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Informal and Non-formal Education: An Outline of History of Science in Museums

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Abstract Although a growing number of research articles in recent years have treated the role of informal settings in science learning, the subject of the history of science in museums and its relationship to informal and non-formal education remains less well explored. The aim of this review is to assemble the studies of history of science in science museums and explore the opportunities for the further use of the history of science in science museum education practice.

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 characterize 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);

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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); and
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 analyze the history of science as an exhibition and communication element; and finally, we approach the subject as an educational element.

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 organized mainly according to 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 categorizations produced by both museum professionals and museum researchers. These categorizations 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 2005; 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

[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 organized 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 organized educational activities (as in the case of educational programmes in museums or programmes that are organized between school and museum).

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 (for example, 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 the first public museums with science collections make their appearance, such as the *Musée des Arts et Métiers* in Paris (Ferriot and Jacomy 2000). In museums of such a type, scientific objects were displayed as art objects and admired by the upper class (Bennett 1995). 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 19th century and World War II another type of museum emerged. During this time, museums also embraced an explicit educational mission following the mid-nineteenth-century demand for educating the lay public. 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 (Durant 2000; Teichmann 1981).

During the twentieth century a new category of a science museum appears, while the rest of the old-style, traditional, science museums are renovating their galleries in such a way as to adapt to the museological approaches and museographical practices of the new type of a science museum. 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).

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; Bud 1997; Camerota 2011). Museums of the history of science are usually university museums that base their 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 (est. 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) is used.

Other categories of a science museum where history of science is potentially present are non-university museums such as the *Musée des Arts et Métiers* in Paris and the *Science Museum* in London that hold rich scientific collections make possible the presentation of a history of science exhibition narrative even though the history of science is not a distinct part of their institutional mission, 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).

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* emphasizes 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* emphasizes 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.

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 assimilated an encyclopedia of natural sciences in wich 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

[2] Lewis Evans (1853–1930) was a collector, brother of the notable archaeologist, Sir Arthur Evans, who excavated the Palace of Knosos, Crete (Greece). See also P. de Clercq (2000). 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 Trade* (pp. 87–108). St. Paul's Bibliographies: Oak Knoll Press.

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–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 century' 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 developed, including non-scientific factors (Golinski 1998; Galison and Thompson 1999; Daston 2000).

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 popularized conception of the content and method of science (Stocklmayer et al. 2010). However, this kind of popularization 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 popularization 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.

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

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 (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 specialized museum educators. The *Deutsches Museum* is one example of a successful implementation of history of science elements in museum educational programmes (Teichmann 1981). 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 artifacts 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 or students' 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, 2009; Paparou 2011; Anderson et al. 2011; Falomo-Bernarduzzi et al. 2012). 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). All the educational attempts that were discussed in the previous sections focus most of the times 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).

5 Conclusions

The variety of reviews that refer to the introduction of elements of history of science in primary and secondary school (Matthews 1994; 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 realization 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? (Lourenço 2012). On the other hand, a primary question that in our opinion should concern science centres that aim at the diffusion and popularization of modern scientific knowledge is 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/museolographical 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. 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 analyzed 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) or/and (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 maximize 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 maximizes visitor learning. 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 that represent a fruitful set for the consideration of the theoretical background, the methodological approach and the social practices of science learning.

References

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

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

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.

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. (2006). *Cabinets for the Curious. Looking back at early English museums*. London: Ashgate.

Bennett, T. (1995). *The birth of the museum: History, theory, Politics*. London & New York: Routledge.

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.

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*. doi:10.1007/s11191-012-9549-2. Special issue 'History of science in museums'.

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. (2005). 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. (2000). 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 Nov 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*. doi:10.1007/s11191-012-9541-x. Special issue 'History of science in museums'.
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, 4*(1), 11–28. Special issue 'University museums.
Filippoupoliti, A., & Koliopoulos, D. (2014). Informal and non-formal education: History of science in museums. In M. R. Matthews (Ed.), *International handbook of research in history* (pp. 1565–1582). Springer, Dordrecht: Philosophy and Science Teaching.
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. (2004). Research on students and museums: Looking more closely at the students in school groups. *Science Education, 88*(S1), 59–70.
Griffin, J., & Symington, D. (1997). Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education, 81*(6), 763–779.
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*. Paris: PUF.
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. (2011). Tools for investigation, tools for instruction: Potential transformations of instruments in the transfer from research to teaching. In P. Heering & R. Wittje (Eds.), *Learning by doing. Experiments and Instruments in the history of science teaching* (pp. 15–30). Stuttgart: Franz Steiner.
Heering, P., & Muller, F. (2002). Cultures of experimental practice. An approach in a museum. *Science & Education, 11*(2), 203–214.
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.
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.
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.
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.
Lourenço, M. C. (2012). Documenting collections: cornerstones for more history of science in museums. *Science & Education*. doi:10.1007/s11191-012-9568-z. Special issue 'History of science in museums'.
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). *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.
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.
Taub, L., & Willmoth, F. (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.
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.