Chapter 49
Informal and Non-formal Education: History of Science in Museums

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I, Clio the Renowned, eldest daughter of Mnemosyne, Muse of History, warden of memory, wish to teach men lest they neglect the past of their knowledge as of their ignorance.

(Jean Marc Levy-Léblond 2012)

49.1 Introduction

History of science has a long presence in formal science education. During the late 1960s and early 1970s, an educational movement emerged (mainly in the Anglo-Saxon literature) that argued for the benefits of using the history of science in secondary education. Initial references also carry some preliminary perspectives on the advantages and disadvantages of such a partnership (Brush 1969, 1974; Klopfer and Cooley 1963). These perspectives characterise the research field diachronically, but the issues of instructional strategy choices and methodological techniques with which history of science can be effectively linked to science education are still open research questions.

The use of history of science in formal education is related to three trends in educational research:

1. A humanistic approach to science teaching that aims to contribute to the 'broad cultivation' and scientific literacy of pupils as citizens (e.g. Klopfer 1969; Langevin 1964; Matthews 1994/2014)

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M.R. Matthews (ed.), *International Handbook of Research in History, Philosophy and Science Teaching*, DOI 10.1007/978-94-007-7654-8_49,

2. The development of student understanding of the nature and characteristics of scientific knowledge, mainly via the 'nature of science' educational movement (e.g. Hodson 2008; Lederman 2007)
3. The cognitive development of pupils and the shift of interest from methodological to conceptual dimensions of scientific knowledge (e.g. Monk and Osborne 1997; Nersessian 1992; Strauss 1988)

Despite the increasing influence of the history of science in formal science education during recent decades, one cannot ignore the difficulties and the obstacles that a broader educational use of the history of science faces. Among these, Hottecke and Silva (2010) refer to the negative stance of educators to any proposed change to the traditional teaching culture and the boundaries imposed upon educators by the official science curriculum that either ignores or degrades the role and importance of history of science in teaching.

It is interesting therefore to examine what happens with the kind of dissemination of history of science that originates or relates closely to the modern science museum. The dissemination of history of science is related in this case with informal and non-formal educational approaches.[1] What are the aims of this sort of dissemination, how are they achieved and how are they related to non-formal and informal education? The present review aims to bring forward these issues and open a potential academic discussion. We first discuss the types of museums that have been developed; we then analyse the history of science as an exhibition and communication element; and finally, we approach the subject as an educational element. The review will not address how the science museum is being treated as a research subject itself by historians of science.

49.2 A Definition of a Science Museum and the Types of Science Museums

Museum studies have grown since the late 1960s following a considerable rise in the number and types of museums worldwide. Museum studies literature offers a wealth of definitions and classifications of museums organised mainly according to

[1] In the present article, the terms *informal education* and *non-formal education* are considered as distinct terms (Coombs and Ahmed 1973; Escot 1999; Eshach 2006). An *informal* educational process is not an organised and systematic one that occurs in different educational settings (schools, museums etc.). It is a process – quite often unintentional – offered by the personal environment of an individual. The interrelationship between the individual and the exhibition during a museum visit is a typical example of an informal educational process. In contrast, *non-formal* educational environments are related to autonomous cultural institutions that provide scientific knowledge, such as museums, and are environments that offer organised educational activities (as in the case of educational programmes in museums or programmes that are organised between school and museum).

the academic disciplines to which they refer through their collections, exhibitions and public programmes.

The science museum is not a homogenous entity. The nature and characteristics of the science museum can be studied through the variety of categorisations produced by both museum professionals and museum researchers. These categorisations group museums based either on the way in which these institutions confront collecting, displaying and interpretation of objects and the way they conceive exhibition space (Wagensberg 2004) or on the evolution of the science museum (de Clercq 2003; Friedman 2010). The latter are significant not solely because the history of the museum as social institution as demonstrated by the related literature on the history of museums and collections is a vital subject (Arnold 2006; Findlen 1989, 1994; Impey and MacGregor [1985] 2001; Yanni 1999), but also because this literature can be used to interpret the function of modern science museums by either researchers coming from fields of inquiry other than museum studies (i.e. science educators) or by science teachers (Koliopoulos 2003).

A history of the science museum goes back to the Renaissance collections of curiosities and learned cabinets (e.g. the cabinet of Francesco I de Medici in Florence (Findlen 2000; Pearce 1993) and the collections of seventeenth-century philosophical and scientific institutions (e.g. collections held by the Royal Society of London). During the second half of eighteenth century, along with the founding of the first public museums, a number of museums of natural history were established. Unlike the earlier cabinets, these were public institutions allowing a large number of visitors into their exhibition spaces. In addition, the galleries exhibited objects according to a classification system that was closely adapted to distinct academic disciplines.

These institutions praised the collected object (e.g. scientific instruments, natural history specimens and technological artefacts), accumulated natural curiosities and man-made artefacts and favoured the wooden or glass-case presentation. The *Musée des Arts et Métiers* in Paris is an exemplary case reflecting this exhibition philosophy (Ferriot and Jacomy 2000). There the visitor was considered a passive admirer of a glorious scientific past. The act of interpretation was not facilitated by the museum curator, although some interpretation was provided by a few means such as the object's label. In this context, scientific objects were displayed as art objects and admired by the upper class (Bennett 1995). The *Natural History Museum* in London took a similar approach.

University science collections fall into the same category given that most of them have been created to act as repositories of worn and outdated scientific apparatus once used in the teaching of physics and chemistry or collections of objects related to the natural sciences (e.g. stuffed animals). The museum of the King's College London that was founded to host the King George III science collections in mid-nineteenth-century London is an interesting case in point, yet by the end of the century it had become a mere repository (Filippoupoliti 2011).

