to perceive evolution in a fresh light and potentially from a different perspective.

> For me, it was about the physical more than it was about the physical being 'real.' I wouldn't have cared if it was plastic, it was just more about the fact that I could see it and touch it, and that really meant something. Adam, PGCE science secondary student (Physicist)

Adam showed passion for learning in the museum from the start. He appreciated the historical events that had led up to the moment of him standing within the museum. He was aware of the opportunities that surrounded him in the forms of the various specimens. But his most memorable experience was the physical contact he had with the animal specimens.

Adam was not the only one who came to this conclusion. Vanessa and Fatima both placed touching the specimens as high on their priority list if they were to bring students to the museum. Perhaps of most interest was the overwhelming power these specimens seemed to have had when the PSTs were asked what aspects of the workshop they would use in their future practice. Inevitably, some mentioned the depressing time constraints due to the overloaded science curriculum content (Ellis and McNicholl 2015). However, almost all the PSTs commented on how the objects would provide another dimension for learning. Given this discussion, we suggested that loan boxes would be a good alternative to bringing students to the museum. Kate commented, "Touching and moving the specimens is useful no matter where you are," whilst Fatima stated "It would be good if we could integrate these objects into the curriculum." Interestingly, Katerina, also shared her experience of having skulls when she was at school:

> I remember learning about adaptations and skeletons with skulls in our classroom. It was great having them in there.

No one can 'learn evolution' in three workshops. The topic is vast and resides within an area that contests the realist nature of science. It spans the sphere of the 'unknown' and involves looking for clues and then piecing it all together. Seeing and touching specimens brought to life the idea of evolution and how animals have changed through time . It helped the PSTs understand the concepts that are at the base of evolution, such as common ancestry. The project also instilled a sense of curiosity within the PSTs, and encouraged them to want to learn more about this fascinating topic. Just as importantly, the workshops inspired them to integrate pedagogical approaches such as inquiry science and object-based learning more into their future teaching careers.

11.4 The Power of Animal Specimens in Learning Biology

Animal specimens are central to learning biology. The OBL approach takes the use of specimens beyond the passive and puts them actively at the forefront of understanding. Touch, and the sensory experiences associated with touching provide opportunities for new learning experiences, which allow the learner to enter new and exciting worlds. Museums throughout the world are embracing this approach to teaching, learning and inquiry (Roberts 2014) with opportunities for visitors to fully interact with biological material and replicas. But not everyone can experience OBL in a museum setting. So, how can the objects be brought to the learners?

Museums have a long history of using loan boxes that schools borrow and use within the classroom (Gurian 2004). The boxes can offer a variety of theme-based objects that can be chosen by the teacher or an existing loan box that has been premade by the museum, such as 'fabulous fossil' boxes including a range of fossils from all different species and ages. Loan boxes offer unique experiences for the student, but the logistics of this innovation, and the expertise required to make the most of the experience, may be challenging for the teacher and learner.

So where next? Technology offers new opportunities that allow teachers and learners access to rare materials with support from museum experts. A good example of how emerging technology is being used in this way comes from innovative work with fossil specimens from Victoria Cave, North Yorkshire, U.K. Here, specimens have been digitised and made available for exploration through a web-based platform (Digventures 2015). Through this platform, members of the public can 'handle', in a virtually environment, materials that they would not normally have access too. Beyond this, the emerging world of augmented reality makes experiences of this type richer and more accessible. And, as Harald Kraemer and Norbert Kanter (2014) argue, it is there where museums will almost certainly look to in the future.

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