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Unfinished Science in Museums: a push for critical science literacy

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Abstract

Communication of scientific knowledge has been caught up in a pedagogical struggle between science literacy ideologies. The backseat role taken by the teaching of the philosophical and sociological aspects of science has come under fire by those calling for a broader view of science to be made public under the umbrella term "critical science literacy". In this paper, we argue that the lack of unfinished science in museums — science still in the making or still being debated — is a paradigm case where the richer, fuller view of science is being denied air by the presentation of science as a finished, objective set of facts. We argue that unfinished science offers us the opportunity to present the full complexity of science, including its social and philosophical aspects, and thus enabling the "critical" of critical science literacy.

Keywords Unfinished science, critical science literacy, museums

Introduction

Communication of scientific knowledge has been caught up in a pedagogical struggle between public literacy ideologies. The backseat role taken by the teaching of scientific methodologies is a reflection of the dominant forms of social discourse, which prioritise the communication of a historicised, chronological progression of scientific advancement and eliminates the idea of subjectivity. While this objective, finished version of science is important for grasping the mechanics of scientific principles, it is the teaching of methodologies and an immersion into the continuous evolution of knowledge that is required for a fuller understanding. The perpetuation of a finished version of science is to some extent attributable both to the complexity of true scientific understanding and the use of key mediums in enabling ongoing informal science learning.

This paper argues that the problem with allowing these mediums to communicate only finished science is that most science is in fact highly dynamic. It is only through an understanding of the dynamic nature of scientific discovery that programmes can hope to gain real, widespread public engagement and political clout [Brand, 2008]. Within this discussion we will take the museum as an example of a technology for informal science education, and single out the exhibition as the dominant communication format within the museum, despite contemporary challenges to the traditional collection-centric structure. Tracing the major influences on the public museum, we consider the effects on communication and on the advancement of science literacy stemming from the museum's role at the intersection between authority, truth and education. Problematizing the distinction between finished and unfinished science within the museum's educational format, we will argue that presentation of only finished science in museums clashes with leading views in both the philosophy and the sociology of science, and that this short coming fails to heed more recent calls with regard to science literacy. Following calls for critical science literacy, we make the case for the inclusion of unfinished science in museums as a object useful in opening spaces for discussion on the dynamism of science and the sociality of science.

The Science Museum

The science museum is intended to act as an informal information source for the public, where they can achieve a basic grounding in scientific principles and advancements [Macdonald and Silverstone, 1992]. The manner in which this scientific education is achieved has shifted dramatically since the 1980s, with the introduction of 'new' museology and the emergence of new paradigms in science communication as a field applicable within the museum [Tlili and Dawson, 2010].

The science museum has traditionally presented scientific knowledge through the display of material culture, within exhibitions focused on giving either an historical account of scientific discoveries or an explanation of isolated scientific principles [Nall, 2011]. This has recently been expanded to include interactive events designed to engage the public further, with community engagement and upstream engagement being key foci of museology and science communication respectively. Unfortunately both these techniques have been restricted in the breadth of their applicability within the existing format of the museum, and as such their impact is qualitative rather than quantitative.

There is a long history behind the operational strategies at work in museums, and it is difficult to implement new approaches effectively without confronting the realities of funding, tradition and the role of the institution.

Civic Education

Basic education is unquestionably a primary goal and driving force behind the museum, and is included as such in most modern museum definitions [Chittenden, 2011; Hein, 2011]. Originally conceived as an institution focusing on collection and display of (exotic) objects, since the 1970s the museum has actively redirected its attention to using the collection to promote continued learning outside formal educational institutions [MacGregor, 2006]. Accordingly, the museum is now one of the key resources for supporting informal adult education [Hein, 1998] and bears a responsibility to continue to provide relevant and contemporary information [Fehlhammer, 1997].

The museum environment is unique amongst learning institutions, with its system of knowledge embodied through its collection. The collection is at the core of the museum's structure, despite recent movements to transform the didactic collection into new modes of interactive experiences [Balloffet, Courvoisier and Lagier, 2014; Bennett, 1998; MacDonald, 1998] and visitors experience the collection in a constructed exhibition that aims to communicate a particular set of information.

The exhibition communicates on many levels, with explicit text providing a didactic experience that is complemented by the visual presentation of carefully curated objects. These objects create relationships amongst themselves, serving as reinforcement for the texts as well as the overarching theme of the exhibition. Objects are also widely acknowledged as the primary learning source in many instances, with visitors inclined towards only a cursory reading of didactics [MacDonald, 1998; Bitgood and Patterson, 1993] and the museum therefore relies heavily on user interpretation and existing visual literacy skills [Jacobs et al., 2009]. In order to effectively achieve a learning outcome within these conditions, visitors must be familiar with the institution's 'spatio-temporal material reality' [Taborsky, 1990] informed by the social system in which the museum resides, and be able to interpret the object and the exhibition within the context of this reality. The visitor's learning experience is both overt and intuitive, differing from other informal learning environments through the inclusion of multi-modal learning facilitated by visual elements, rather than language, written or verbal, in isolation.