Between the middle of the nineteenth century and World War II, another type of museum emerged that differed from the traditional museums just described. During this time, museums also embraced an explicit educational mission following the mid-nineteenth-century demand for educating the lay public. Interpretation of the

exhibition was performed by presentation of a series of objects that reflected a certain scientific concept or idea, and an attempt was made to form concise units according to certain scientific themes (e.g. energy, power, physics etc.). The *Science Museum* in London (est. 1885) and the *Deutsches Museum* (est. 1903) in Munich are examples of this category, although in recent decades these museums have enhanced the exhibition space with modern design and interactive exhibits. Along with the older galleries, a series of interactive hands-on exhibits are presented to update the established scientific narrative (Durant 2000). This category also includes the *Museum of the History of Science* at Oxford (est. 1925) and the *Whipple Museum of the History of Science* at Cambridge (est. 1944), the former *Istituto e Museo di Storia della Scienza* now the *Museo Galileo* (est. 1927) in Florence and the *Museum Boerhaave* (est. 1928) in Leiden, Holland (de Clercq 2003).

Although science centres differ from science museums, they are usually treated together in the literature. A science centre has a distinct experimental philosophy that moves from the display of the authentic object to create an original/meaningful museum experience through active visitor participation. Beyond object worship, it is the exhibition space that matters more as it assimilates the laboratory, a gallery of research and a place of demonstration. Historically, this type of a science institution can be traced back to the 1930s, when the *Palais de la Découverte* in Paris was founded according to a rationale relevant to the division of academic scientific disciplines, followed by the San Francisco *Exploratorium: The Museum of Science, Art and Human Perception (*est. 1960s), which is regarded as the 'father' of science centres (Hein 1990; Cole 2009). Another example is the *Cité des Sciences et de l'Industrie* in Paris, in which the focus of exhibition activity is the social use of natural sciences and technology (Caro 1997; Zana 2005). This science centre has created a special children's science museum that offers exhibitions and activities designed to address the cognitive and emotional needs of young children (Guichard 1998).

The development of science centres has considerably influenced museological approach and museographical practice of even the most traditional museums. For example, the recently renovated *Museo Galileo* in Florence and the *Museum of the History of Science* at the University of Oxford have improved their approaches to the display of objects. They have modernised the permanent and temporary exhibitions as well as their communications approach to the public (e.g. including new interactive activities as part of an exhibition and providing virtual tours via the museum website). The hybrid form that such museums have become raises the issue of establishing a new educational identity for these institutions (Quin 1993).

We pose the following questions which we will tackle in the following section: How does each of the science museum types implement the history of science in exhibition and educational practice? What sort of interpretation do they offer? Do each of these different interpretation patterns offer the same epistemological status and give a certain communication role to the history of science? Does the history of science constitute one of the seminal elements in the diffusion of scientific knowledge communicated via science museums, or are museums designated solely for the history of science the only appropriate institutions to research, exhibit and diffuse objects, ideas and issues related to the history of science?

49.3 History of Science as an Exhibit and Communication Element

History of science is an exhibited theme found in a variety of museum types. Museums of the history of science distinctly safeguard, interpret and display the material culture of science (Bennett 1997, 2005; Camerota 2011). Museums of the history of science are usually university museums that base their foundation on collections of scientific instruments and apparatuses once used in research and university teaching or on private collections that have been donated to the museum. Two characteristic examples are the *Museum of the History of Science* in Oxford (established 1924) by the gift of the collection of Lewis Evans[2] to the University and the *Whipple Museum of the History of Science* at the University of Cambridge founded in 1956 to house Robert Whipple's[3] collection of scientific instruments and rare books (Bennett 1997; Taub and Willmoth 2006). In these institutions, the history of science is present in many ways, most importantly in the use of elements of the history of science in exhibitions in which a part or the majority of the scientific collections (authentic scientific instruments or biological specimens) are used.

How then does a museum of the history of science differ from a science museum? Bennett (2005) notes that

> museums of the history of science contain old instruments and apparatuses, just like any science museum … If it is not the nature of the collections that is different, it should be the assumptions about what the collections are for, which will inform how they are selected and how they are used. (pp. 606–607)

Because of their privileged relationship with academic history of science, museums of the history of science can certainly provide exhibitions of their collections that gain their meaning from the cognitive, methodological and cultural dimension of the history of science.

Another category of science museum where history of science is present includes those institutions whose historical tradition, collections and particular museological/museographical approaches make possible the presentation of a history of science exhibition narrative even though the history of science is not a distinct part of the institutional mission such as university museums that hold collections of scientific instruments and natural history and biological specimens (Tucci 2002; Lourenço 2005; Subiran et al. 2009). One difficulty that this type of museum confronts in presenting collections to the broader audience is the absence of a unified and coherent theme

[2] Lewis Evans (1853–1930) was a collector, brother of the notable archaeologist, Sir Arthur Evans, who excavated the Palace of Knossos, Crete (Greece). See also P. de Clercq, Lewis Evans and the White City Exhibitions, *Sphaere. The online journal of the Museum of the History of Science, University of Oxford,* available at http://www.mhs.ox.ac.uk/sphaera/index.htm?issue11/articl4.

[3] Robert Stewart Whipple (1871–1953) donated more than 1,000 scientific instruments to the University of Cambridge in 1944. See also S. De Renzi (1998). Between the market and the academy: Robert S. Whipple (1872–1953) as a collector of science books. In R. Myers and M. Harris (eds), *Medicine, Mortality and the Book Trad*e (pp. 87–108). St. Paul's Bibliographies: Oak Knoll Press.

topic that could become the basis of an institution recognisable by non-experts (Antoine 2010, p. 9). One such theme topic, according to Antoine (2010), is the implementation of the scientific method via elements from the history and philosophy of science.

