The exhibition of scientific principles: a case study from the Biological Sciences Museum at Macquarie University

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Abstract

The educational role of museums requires that exhibition practice be informed by sound scholarship. In a university science museum, exhibitions should deploy objects and use space in a way that exemplifies the scientific principles that underpin learning and teaching programs of the host department or faculty. In this paper, a form of diacritical analysis of a number of individual exhibitions in the Biological Sciences Museum at Macquarie University is applied to elucidate these scientific principles. The analysis has significance when considering potential audiences. Visitors to the museum who are enrolled as undergraduates within the host department will bring existing knowledge to the museum. In this example, students should have existing knowledge of evolution, adaptation and comparative morphology. Other visiting audiences may not. Therefore, a university museum that wishes to engage with audiences beyond the discipline-specific student body need to strike a balance and carefully frame their exhibition work in a way that does not alienate those already familiar with the underlying principles of the didactic content. It is proposed that this form of pedagogic methodology can be constructively applied to inform exhibition work in other scientific disciplines.

Introduction

It is well established that museums, through their exhibition work, attempt to impart much more than didactic content (MACDONALD 1998). Their historical development as engine rooms of knowledge has also been elucidated (BOYLAN 1999) and the role of contemporary museums as mediators of informal learning experiences is similarly well established (HOOPER-GREENHILL 1994; FALK & DIERKING 2000).

In science exhibitions, objects or specimens are decontextualized and presented in alignment with others, and interspersed with additional contextual material, in a way intended to evoke certain didactic principles representative of accepted scientific paradigms. Much of the literature on this is focused on individual examples and couched in terms of the achievement of successful audience outcomes (e.g. MCLEAN & MCEVER 2004). Asma (2001) presented a comparative analysis of exhibition methodologies in major national natural history museums that indicated methodological diversity driven by cultural perspectives for exhibitions centered on the globally accepted scientific paradigm of evolution. These institutions engage with large and diverse audiences, their exhibition strategies are often emotional audience engagement rather than imparting didactic content. Hein (1996, 297) makes the point that “the pleasure of losing oneself in that experience displaces the desire to know the reality that it purports to explain”.

University museums, however, have a more complex relationship with their respective audiences. Whilst they can be viewed as enabling an aesthetic experience that generates audience interest, often viewed by university administrators as a recruiting function, they are also often designed to inculcate didactic content in support of formal teaching programs.

This paper reviews the exhibition methodologies used in the display of scientific principles within the Biological Sciences Museum at Macquarie University. The museum collection developed over a period of 40 years as a result of teaching programs in Biological Sciences at the University. It has only been in the last 20 years that the collection has had a dedicated but small exhibition space. The museum utilizes traditional natural history exhibition techniques and hosts visits from a number of school groups visits primarily from adjacent geographical areas (approximately 600 students per annum – unpubl. data). The number of annual external visitors is roughly equivalent to the current undergraduate cohort studying a suite of academic units some of which use the museum's exhibition resources in formal classes, but many of these units don't integrate the museum into formal teaching time. The museum is also utilized by some academic units outside of the biological sciences, principally early childhood studies, museum studies and visual arts. The museum is occasionally used as a showcase for visiting delegations to the university particularly those with biological or general science interests.

The exhibitions that are discussed in this paper are *Human Development*, *Phylum Arthropoda*, *Molluscs*, *Skull Adaptations of Mammals*, *Locomotion and the Vertebrate Skeleton*, *the Australian Ark* and *Specimens in Jars*. The paper consists of a diacritical analysis that includes an interpretation of the effectiveness of each exhibition based upon how directly and overtly scientific principles are communicated visually via the design of each exhibition. As the undergraduate student clientele comprise a specialized audience of university museums, these can be directly mapped against learning outcomes in undergraduate unit study guides.

The Biological Sciences Museum at Macquarie University has a strong design aesthetic with standardized red and green colors within the exhibition furniture and consistent interpretive text panels. The red and green colors are intended to be representative of the faunal and floral biological realms. This gives the museum a distinctively different atmosphere from laboratories and other teaching spaces within the Biology precinct.