While the visitor's interpretive experience with exhibitions may be complex, the museum's perception of its public has historically meant the simplification of concepts and the re-casting of them as factual, objective and, particularly in the case of the science museum, 'fun' [Hackmann, 2002]. The science institution, and particularly the science centre, has been one of the most enthusiastic advocates for the 'edutainment' movement in museum education that rejects the use of the collection in favour of 'hands-on' exhibits. Spearheaded by the opening of the Exploratorium in 1969 [Oppenheimer and Cole, 1974] edutainment has become one of the most prevalent forms of informal science education. Intended to increase interest in scientific learning, this exhibiting technique nevertheless continues to present decontextualized explorations of scientific principles [Bell, 2008] in much the same manner as the traditional science exhibit, removing the social, economic and ethical aspects of discoveries. It has also meant the isolation of adults within the scientific institution, with hands-on exhibits aimed at children and adolescents. Museum educators cite the declining interest in science characterized by falling numbers in formal scientific education as justification for this audience focus [Renner, 2009].

The emphasis on entertainment has had a number of far-reaching consequences on the educational mission of science museums. It has limited the accessibility of the science museum for adults, and has simultaneously restricted the degree to which complex discussions around scientific topics can be presented.

Museums as Authorities

The museum's educational mission cannot be held entirely to blame for the simplification of knowledge however. The very construct of the museum is steeped in a distinction between public and aristocracy, the latter of which later morphed into administration, both governmental and institutional. With the growth of social idealism in the middle of the seventeenth century [Abt, 2011] the public began to emerge as an audience to whom the museum specifically catered. Like the Great Exhibitions, however, the museum was crafted as an instrument for creating a self-regulating public with citizens that understood their place within society, transforming an 'ungovernable *populace* to a multiply differentiated *population*' [Bennett, 1998]. This role is activated through powerful symbolism that emerged via the strategic deployment of collections, exhibitions and spatial design [Duncan, 1995] enabling the administration to capture 'hearts and minds' [Bennett, 1998].

Creating an environment that is able to achieve such a civic transformation necessitates the cultivation of an institutional authority; there must be trust in the exhibition as representational of a set of truths that reflect the beliefs of a society. The role of governments in controlling public museums (with the exception of some North American museums) ensures that the beliefs relevant to the social system of the region are reflected in the museum's teachings, no longer under the guise of population control but instead labelled as a public service, as informal education. Accordingly, the public has come to expect 'absolute truths' from the museum, reflecting either social beliefs or, in the case of the science museum, standard scientific principles; '[visitors] still expect the museum to present exhibits that demonstrate science's conclusiveness, rather than its doubt' [Conn, 2011].

The simplification of knowledge, therefore, cannot be attributed exclusively to the changing format of museum presentation, but also to the overarching forces that guide the museum's objectives, and the learned behaviour of the visitor in relation to the exhibition. Despite the apparent abandonment of the 'civilizing' mode of operation within the modern museum in favour of an invigoration of its social purpose [Kriegel, 2006] it is important to keep in mind the underlying political nature of the museum, particularly in relation to its role as public educator.

Science in the Museum

Taking into account the impact of both the educational mission and the onus of authority borne by the modern museum, it is somewhat unsurprising that most science museums have focused on presenting a particular form of scientific knowledge that corresponds to the established institutional objectives. There is a tendency towards stasis, with science portrayed as 'objectivist, aproblematic and positive' [Delicado, 2009] and in order to achieve this there needs to be not only a separation of science from real-world issues that impact on its practical application, but also an elimination of scientific debate whether competing with existing theories or at the cutting edge of development. While there has been a significant impact from engagement advocates on the material included within the science museum, major challenges to the standard system of displaying scientific principles are primarily relegated to event-based engagement activities.

The nature of science within the science museum oscillates between the pedagogical and popular stages of information evolution, or Expository Continuum [Bucchi, 1998; Cloître and Shinn, 1985] with discoveries distilled into forms that are readily accessible to non-specialist and lay audiences.

The pedagogical stage is 'characterised by abundant historical references and the frequent use of reification' [Cloître and Shinn, 1985] and requires an established knowledge of existing scientific paradigms. Without these established knowledge structures there would be no context for the non-expert/student to place the new knowledge within.

The popular stage includes very little technical information, dwelling instead on the phenomena that the general public can associate with. Less general knowledge than previous stages is required to establish an understanding. Indeed, popularisation 'is tantamount to the treatment of a subject about which it is more crucial to know that something has occurred than it is to know the minutiae of the occurrence itself' [Cloître and Shinn, 1985].