Non-university museums such as the *Musée des Arts et Métiers* in Paris and the *Science Museum* in London that hold scientific collections are good examples of this category of museum. Although their original aim was not the dissemination of the history of science,[4] today these museums are ideal places for the display of science because of the richness of their collections. Also, institutions such as centres of scientific research and for the popularisation of science (e.g. *Royal Institution of Great Britain*), scientific institutions (e.g. *Royal Observatory*, Greenwich, England) and laboratories or the private premises of eminent men of science that have become house museums (e.g. the *Charles Darwin Down House* in England and the *Maison d'Ampère* in France) are potential places for disseminating the history of science.

The implementation of history of science can differ among museums according to their type. Studying three institutions that display collections of historic astronomical instruments, Maison (2002) suggested three different ways of exhibiting such collections. The *Musée des Arts et Métiers* emphasises the technological dimension of the displayed scientific instruments, and the exhibition is based on historical evidence that presents a holistic view of the technical culture from Renaissance to the present day. In contrast, the *Observatoire de Paris* emphasises the concepts of the physical sciences and how these are intertwined with the function of astronomical instruments. Finally, the *Royal Observatory of Greenwich* displays collections with the aim of presenting the social and economic aspects related to the development of astronomy research over time.

Finally, even though science centres don't hold any permanent collections of authentic/historical objects, occasionally they may host temporary exhibitions that present elements of the history of science. These centres seem to function as contemporary scientific textbooks that, according to Kuhn, can hide the process of how scientific knowledge is obtained. If someone replaces the word 'textbooks' with 'science centres' in the next extract, the meaning would not be twisted:

> Textbooks thus begin by truncating the scientist's sense of his discipline's history and then proceed to supply a substitute for what they have eliminated. Characteristically, textbooks of science contain just a bit of history, either in an introductory chapter or, more often, in scattered references to the great heroes of an earlier age. From such references both students and professionals come to feel like participants in a long-standing historical tradition. Yet the textbook-derived tradition in which scientists come to sense their participation is one that, in fact, never existed. For reasons that are both obvious and highly functional, science textbooks (and too many of the older histories of science) refer only to that part of the work of past scientists that can easily be viewed as contributions to the statement and solution of the texts' paradigm problems. Partly by selection and partly by distortion, the scientists of earlier ages are implicitly represented as having worked upon the same set of fixed problems and in accordance with the same set of fixed canons that the most recent revolution in scientific theory and method has made them seem scientific. (Kuhn 1970, pp. 137–38)

[4] Moreover, history of science as an academic discipline emerged later.

What is the mode of history of science as an *exhibition narrative*? Which one of the history of science narratives one occasionally confronts in museum exhibitions? Are historical facts explained and interpreted? Is emphasis being given to historical moments/turning points and the importance of controversies and scientific revolutions? Is it more important to research science as a social action that is formed by the social-historical-cultural context? Or is it more seminal to trace the history of science as a history of ideas or as an exploration of the material culture and non-literary traditions? A first attempt to answer these questions will be presented in the following paragraphs.

Even though history of science as an academic discipline emerged during the first part of the twentieth century, historic scientific instruments were already on display by the second half of the nineteenth century in museums such as the King's College London King George III Museum as well as in international/world exhibitions such as the Special Loan Exhibition in London in 1876. Historian Steven Conn has called the museum exhibition culture of that period an 'object-based epistemology' (Conn 2000). According to that perspective, the exhibited object (e.g. a scientific instrument) is able to confirm and support the 'scientific power' of a phenomenon or an idea and therefore as a historic object can stand as a symbol of scientific progress. For many decades in the early twentieth century, museums preserved the type of museological narrative that they inherited from their nineteenth-century predecessors. For instance, scientific instruments and apparatuses were preferably displayed in a thematic way, and their mode of display reflected an encyclopaedia of natural sciences in which each displayed object stood for a particular scientific phenomenon or process.

During the 1980s, shifts in the museological and museographical approach to science museums (Schiele and Koster 1998) in research trends in the history of science and in the increasing interest of historians of science in science collections led to important changes in the ways museum curators displayed the history of science in exhibitions. At least three epistemological approaches can be identified in these museum exhibitions. The first approach is the traditional one mentioned earlier that treats the history of science as the documentation of objects and facts. The second approach treats the history of science as a history of ideas and is not broadly used to weave a narrative into a science exhibition. In this case, the authenticity of the science collection is of minor importance (i.e. whether objects are historic scientific instruments or reconstructions). Emphasis is being given to how an idea (or ideas) is born, developed and cognitively treated in order to give meaning to objects. The *Grande Galerie de l'Evolution* of the *Muséum National d'Histoire Naturelle* in Paris focuses on the evolution of species (Van Praet 1995). Other examples of such an exhibition approach include the following: The exhibition 'Exploring the World, Constructing Worlds: Experimental Cultures of Physics from the sixteenth to nineteenth Century' in the *Museum of Natural History and Pre-History* in Oldenburg, Germany (Heering and Muller 2002), which addresses issues such as 'astronomical and experimental practice in the sixteenth and seventeenth centuries' and 'the science of precision measurement in the nineteenth century' and the Galilean exhibit of the *Exploratorium*

in San Francisco, entitled 'The Gravity-Powered Calculator', which was also reconstructed by Cerretta (2012).

Exhibitions belonging to the above-mentioned two categories aim at disseminating the content, the process and the product of science from an internal point of view, the view of science. In contrast, a third approach considers trends in the history of science literature that view science as an example of culture with particular practices and tools that are affected, developed and transformed according to the cultural and historical context in which they have been developed, including non-scientific factors (Golinski 1998; Galison and Thompson 1999; Daston 2000).