Human Development exhibition

The exhibition on human development is the one that most effectively communicates its scientific principle within the museum. This display shows the process of human development in two ways. First and foremost, the time taken for development is shown through the use of exhibition space. At one end of the exhibition, there is a preserved embryo at seven weeks of age and at the other end of the display there is a preserved fetus aged 21 to 24 weeks, with an additional six stages represented in between. Furthermore, still photographs are used to fill in the missing stages extending from conception through to an eight month old fetus. A timeline along the top of the exhibition also graphically interprets the different stages of human development. By using horizontal space to represent time, the exhibition effectively narrates the stages of development in a chronological fashion. Secondly, human development is exhibited through the use of comparative biology. Alongside the human embryos and fetuses are the developmental series of the domestic chicken and the brush tail possum. The positioning of these developmental series beside the human developmental series allows for visual comparisons to be made by the visitor whilst still addressing the unifying embryological principles. Fig. 1 illustrates how these elements have been combined to produce an effective, scientific exhibition.

Fig. 1 - *Human Development* exhibition. The use of horizontal space, still photographs, developmental series, a timeline and text combine to effectively communicate the exhibition's underlying scientific principle.

The use of exhibition space to represent chronology is a standard natural history interpretive technique. Progressive embryological development for the visitor runs from left to right. Space can be related to chronology in exhibitions by either an indicative or representational method. In this case it is representational as the time span can be subdivided into components of equal space. The indicative method is more commonly used when interpreting extensive time spans, such as geologic time, where space restrictions and content are skewed towards specific time intervals (e.g. SIMPSON 1998) towards one of the time span represented.

The exhibition text identifies the three stages of human development – pre embryonic, embryogenesis and fetogenesis – and lists the milestones of each stage. It is left up to the visitor to identify exactly when within the displayed human developmental series these milestones occur. Not dictating this information provides a means by which a visitor can be actively engaged with the displayed material.

The exhibition text also highlights the effects of environmental influences on human development, with a particular focus on drugs, both those that are illegal such as heroin and LSD and those that are socially acceptable such as alcohol, nicotine and caffeine. The developmental issues raised in the text are not visually represented, and given the sensitive and distressing nature of the topic being exhibited, this is the responsible approach for the museum to take. The exhibition text brings a political and socio-cultural element to the exhibition by reminding visitors that a parent's responsibility begins before the birth of their child by minimizing the harm that environmental influences can have upon their unborn child. This therefore raises the question of the right of an exhibition curator to decide on who are responsible and irresponsible parents by invoking an ethical conceptual judgment.

Although this exhibition is about a scientific principle, and human fetuses are displayed in the name of science, there will be people that object to the use of human remains in an exhibition for variety of reasons. Furthermore, whilst this exhibition is merely presenting the scientific facts surrounding human development, for some, this display will be more emotive than scientific. Due to the sensitive nature of the display, it is therefore wise to have the exhibition off to the side where it is not in a visitor's direct line of sight when entering the Biological Sciences Museum. The exhibition of human remains is a diverse practice (TOWNLEY 2000) and a complex ethical question (LUCAS 2000). This exhibit is one of the most popular with external visitors and always prompts strong reactions. Beyond it's use in the teaching of embryological development in the biological sciences, it is most useful as a museological construct in the delivery of museum studies programs.

Phylum Arthropoda exhibition

The *Phylum Athropoda* exhibition attempts to interpret the scientific principles of evolution and diversity. Whilst it does highlight the diversity within the arthropods, the evolution side of the exhibition is not interpreted in a particularly convincing manner.

Fig. 2 - *Phylum Arthropoda* exhibition. By confining the phylogenetic tree to one end of the exhibition, the viewer loses sight of the evolutionary relationships. By extending the tree through the entire exhibition and placing the shelves along the tree at different heights, evolutionary relationships would be further developed.

Within this exhibition, the only tool used to highlight evolution is the phylogenetic tree, as seen in fig. 2. To a visitor with little knowledge of biology, a phylogentic tree is of little help explaining the evolution of the arthropoda. Here, phylogenetic distance is represented by exhibition space. This is possibly arbitrary as phylogeny can be interpreted by either molecular or morphologic means sometimes with differing results.

This exhibition is therefore designed with the biologist in mind. The text below the phylogenetic tree didactically describes what the tree is attempting to depict visually; that is, despite their diversity, arthropods come from a common ancestor. As one moves along the length of the exhibition, one loses sight of the phylogenetic tree as it only extends through one third of the exhibition space. This makes it very difficult for the viewer to see the origin of each of the anthropod classes and their relationships with other classes. In order for the scientific principle of evolution to be developed further within this exhibition, it is suggested that the phylogenetic tree forms the backdrop of the exhibition, going for its entire length. This way, the text on each class and the associated specimens can be slotted in along the appropriate branch of the phylogenetic tree.

The time taken for the evolution of the arthropoda would therefore be displayed through horizontal space, which as previously mentioned, is an effective means of display when representing time and order. The use of the phylogenetic tree however in this manner will not solve the problem of providing information on evolution to the visitor that is not armed with pre-existing biological knowledge. Interestingly, studies of visitor understanding of evolution in a museum context show distinctively different preconceptions depending on the organisms involved (SPIEGEL ET AL. 2006). In general, some of the most creative exhibition methodologies tend to focus on the question of human origins (SCOTT & GIUSTI 2006) rather than the relationships of humble invertebrates.

Asma (2001) describes the American Museum of Natural History where the representation of phylogeny comes out of the display case and onto the floor plan of the museum. Given the audience diversity at this museum, it would be interesting to gain some insights into the visitor conceptions of the underlying scientific principles enmeshed in the floor plan.

The scientific principle that the *Phylum Arthropoda* exhibition does explore and display effectively is diversity. The arthropoda represented within the exhibition include eurypterids, trilobites, onychophorans, crustaceans, myriapoda and hexapoda. Each of these is described in some detail in small text panels, with particular attention being paid to the distinguishing features of each group of organisms. Specimens or photographs are placed above the text in order to physically represent the articulated characteristics. At no point within the exhibition is there a labeled specimen with all the characteristics clearly indicated. The visitor is instead left to identify these features for themselves. This is a process that is only suitable for those that are capable of interpreting visual biological data. It is very difficult to identify these distinguishing features of the specimens, however, if they are absent from the exhibition as was the case with the hexapoda and the myriapoda. It must also be remembered that due to limitations of space, the diversity of arthropoda represented within this exhibition is at a subphylum level and as such, it is a highly selective and constructed sample of the diversity of the whole phylum down to species level. Better utilization of the exhibition space, such as the inclusion of more shelves to display specimens would allow for an increased diversity to be exhibited.

Molluscs exhibition

The *Molluscs* exhibition effectively communicates the scientific principles of class diversity and functional morphology, by focusing on the single shelled gastropods. Due to the limitations of space, focusing on one class is appropriate as neither the space, nor the collections resources can do justice to the diversity and functional morphology of all classes. There is no divide in this exhibition between diversity and morphology with the two being displayed in association with one another. These scientific principles are primarily explored through the shell of the gastropod with only fleeting references to soft tissue made in the text. This implies that when biologists deal with the diversity and functional morphology of gastropods, the soft tissue is not a discriminating factor between organisms.

The two main ways by which the scientific principles are explored within this exhibition are through the use of text and the use of specimens. In this exhibition, the text is kept to a minimum. The visitor is provided with a small amount of information regarding the mollusc phylum, with the remainder of the text focusing on gastropods in general and the functional morphology of gastropod shells. It is this text that provides an explanation for the visible differences between the gastropod shells. Without it this exhibition would just be a display of aesthetically appealing shells, rather than one that involves any scientific principles. The specimens are what tie both scientific principles together. The gastropod shell specimens are the physical manifestations of the morphologies mentioned in the text, such as spines, flattened tent shapes and spires. Each morphological type is represented by a cluster of sample specimens, as seen in fig. 3. Diversity is not only shown by comparing individual families and species but also by comparing individuals within a particular species using characteristics such as size, color and patterning.

Fig. 3 - *Molluscs* exhibition. Small clusters of shells are used to illustrate diversity within species and diversity between species.