In addition, the emergence of Social Studies of Science since the 1980s has provided researchers with fresh perspectives on understanding the intersection of scientific practice and culture (Latour and Wooglar 1986; Latour 1987). In this context, emphasis is given to how scientific practice is being formulated in the laboratory and in the performance of crucial experiments (Arnold 1996; Chittenden et al. 2004). For instance, the exhibitions hosted at the *Wellcome Collection* of the Wellcome Trust in London and the temporary exhibitions hosted in the Science Museum in London and the Nobel Museum in Stockholm are examples of cultural turns in the reading of the history of science.[5] From the perspective of science education, Pedretti (2002) also refers to the use of the history of science by science museums addressing socioscientific issues.

The above-mentioned modes of introducing the history of science in museums lead to informal education and informal learning. Museum visitors and school groups in particular can gain an interest in science as well as gain a popularised conception of the content and method of science (Stocklmayer et al. 2010). However, this kind of popularisation eliminates the systemic dimension of the meaning of scientific and historic knowledge and consequently sometimes deforms and transforms it to such an extent as to alter totally its meaning and, in still other instances, leads to paradoxical assertions (Jacobi 1999; Jurdant 2009). The risks stemming from the popularisation of scientific and historical knowledge could possibly be reduced if museums place more emphasis on the educational dimension of communication and on their function as institutions for non-formal education (Escot 1999). This issue will be analytically treated in the following section.

49.4 History of Science as an Educational Tool

Science museums are gradually increasing their emphasis on their science education functions (Teichmann 1981; Tran 2007; Stocklmayer et al. 2010). Museums produce a wealth of educational material for all types of visitors, the design of which varies according to type, content and creator. For instance, some materials are composed by

[5] See, for example, the Nobel Museum Centennial exhibition *Cultures of Creativity* (Stockholm, Sweden) which examines creativity in science. Available at http://www.nobelmuseum.se/en/exhibitions/cultures-of-creativity

in-house museum professionals linking the programme directly to certain exhibits and perhaps implying that an exhibit can easily be transformed to educational material.

Many science museums design programmes in collaboration with schools and other educational institutions, either because they seek to consider the concerns raised by such institutions or because they seek theoretical and/or practical tools to support exhibit design. University departments that offer postgraduate museum studies courses or science education courses provide essential support towards the design of meaningful educational programmes for museums' visitors. Does the history of science have a specific role in the design of museum educational programmes? Do science museum professionals need formal education about how to give certain meanings to science collections through the aid of history of science, exhibitions and associated narratives? Or, is non-formal/informal education sufficient to act as a means of diffusing scientific knowledge?

Our review of the educational tools used by museums to communicate the history of science elements identified four categories of educational material:

(1) *Guided tours focused on narratives from the history of science.* This is the simplest educational intervention, engaging the history of science in a sequential science museum-guided tour. These tours typically present stories of people, ideas and/or practices from the history of science field and may contribute to raising the interest of visitors for the exhibition or to making meaning from an exhibition.

For instance, Fadel (2011) uses history of science elements in lectures given during the performance of experiments at the *Palais de la Découverte* in Paris. He notes that the history of science can be a very powerful tool for introducing a new concept, idea or theory. Sometimes, stories and anecdotes taken from history are helpful as brief breaks to keep the attention of the audience. In other cases history can help people realise how answers to questions always seem obvious when one already knows the answer but seldom are apparent beforehand (Fadel 2011).

In formal education, the design and narration of stories that introduce elements of the history of science is a common practice (Stinner et al. 2003). Unlike formal education, during a guided tour in the museum, the guide cannot expand the narration to explain a topic in detail. In this context, guided museum tours using narratives from the history of science are the weakest type of educational programme for presenting the history of science.

(2) *Museum educational programmes/workshops.* These activities are designed mostly for students and teachers, not the general public. In many instances, these programmes are developed and performed by specialised museum educators (Tran 2007). The *Deutsches Museum* is one example of a successful implementation of history of science elements in museum educational programmes. Teichmann (1981) points out that

> historical objects displayed are to be integrated into the other educational activities of the museum and not simply remain commemorative pieces; i.e. historical collections and modern didactics are to be united according to the following aspects: (a) often modern situations can be clarified by means of historical explanations; (b) the completely different conditions of the past and the then existing specific difficulties in the realization of new

> knowledge, can offer a valuable lesson in questioning the apparently foregone conclusions of today; (c) the incorporation of modern and historical objects into the framework of human science and cultural development, can exhibit the characteristic position of science and technology (p. 474).

Educational programmes are structured educational environments designed to acquaint students and teachers with scientific and historical knowledge in a systematic way. For example, the context for knowledge could be the experimental history of physical sciences (Sibum 2000), the construction of concepts and methods via the reconstruction of artefacts or historical experiments (Teichmann 1999; Heering and Muller 2002) or the historical development of our understanding of the taxonomy of biological organisms (Faria et al. 2012).

(3) *The collaboration between museums and formal education.* Many researchers have argued that the collaboration between school and museum can promote achieving both cognitive and emotional student outcomes. A number of studies suggest that the museum visit and the children's activities during the visit should be accompanied by school before and after the visit (Griffin and Symington 1997; Anderson and Lucas 1997; Anderson et al. 2000; Guisasola et al. 2005; Guisasola et al. 2009). Other researchers claim that the involvement of teachers in non-formal educational settings such as science museums should be part of teacher training in science and pedagogy (DeWitt and Osborne 2007).

Unfortunately, studies of the development and evaluation of educational programmes in museums that introduce elements of the history of science are few. Anderson and colleagues (2011) describe a museum workshop about the role of artefact analysis/manipulations on research and teaching in the history of science and technology. In this study students from university departments of education also addressed this subject during classroom coursework using Eotvos torsion balance, an instrument used to measure small gravitational variations. Students constructed three narratives related to the science of geodesy and discussed issues related to laboratory practice and the nature of science.