The use of clusters containing numerous specimens of the one gastropod shell type within the exhibition is an effective way to visually establish this diversity between individuals. This methodology therefore provides a visual basis for an important principle in understanding Darwinism. While this exhibition tactic may miss the mark with many visitors lacking a pre-existing understanding, it does provide a framework for contemplating the relationships between individuals and groups of individuals. Like the *Phylum Arthropoda* exhibition, the viewer is left to make one's own connections between the text and the specimens. The text is continually drawing the viewer back to the exhibit to see an example of the gastropod being elucidated.

In order for the functional morphology side of the exhibition to be improved, rather than just dictate the morphological adaptations, it would be useful to have diagrams or photographs showing the gastropods in situ. Without such diagrams or photographs, it is hard for those that have never encountered such gastropods to imagine where they would be situated in nature. Rather than just connecting to those with a specialist knowledge of gastropods, such visual ecological parameters would connect this exhibition with a broader audience. Without such an ecological parameter, this display probably seems decontextualized and meaningless to a non-biologist visitor.

Skull Adaptations of Mammals exhibition

The scientific principles investigated in this exhibition are adaptation and comparative anatomy, with a focus being on how mammal skulls have adapted for different feeding habits. The different categories of mammal of particular interest in this exhibition are monotremes, marsupials and placentals and the adaptations of the skull that are specifically dealt with are the brain case, jaws and teeth.

The comparative anatomy side of this exhibition is explored through the use of skull specimens and the exhibition text. By placing the skulls side by side, the visitor is provided with a means by which to compare the size and shape of different skulls and the size, shape and number of teeth. Whilst some of these differences are explained in the exhibition text, it is very much left up to the visitor to make comparisons and determine reasons for the differences and similarities observed. The visitor is therefore invited to become actively engaged with the skull specimens. This is done by suggesting the visitor look for particular differences between skulls, such as the enlarged cerebral hemispheres in primates. Furthermore, the visitor is continually drawn from the text to the skull specimens in order to acquire a visual representation of what is presented as didactic text – for example, the large canine teeth discussed in the text can be seen on the tiger and jaguar skulls.

This exhibition stands out from all others in the Biological Sciences Museum as it uses diagrams to highlight differences in musculature and jaw bone configuration between different groups of organisms. Without these diagrams, the visitor would be overwhelmed with scientific jargon unrelated to anything visual. However, in order for the visual side of this exhibition to be improved, there needs to be diagrams of teeth or labels on the skull specimens highlighting the different types of teeth. Without such labels, it is assumed that the visitor has some prior knowledge of mammalian biology. A visitor cannot make comparisons of different teeth and their function if they are unsure of what they look like.

One other point of improvement would be to link all the skull specimens up to the text. As the exhibition currently stands, there are skulls on display such as the black rhinoceros, common zebra and wild boar, that although they are interesting to look at, they play no role in advancing the exhibition's line of argument. At the same time however these skulls do add to the comparative anatomy side of the exhibition. It would also be more helpful for the visitor if the skulls on display were directly above the text in which each organism was mentioned – the platypus jaw is currently placed above the discussion on brain case size when it would be more beneficial situated above the text on monotreme jaws.

In many ways this exhibition is a three dimensional representation of illustrations from a biology text. The lack of diagrammatic contextual material implies a pre-existing level of biological knowledge is required of visitors. It is structured however in a way that will challenge visitors without such knowledge to consider the concept of homology through form and function.

Locomotion and the Vertebrate Skeleton **exhibition**

This exhibition explores the adaptations that vertebrates have utilized in order to undertake locomotion. The methods of locomotion addressed are flight, loss of limbs, bipedal hopping and cursorial locomotion of quadruped animals. The use of skeletons to support each adaptation also allows for the scientific principle of comparative anatomy to be investigated.

The scientific principle of adaptation is clearly explained in this exhibition through a combination of text and skeletal specimens. The text very clearly and simply describes each method of locomotion whilst also highlighting the main adaptations needed for each particular method of locomotion. By listing these adaptations, rather them specifically pointing them out on each skeleton, it is very much the responsibility of the visitor to locate them on the skeletons. As previously argued, this provides the visitor with a means of being actively involved in their museum experience. Where possible, the skeletons have been displayed in association with their habitats – the snake skeleton is curled around a tree branch and the koala skeleton is nestled in the fork of a tree. By displaying the skeletons in such a manner, the exhibition dictates that adaptations for locomotion have allowed for the utilization of specific habitats by different organisms. Whilst each adaptation could be represented by any number of organisms, the small amount of space has limited the number of displayed specimens to one per adaptation. In most cases, one skeleton is effective in illustrating each adaptation, yet for those organisms that have adapted to limbless locomotion, there are a variety of bodily forms that these organisms can have. By including a fish skeleton and utilizing the whale skeleton hanging from the ceiling of the museum, the scientific principle of adaptation would be surveyed at a greater depth.

Comparative anatomy is explored within this exhibition in two main ways. Firstly, the skeletons provide a means by which the visitor can compare different vertebrate skeletons as a whole, identifying features that are common to all vertebrates, such as the vertebral column and a rib cage. Secondly, the skeletons allow the visitor to establish how individual skeletons compare to one another as a result of the different modes of locomotion. Whilst the exhibition text states the differences, it is only by viewing the skeletons that the visitor can fully comprehend the skeletal differences needed for different methods of locomotion.

Putting the exhibition in chronological order by representing time across horizontal space, with the most primitive condition for locomotion first, moving through to the most recent form of locomotion would greatly improve this exhibition through the addition of context. As the exhibition currently stands, it is difficult for the visitor to establish how each adaptation for locomotion developed and evolved from a pre-existing condition. Chronological order would therefore also allow for the scientific principle of evolution to be represented. One section of the exhibition that is in chronological order is the cursorial locomotion of quadruped mammals. It is this section of the exhibition that clearly communicates how the different forms of locomotion have developed and evolved.

Fig. 4 - *Locomotion and the Vertebrate Skeleton* exhibition. Additional environmental context is provided for some specimens.

As with the skull adaptations of mammals, this exhibition (fig. 4) can also be considered a three dimensional representation of a biological text, the environmental context utilized within the display space, however, makes this one more accessible for the non-biologist.

Australian Ark exhibition

There are three sections to this exhibition – Australian mammals, Australian water birds and Australian reptiles, with each section attempting to explore the scientific principles of endemism, adaptation and diversity.

The scientific principle of adaptation is evident in the Australian mammal and Australian water birds sections of the exhibitions. Much of the text in the Australian mammals section focuses upon the different adaptations these organisms have developed as a result of exploiting specific habitats. The display of taxidermy specimens in their life habitat further supports this notion. Within the Australian water birds section the adaptations needed for different habitats and lifestyles are highlighted in terms of feet, bills and coloring. The text elucidates the differences between these particular features on different birds and why these adaptations have evolved. The taxidermy bird specimens provide a way of physically representing these different adaptations. The text and specimens are very closely linked with each bird mentioned in the text being represented by a specimen. The scientific principle of adaptation is therefore effectively conveyed through the display by standard techniques of specimen and text.

The scientific principle of diversity is most clearly illustrated in the Australian reptile section of this exhibition. The exhibition text here highlights that Australia is home to many different species of crocodiles, turtles, lizards and snakes and the accompanying specimens illustrate this diversity through varying sizes, shapes and coloration. The exhibition is self contained within the cabinet and unfortunately does not attempt to integrate or in fact make any use of a large turtle specimen hanging on the wall next to this section of the exhibition. Not only would this increase the diversity of specimens already represented in the exhibit, but it would also utilize a specimen that currently appears to serve no educational purpose despite occupying a significant space in a visually striking manner.

Fig. 5 - *Australian Ark* exhibition. This exhibit assumes knowledge of endemism.