Falomo-Bernarduzzi and colleagues (2012) have developed activities related to Galileo's laboratory that are designed to take place either in the museum or in the school and explain that these

> activities do not 'incidentally' interest schools, because they happen to connect with the school curriculum, but they are thought out with each school for the school. These workshops give clues which are the starting points for classroom activities linked to the project but also part of normal school learning. (Falomo-Bernarduzzi et al. 2012)

The researchers describe projects that rely extensively on the history of science in a number of ways using primary and secondary sources, museum exhibitions, multimedia and hands-on reconstructions of historical experiments. More specifically, they present activities that are based on the exhibition 'Laboratorio di Galileo' which includes reproductions of the apparatuses designed and used by Galileo for his experiments in mechanics.

Finally, Paparou (2011) describes lecture-demonstration activities created and performed by teachers in the classroom using collections of scientific instruments from the local *Museum of History and Physics* of the first high school of Chios

Island (Greece). Examples of such lecture-demonstrations include 'The first days of electricity' and 'The history of magnets and compasses'. During these programmes, participants were invited to observe and compare scientific instruments, conduct experiments and evaluate the experimental results, make explanatory hypotheses and explore historical scientific documents (Paparou 2011).

All the educational attempts that were discussed in the previous sections focus on the study of scientific instruments and experiments as tools for educating students and teachers about history of science issues in the context of collaboration between museums and formal education institutions. It is apparent that such a collaboration can play a seminal role in evaluating and transforming scientific collections (original/historical collections, digital collections or collections of reconstructed instruments) from tools of research to tools of education (Heering 2011).

49.5 Conclusion

The variety of reviews that refer to the introduction of elements of history of science in primary and secondary school (Matthews 1994/2014; Duschl 1994; Seroglou and Koumaras 2001; Hottecke and Silva 2010) indicates the systematic and continuous involvement of historians of science and science educators with the issue of introducing elements from the history of science into formal science education. In contrast, as the present review has shown, the study of the role of the history of science in informal and non-formal science education is heterogeneous and fragmentary. It is necessary to raise new research questions and construct new lines of research to investigate the subject in a more systematic way.

We have suggested three lines of research strands below:

(1) *The epistemological research strand.* This strand refers to those research questions primarily of interest to science museum professionals related to the role that history of science can play in the realisation of the communication and education objectives of museums. How and why can the history of science as presented through museum collections contribute to the rescue, preservation and diffusion of scientific heritage and culture at local, national and international levels? Lourenco (2012), for example, suggests that

> the increased interest by the historian of science creates opportunities for a more significant role of history in museums of science, potentially resulting in better documented collections, as well as more meaningful and contextualized exhibitions and educational programmes. However, more history in museums of science requires considerable structural and cultural changes in their traditional missions, roles and practices. (Lourenco 2012)

On the other hand, primary questions that in our opinion should concern science centres that aim at the diffusion and popularisation of modern scientific knowledge are the following: Is it possible, and if so, how could the history of science contribute to reducing the ever-growing gap between the production of scientific knowledge and its understanding by lay people? How could the

history of science contribute to restorating the relationship between science and culture that has increasingly soured since the early twentieth century? (Bensaude-Vincent 2001; Lévy-Leblond 2004). Is it possible to incorporate the narrative of the history of scientific ideas into the narrative of the modern world and its relationship to contemporary society, or should they be considered two epistemologically incompatible narratives? These questions are also interrelated to the following research strand.

(2) *The museological/museographical research strand.* This strand is mostly related to the way in which science museums take into account the history of science and translate it into a communication and educational tool to achieve their educational mission. Historians of science, museologists and possibly science educators need to collaborate towards that end. Referring to collections and exhibitions of the *Science Museum* in London, Bud (1997) noted that

> before the Second World War the progressivism of the galleries and the inspiration of its greatest icons mostly matched the views of academics. However, the post-war years, which saw an efflorescence of paper-based historiography of science, saw too a decoupling between the interests of academics interested in intellectual process and of curators focused upon their objects. This decoupling meant that the history of science of which the Museum was the public space, was somewhat distanced from the burgeoning academic discipline. (pp. 50–51)

Bud makes clear that exhibitions of science act as important means of transformation of scientific knowledge, scientific and social practices and authentic objects to content, exhibits and forms of display, so that they could be successfully communicated to broader audiences. The concept of 'mediating transposition' used by Guichard and Martinand (2000) and the 'museographic transposition' used by Simonneaux and Jacobi (1997) constitute a proper context in which exhibitions that introduce elements of history of science used in combination with contemporary communication strategies and museographical techniques could be analysed or designed. In this context, further research questions could be posed in the following broad areas: (a) in relation to the deconstruction and reconstruction of a historical subject in science and the identification of possible related misconceptions often found in exhibitions (i.e. epistemological analysis, see Foss Mortensen 2010) and/or (b) the decoding and recoding of messages, if we regard exhibitions as pedagogical multi-modal texts (i.e. semiotic analysis, see Anyfandi et al. 2010).

(3) *The learning/pedagogical research strand.* In this noteworthy heterogeneous strand, the main issue is the investigation of learning in informal and non-formal settings and more particularly if and how cognitive progress of visitors is achieved during a science museum visit (e.g. Anderson et al. 2003; Martin 2004; Griffin 2004). Can history of science maximise visitors' learning best when designed as a communicational element or as an educational tool? Is it better to use the history of science so that museum visitors can construct understandings of the nature of science and of conceptual elements of science? Studies addressing such questions can inform researchers in the fields of psychology and science education as well as designers of science exhibitions who seek to develop

a museological/museographical approach that maximises visitor learning. An important dimension of this research strand is developmental studies that investigate possible correlations between student learning of the official school programme and the coordinated activities that take place in schools and museums conjointly. In addition, existing didactic models that investigate how the introduction of elements of the history of science into formal education influence students' cognitive progress (e.g. Monk and Osborne 1997; Hottecke et al. 2012) could be altered to include activities in museum settings.