The introductory text to the *Australian Ark* exhibition mentions the unique nature of Australian fauna which suggests that the exhibition is exploring the scientific principle of endemism (fig. 5). The remainder of the exhibition however, very much assumes that the visitor knows that due to its isolation, Australia has native fauna that cannot be found anywhere else in the world. Whilst it is probably safe to assume that most visitors would be aware of Australia's unique mammals, it is important to stress that Australia has water birds and reptiles that are also endemic species. Without any development of contextual material about the nature of endemism, the exhibition can be easily just considered a display of mammals, water birds and reptiles that are present in Australia and possibly in the rest of the world. The use of a larger introductory text panel and the use of maps to show the distribution of each organism represented within the exhibition are two ways that greater coherency between the exhibition as a whole could be improved thus further developing the visitor's understanding of the scientific principle of endemism

Specimens in Jars exhibition

The *Specimens in Jars* exhibition demonstrates the importance of wet specimen preservation for the keeping of biological specimens. Whilst not a scientific principle, it is a technical methodology that is inherent to all museums and collections dealing with natural history. The value of this technique to natural history collections and therefore the history of much basic research on the natural world will not be readily apparent to a non-biologist viewing this exhibition. There is no coherent theme to the specimens on display, they include everything from cuttlefish to sheep tape worm and it does appear that this exhibit was one method of simply filling shelves within the museum. That being said, the material on display in this exhibition provides the visitor with a sense of wonder. There is no text other than specimen labels and as such it is left to the visitor to contemplate and appreciate the specimens without distraction.

No other preservation technique preserves specimens in such a life like and complete manner and as such the specimens can be appreciated for how they were in life. Such an exhibition provides the visitor with the opportunity to see organisms they may not have previously encountered – there would be no other way that a viewer would be able to encounter a chimera, a fish that lives at depths of over 4,000 meters below sea level other than in such an exhibition. There is therefore an "other worldliness" to the material on display that is well beyond normal human experience. Despite not demonstrating a scientific principle or having a coherent theme, this exhibition is worthy of a place in the Biological Sciences Museum as a result of its aesthetic nature.

Conclusion

The Biological Sciences Museum at Macquarie University explores numerous scientific principles including evolution, adaptation, human development and functional morphology. These principles are all explored through a variety of exhibition methodologies including didactic text, specimens, pictures and diagrams.

The Department of Biological Sciences at Macquarie University offers a diverse range of study units in its undergraduate program. Foundation units during first year (100 level units) have the largest enrolments as many students undertaking a study major elsewhere in the sciences will include 100 level biology units. Second year units (200 level units) cover more advanced and specialized biology topics. Third year units (300 level), a combination of which comprise a major in biological sciences, cover the most advanced and highly specialized study units.

The Department offers five 100 level units (2009 offerings). Two of these are in a separate advanced biology seminar stream and structured differently from the other three (although the content of seminars can often relate to museum content). These three act as broad-based introductory units that traditionally have relatively high enrolment numbers. The units *The Thread of Life* and *Evolution and Biodiversity* strongly relate to the content of all the exhibitions discussed above. The third introductory unit *Human Biology* strongly relates to the *Human Development* exhibit, but less so to the others discussed here.

Eleven units are offered at 200 level, two of which are delivered through the advanced biology seminar stream. The remaining nine include two units entitled *Plant Structure and Function* and *Biostatistics* that seem to have little or no connection with the didactic content of museum displays. The units *Genetics*, *Ecology* and *Tropical Marine Ecosystems* have little direct connection with the museum exhibitions although exemplars illustrating some of the learning outcomes of these units are embedded in museum exhibitions. The units *Human Physiology* and *The Science of Sex* obviously relate directly to the *Human Development* exhibition. Of the remaining 200 level units, *Palaeontology* links in part to phylum arthropoda evolution exhibition and animal structure and function links in part to both the phylum arthropoda evolution and the *Molluscs* exhibition (this unit is primarily focused on invertebrates).

At 300 level 21 units of study are offered. Here the content is more specialized and the value of the museum exhibits to learning outcomes more tenuous, although some strong linkages still exist. For example the units *Invertebrates: Evolution, Behavior and Diversity* is linked to both the *Phylum Arthropods* and the *Molluscs* exhibitions, though it can be argued that their utility in terms of learning outcomes has been largely expended at 200 level. Other units such as *Vertebrate Evolution* find some indicative value in the *Skull Adaptations of Mammals* and the *Locomotion and the Vertebrate Skeleton* exhibitions.

From a cursory analysis of unit content it is obvious that the museum is of most value for the small number of introductory units (100 level) with high enrolment numbers and of less value to more specialized, advanced units of study. This “pyramid” model of connections best serves the undergraduate teaching goals by connecting with the broadest possible student clientele.

As noted above, however, there is also an external audience of approximately the same size as the enrolled student audience for the museum. The analysis above clearly demonstrates that some form of pre-existing biological knowledge is required to fully engage with the museum exhibitions. The part of the external audience that consists of high school students studying biology at senior levels could realistically be expected to have some of this knowledge and engage with the exhibition content at some levels. But little is known of the diversity of the external audience and some analysis is required to ascertain whether the museum exhibitions connect effectively.

Any museum visitor, regardless of levels of pre-existing knowledge, however, does not come to a museum as a blank slate. They come to build on what they already know to create new meaning. For those without previous exposure to biological concepts this new meaning can include reinforcing scientific misconceptions. Therefore, to reach this part of the museum’s audience, it is worth considering additional contextual material as learning scaffolding in exhibition development. If the university's mission does not include engagement with this audience segment, then such work is obviously not essential. This, however, is contrary to recent trend of audience inclusion in the work of the broader museum sector.

The suggested improvements for the exhibitions would provide the visitor with a greater understanding of the above-mentioned scientific principles regardless of their pre-existing knowledge, whilst also enhancing the use of the museum's resources. It now needs to be established how effectively the exhibitions contained within the Biological Sciences Museum and the scientific principles they explore relate to the teaching of the Department of Biological Sciences at Macquarie University through closer analysis of individual learning outcomes for specific units of study.

It is suggested that the methodology adopted in this paper can be applied to any university science museum. Through a meta-analysis of the scientific principles underpinning exhibition development, an understanding of the different audiences served by the museum, and mapping the results against learning outcomes, the museum has developed a mechanism for leveraging the maximum potential from its exhibition work in support of teaching programs.

Literature cited

ASMA, S. T. 2001. *Stuffed animals and pickled heads. The culture and evolution of natural history museums*. Oxford: Oxford University Press.

BOYLAN, P. J. 1999. Universities and museums: Past, present and future. *Museum Management and Curatorship* 18, 1: 43–56.

FALK, J. H. & L. D. DIERKING 2000. *Learning from museums, visitor experiences and the making of meaning*. California: Altamira Press.

HEIN, H. 1996. The art of display: Science museum exhibitions. In: *Elusive synthesis: Aesthetics and science*, ed. A.I. TAUBER (Boston Studies in the Philosophy of Science 182), 267–288.

HOOPER-GREENHILL, E. 1994. *The educational role of the museum*. Leicester: Routledge.

LUCAS, B. 2000. Exhibiting human remains: What are the ethical issues? In: *Collected Papers from 'Exhibiting Human Remains': A seminar presented by Health and Medicine Museums (a Special Interest Group of Museums Australia Inc.) held at the Powerhouse Museum, Sydney, 12 May 2000*, ed. M. HICKS, 12–20. archive.amol.org.au/hmm/pdfs/exhibiting%20remains.pdf (accessed August 28, 2009).

MACDONALD, S. 1998 (ed.) *Politics of display, museums, science and culture*. London: Routlege.

MCLEAN, K. & C. MCEVER 2004. *Are we there yet? Conversations about best practice in science museum exhibits*. California: Left Coast Press.

SCOTT, M. & E. GIUSTI 2006. Designing human evolution exhibitions. Insights from exhibitions and audiences. *Museums and Social Issues* 1, 1: 49–67.

SIMPSON, A. 1998. The redevelopment of the Geology Museum at the University of Queensland. *The Queensland Science Teacher* 24, 6: 15–24.

SPIEGEL, A. M., E. M. EVANS, W. GRAM, & J. DIAMOND 2006. Museum visitors' understanding of evolution. *Museums and Social Issues* 1, 1: 69–85.

TOWNLEY, P. 2000. A personal view exposed. In: *Collected Papers from 'Exhibiting Human Remains': a seminar presented by Health and Medicine Museums (a Special Interest Group of Museums Australia Inc.) held at the Powerhouse Museum, Sydney, 12 May 2000*, ed. M. HICKS, 25–28. archive.amol.org.au/hmm/pdfs/exhibiting%20remains.pdf (accessed August 28, 2009).

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