A necessary precondition for the establishment of the above-mentioned research strands is the acceptance of the strong transdisciplinary and interdisciplinary nature of this research and the creation of a collegial environment among the researchers involved. In other words, we need to accept that the intersection of the history of science, scientific museology and science education represents a fruitful set for the consideration of the theoretical background, the methodological approach and the social practices of science learning.

References

Anderson, D. and Lucas, K.B. (1997). The effectiveness of orienting students to the physical features of a science museum prior to visitation. *Research in Science Education*, 27(4), 485–495.

Anderson, D., Lucas, K.B., Ginns, I.S. & Dierking, L.D. (2000). Development of knowledge about electricity and magnetism during a visit to a science museum and related post-visit activities. *Science Education*, 84(5), 658–679.

Anderson, D., Lucas, K.B. & Ginns, I.S. (2003). Theoretical perspectives on learning in an informal setting. *Journal of Research in Science Teaching*, 40(2), 177–199.

Anderson, K., Frappier, M., Neswald, E. & Trim, H. (2011) Reading instruments: Objects, texts and museums. *Science & Education*, doi: 10.1007/s11191-011-9391-y

Antoine, M. (2010). Les universités doivent-elles vraiment exposer leurs collections au grand public? *La Lettre de l'OCIM*, 129, 7–12.

Anyfandi, G., Koulaidis, V. & Dimopoulos, K. (2010). A social-semiotic framework for the analysis of science exhibits. In A. Filippoupoliti (ed.) *Science Exhibitions: Communication and Evaluation* (pp. 102–149). Edinburgh: Museums Etc.

Arnold, K. (1996). Presenting science as product or as process: Museums and the making of science. In S. M. Pearce (ed.) *Exploring Science in Museums* (pp. 57–78). London: Athlone Press.

Arnold, K. (2006). *Cabinets for the Curious. Looking back at Early English Museums.* London: Ashgate.

Bennett, J. (1997). Museums and the establishment of the history of science at Oxford and Cambridge. *British Journal for the History of Science*, 30, 29–46.

Bennett, J. (2005). Museums and the history of science: Practitioner's postscript. *Isis*, 96(4), 602–608.

Bennett, T. (1995). *The Birth of the Museum: History, Theory, Politics*. London & New York: Routledge.

Bensaude-Vincent, B. (2001). A genealogy of the increasing gap between science and the public. *Public Understanding of Science*, 10(1), 99–113.

Brush, S.G. (1969). The role of history in the teaching of physics. *The Physics Teacher*, 7, 271–280.

Brush, S.G. (1974). Should the History of Science be rated X? *Science*, 183 (4130), 1164–1172.

Bud, R. (1997). History of science and the Science Museum. *British Journal of the History of Science*, 30, 47–50.

Camerota, F. (2011). Promoting scientific heritage and disseminating scientific culture: The role of the Museo Galileo in Florence. In F. Seroglou, V. Koulountzos & A. Siatras (eds) *Proceedings of the 11th International IHPST and 6th Greek History, Philosophy and Science Teaching Joint Conference* (pp. 117–119). Thessaloniki: Epikentro.

Caro, P. (1997). Tensions between science and education in museums and elsewhere. In G. Famelo & J. Carding (eds) *Here and Now, Contemporary Science and Technology in Museums and Science Centres* (pp. 219–225). London: The Trustees of the Science.

Cerretta, P. (2012). Gravity-powered calculator, a Galilean exhibit. *Science & Education* special issue 'History of science in museums', doi: 10.1007/s11191-012-9549-2.

Chittenden, D., Farmello, G. & Lewenstein, B. (2004). *Creating Connections, Museums and the Public Understanding of Current Research*. Creek CA: Altamira Press.

Cole, K.C. (2009). *Something Incredibly Wonderful Happens: Frank Oppenheimer and the World He Made up.* Boston: Houghton Mifflin Harcourt.

Conn, S. (2000). *Museums and American Intellectual Life 1876–1926.* Chicago: University of Chicago Press.

Coombs, P.H. & Ahmed, M. (1973). *New Paths to Learning for Rural Children.* New York: International Centre for Educational Development.

Daston, L. (ed.) (2000). *Biographies of Scientific Objects*. Chicago: University of Chicago Press.

De Clercq, J.S. (2003). Museums as a mirror of society: a Darwinian look at the development of museums and collections of science. In P. Tirell (ed.) *Proceedings of the 3rd Conference of the International Committee for University Museums and Collections* (pp. 57–65). Oklahoma: UMAC Publication.

De Clercq, P., Lewis Evans & the White City Exhibitions. *Sphaere. The online journal of the Museum of the History of Science, University of Oxford.* http://www.mhs.ox.ac.uk/sphaera/index.htm?issue11/articl4. Accessed 28 November 2012.

De Renzi, S. (1998). Between the market and the academy: Robert S. Whipple (1872–1953) as a collector of science books. In R. Myers & M. Harris (eds), *Medicine, Mortality and the Book Trade* (pp. 87–108). Newcastle, DE: Oak Knoll Press.

DeWitt, J. & Osborne, J. (2007). Supporting teachers on science-focused school trips: Towards an integrated framework of theory and practice. *International Journal of Science Education*, 29(6), 685–710.

Durant, J. (2000). The Wellcome Wing at the Science Museum London. A breathtaking theatre of contemporary science. *Museologia, An International Journal of Museology,* 1, 43–48.

Duschl, R. (1994). Research on the history and philosophy of science. In D. Gable (Ed.) *Handbook of Research in Science Teaching* (pp. 443–465). New York: Macmillan.

Escot, C. (1999). *La culture scientifique et technologique dans l'éducation non formelle*. Paris: UNESCO Publications.

Eshach, H. (2006). Bridging in-school and out-of-school learning: formal, non-formal and informal. In H. Eshach (ed.) *Science literacy on primary schools and pre-schools* (pp. 115–141). Dordrecht Netherlands: Springer.

Fadel, K. (2011). History of science, education and popular science show: The case of the particle accelerator at the Palais de la Découverte (Paris). Paper presented in the 11th International IHPST and 6th Greek History, Philosophy and Science Teaching Joint Conference, Thessaloniki, 1–5 July 2011.

Falomo-Bernarduzzi, L., Albanesi, G. & Bevilacqua, F. (2012). Museum heroes all: the Pavia approach to school-science museum interactions. *Science & Education* special issue 'History of science in museums', doi: 10.1007/s11191-012-9541-x

Faria, C., Pereira, G. & Chagas, I. (2012). D. Carlos de Bragança, a pioneer of experimental Marine Oceanography: Filling the gap between formal and informal science education. *Science & Education*, 21(6), 813–826.

Ferriot, D. & Jacomy, B. (2000). The Musée des Arts et Métiers. In S. Lindqvist (ed.) *Museums of Modern Science*, (pp. 29–42). New York: Science History Publications.

Filippoupoliti, A. (2011). Premises for exhibition and for use: King's College London Museum, mid to late nineteenth century. *Museum History Journal* special issue 'University museums', 4(1), 11–28.

Findlen, P. (1989). The museum: its classical etymology and Renaissance genealogy, *Journal of the History of Collections*, 1(1), 59–78.

Findlen, P. (1994). *Possessing Nature: Museums, Collecting and Scientific Culture in Early Italy*. Berkeley: University of California Press.

Findlen, P. (2000). The modern muses. Renaissance collecting and the cult of remembrance. In S.A. Crane (ed.) *Museums and Memory* (pp. 161–178). Stanford CA: Stanford University Press.

Foss Mortensen, M. (2010). Museographic transposition: The development of a museum exhibit on animal adaptations to darkness. *Education et Didactique*, 4(1), 115–138.

Friedman, A. (2010). The evolution of the science museum. *Physics Today*, 63(10), 45–51.

Galison, P. & Thompson, E. (eds) (1999). *The Architecture of Science*. Cambridge MA: MIT Press.

Golinski, J. (1998). *Making Natural Knowledge: Constructivism and the History of Science*. Cambridge: Cambridge University Press.

Griffin, J. & Symington, D. (1997). Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education*, 81(6), 763–779.

Griffin, J. (2004). Research on Students and Museums: Looking More Closely at the Students in School Groups. *Science Education*, 88(S1), 59–70.

Guichard, J. (1998). Adapter la muséologie aux enfants. In B. Schiele & E.H. Koster (eds) *La révolution de la muséologie des Sciences: Vers les musées du XXI siècle* (pp. 207–248). Lyon: Presses Universitaires de Lyon.

Guichard J. & Martinand J.-L. (2000). *Médiatique des Sciences*. Presses Universitaires de France.

Guisasola, J., Morentin, M. & Zuza, K. (2005). School visits to science museums and learning sciences: A complex relationship. *Physics Education*, 40(6), 544–549.

Guisasola, J., Solbes, J., Barragues, J.-I., Morentin, M., & Moreno, A. (2009). Students' understanding of the special theory of relativity and design for a guided visit to a Science Museum. *International Journal of Science Education*, 31(15), 2085–2104.

Heering, P. & Muller, F. (2002). Cultures of experimental practice. An approach in a museum. *Science & Education*, 11(2), 203–214.

Heering, P. (2011). Tools for investigation, tools for instruction: Potential transformations of instruments in the transfer from research to teaching. In P. Heering and R. Wittje (eds) *Learning by Doing. Experiments and Instruments in the History of Science Teaching* (pp. 15–30). Stuttgart: Franz Steiner Verlag.

Hein, H. (1990). *The Exploratorium. The Museum as Laboratory*. Washington: Smithsonian Institution.

Hodson, D. (2008). *Towards Scientific Literacy: A Teachers' Guide to the History, Philosophy and Sociology of Science*. Rotterdam: Sense Publishers.

Hottecke, D. & Silva, C. (2010). Why implementing history and philosophy in school science education is a challenge: An analysis of obstacles. *Science & Education*, 20(3–4), 293–316.

Hottecke, D., Henke, A. & Riess, F. (2012). Implementing history and philosophy in science teaching: Strategies, methods, results and experiences from the European HIPST Project. *Science & Education*, 21(9), 1233–1261.

Impey, O. & MacGregor, A. (eds) (1985 [2001]). *The Origins of Museums: The Cabinets of Curiosity in the Sixteenth- and Seventeenth-century Europe*. London: House of Stratus.

Jacobi, D. (1999). *La Communication Scientifique. Discours, Figures, Modèles*. Grenoble: Presses Universitaires de Grenoble.

Jurdant, B. (2009). *Les Problèmes Théoriques de la Vulgarisation Scientifique*. Paris: Editions des Archives Contemporaines.

Klopfer, L. (1969). The teaching of science and the history of science. *Journal of Research in Science Teaching*, 6(1), 87–95.

Klopfer, L. & Cooley, W. (1963). The history of science cases for high schools in the development of student understanding of science and scientists: A report on the HOSG instruction project. *Journal of Research in Science Teaching*, 1(1), 33–47.

Koliopoulos, D. (2003). Blunting the tensions between informal and formal education in science: Reforming the relationship between the school and the science museum in Greece. *Mediterranean Journal of Educational Studies*, 8(1), 81–95.

Kuhn, T. (1970). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.

Langevin, P. (1964). La valeur éducative de l'histoire des sciences. In P. Labérenne (ed.) *La Pensée et l'Action* (pp. 193–208). Paris: Les éditeurs Français Réunis.

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers through Society.* Milton Keynes: Open University Press.

Latour, B. & Woolgar, S. (1986). *Laboratory Life: The Construction of Scientific Facts.* London: Sage.

Lederman, N. (2007). Nature of science: past, present, and future. In S. Abell & N. Lederman (eds) *Handbook of Research on Science Education* (pp. 831–879). London & New York: Routledge.

Lévy-Leblond, J.M. (2004). *Science in Want of Culture*. Paris: Futuribles.

Lévy-Leblond, J.M. (2012). The muses of science. A utopian oracle. *Science & Education* special issue 'History of science in museums', doi: 10.1007/s11191-012-9522-0

Lourenço, M.C. (2005). *Between Two worlds: The Distinct Nature and Contemporary Significance of University Museums and Collections in Europe*. Unpublished doctoral thesis, Conservatoire National des Arts et Métiers, Paris.

Lourenço, M.C. (2012). Documenting collections: cornerstones for more history of science in museums. *Science & Education* special issue 'History of science in museums', doi: 10.1007/s11191-012-9568-z.

Maison, L. (2002). L'exposition des instruments anciens d'Astronomie: histoire et défis actuels. *La Lettre de l'OCIM*, 84, 39–44.

Martin, L.M.W. (2004). An emerging research framework for studying informal learning and schools. *Science Education*, 88(S1), 71–82.

Matthews, M. (1994/2014). *Science Teaching. The role of History and Philosophy of Science.* London & New York: Routledge.

Monk, M. & Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: a model for the development of pedagogy. *Science Education*, 81(4), 405–424.

Nersessian, N. (1992). How do scientists think? Capturing the dynamics of conceptual change in science. In R. Giere (ed.) *Cognitive Models of Science* (pp. 5–22). University of Minneapolis: Minnesota Press.

Paparou, F. (2011). Shall we stroll to the museum? Educational proposal for the exploration of a historic school scientific instrument collection. In F. Seroglou, V. Koulountzos & A. Siatras (eds) *Proceedings of the 11th International IHPST and 6th Greek History, Philosophy and Science Teaching Joint Conference* (pp. 574–580). Thessaloniki: Epikentro.

Pearce, S.M. (1993). *Museums, Objects and Collections. A Cultural Study.* Leicester: Leicester University Press.

Pedretti, E. (2002). T. Kuhn Meets *T. Rex*: Critical conversations and new directions in science centres and science museums. *Studies in Science Education* 37(1), 1–41.

Quin, M. (1993). Clones, hybrides ou mutants ? L'évolution des grands musées scientifiques européens. *Alliage,* 16–17, 264–272.

Schiele, B. & Koster, E.H. (1998). *La Révolution de la Muséologie des Sciences.* Lyon : Presses Universitaires de Lyon.

Seroglou, F. & Koumaras, P. (2001). The contribution of the history of physics in physics education: a review. *Science & Education*, 10(1–2), 153–172.

Sibum, H.O. (2000). Experimental history of science. In S. Lindqvist (ed.) *Museums of Modern Science* (pp. 77–86). Canton MA: Science History Publications/USA.

Simonneaux, L. & Jacobi, D. (1997). Language constraints in producing prefiguration posters for a scientific exhibition. *Public Understanding of Science,* 6, 383–408.
Stinner, A., MacMillan, B., Metz, D., Jilek, J. & Klassen, S. (2003). The renewal of case studies in Science Education. *Science & Education,* 12(7), 617–643.
Stocklmayer, S., Rennie, L. & Gilbert, J. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education*, 46(1), 1–44.
Strauss, S. (ed.) (1988). *Ontogeny, Phylogeny and Historical Development.* Norwood, New Jersey: Ablex Publishing.
Subiran, S., Lourenco, M., Wittje, R., Talas. S. & Bremer, T. (2009). Initiatives européennes et patrimoine universitaire. *La Lettre de l'OCIM*, 123, 5–14.
Taub, L. & F. Willmoth (eds) (2006). *The Whipple Museum of the History of Science: Instruments and interpretations, to celebrate the 60th anniversary of R.S. Whipple's gift to the University of Cambridge.* Cambridge: Cambridge University Press.
Teichmann, J. (1981). Deutsches Museum, München. Science, technology and history as an educational challenge. *European Journal of Science Education*, 3(4), 473–478.
Teichmann, J. (1999). Studying Galileo at secondary school: A reconstruction of his 'jumping-hill' experiment and the process of discovery. *Science & Education*, 8(2),121–136.
Tran, L. (2007). Teaching science in museums: The pedagogy and goals of museum educators. *Science Education*, 91(2), 278–297.
Tucci, P. (2002). Role of university museums and collections in disseminating scientific culture. *Museologia*, 2, 17–22.
Van Praet, M. (1995). Les expositions scientifiques miroirs épistémologiques de l'évolution des idées en sciences de la vie. *Bulletin d'Histoire et d'Epistémologie des Sciences de la Vie*, 2, 52–69.
Wagensberg, J. (2004). The basic principles of modern scientific museology. *Museos de Mexico y del Mundo,* 1(1), 14–19.
Yanni, C. (1999). *Nature's Museums. Victorian Science and the Architecture of Display*. London: Athlone Press.
Zana, B. (2005). History of the museums, the mediators and scientific education. *Journal of Science Communication,* 4(4), 1–6.

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