These two stages are consistent with the objectives of the institution, prioritizing a quantitative educational impact characterized by simple informational chunks, and adhering to the 'public deficit' model of communication [Besley and Tanner, 2011; Schiele, 2008]. The public deficit model assumes a gap between expert and public and advocates 'knowledge and information about science [. . .] diffused from science via some medium to an audience' [Horst and Michael, 2011]. In this case the exhibit fulfils the role of 'medium', and the museum is able to use its intermediary position to form its own vision of what constitutes science and scientific advancements. It removes the context of research from the context of reception (the museum exhibit) and creates a definitive, decontextualized version of science.

Unfinished Science

Through the medium of the museum Latour's 'black box' [Latour, 1987] is established. This concept is elegantly explained by Stafford as describing 'those assumptions in science that are taken as givens, that are presumed no longer to require discussion and thus have become invisible' [Stafford, 1999]. Through the application of the black box to scientific trajectories, science is constructed for presentation as a 'polished, objectified, linear and persuasive story' [Bucchi, 1998]. As it progresses through this narrative reworking it similarly passes into the pedagogical and popular stages of the expository continuum, adapted to fit within an existing paradigm and simplified for a non-technical audience. The result of this transformational process is *finished* science. *Un*finished science, in contrast, is unable to be packaged in such a way because there is no conclusion or definitive outcome from which the story can be constructed.

Unfinished science is an umbrella term that encompasses various definitions and subcategories, including science-in-the-making [Latour, 1987] and Public Understanding of (Current) Research [Lewenstein and Bonney, 2004; Yaneva, Rabesandratana and Greiner, 2009; Farmelo, 2004]. A brief definition can be understood as 'scientific claims and conclusions that, for whatever reasons — the novelty of the subject matter, the availability of new research techniques, the absence or inconsistency of evidence, the paucity of theory- are unsettled within the scientific community' [Durant, 2004]. As Latour notes by casting them as two faces of a single being, Janus, finished and unfinished science are two sides of a whole [Latour, 1987]. Unfinished science remains primarily in the more technically complex stages of the expository continuum, with the unproven nature of the theory preventing it from progressing to the pedagogical and popular stages of information evolution that remain the domain of finished science.

One of the steps needed to begin rethinking the communicative strategies of the museum exhibit is to unpack unfinished science and identify the forms of research and discussion that are collected within the umbrella term. There are two major strands of unfinished science, scientific controversy and science-in-the-making, and they differ significantly from each other in both structure and contents. Indeed, the grouping of them together may be attributed to the challenge they pose to established modes of communication rather than any direct parallels.

Forms of Unfinished Science

Scientific controversy is closely related to ethics, and is situated primarily within the later stages of knowledge transformation. As such it relies on the standard model of knowledge transformation that allows the ordinary diffusion of ideas from experts to the public, who may then form an opinion in the context of popular culture, including, at times, the science museum [Macdonald and Silverstone, 1992]. This generally takes the form of an ethical discussion around the principles the black box reveals, accepting the completed nature of the research but introducing the second aspect of a political argument. Effectively, controversy takes the completed black box and builds upon it without questioning the science itself.

The controversy model is very open to public debate and can have implications for the conversion of findings into technologies. It is frequently initiated and perpetuated by the media, and misinformation is rife as the intricacies of discoveries are lost during the journey from expert to wider public. Indeed, dubious reporting in the mass media is a considerable problem for the promotion of real understanding of science [Durant, 2002].

Science-in-the-making revolves around two forms of debate, both of which are very similar but differ in terms of the age of the argument. The first is concerned with cutting edge science and technology that is still in the research stage [Lewenstein and Bonney, 2004; Delicado, 2009]. The latter encompasses those ongoing debates that have yet to be resolved but have established a preference for a particular theory regardless.

In the case of science-in-the-making, there is no opportunity for the scientific knowledge to be transformed for public consumption, as it remains in the discussion phase amongst experts. It is therefore very difficult for the public to entirely comprehend the complexities of the discovery, because it has not gone through a simplification process en route to becoming a static 'truth'. Communicating science-in-the-making therefore requires a deviation from the regular information continuum in order to temporally align the timeframe of public awareness with that of the expert, situating it prior to black box formation.

Although both scientific controversy and science-in-the-making fall under the umbrella term of unfinished science, they approach engagement with the public in very different ways. They both work to reveal the dynamic nature of science, however, regardless of which phase of scientific research they focus on; whether pure research or its practical application as technology. Both act to question the myth of finished science, and their removal from the exhibit to the collaborative discussion model is a reflection not only of the tension experienced within the museum between education and communication, but echoes the broader social debate over the level of involvement the public should have in scientific development.

Theoretical mismatch: science is never finished.

While the museum has grown to accept that unfinished science is an important element in science communication [Chittenden, 2011] there is a conflict of purpose over the sociality of science and the museum's educational mission. The pervasive observation is that most of the science museums avoid dealing with controversy, and more broadly unfinished science, within their static displays [Macdonald and Silverstone, 1992; Arnold, 1996; Delicado, 2009]. Accordingly, there has been a subtle move to relegate science-in-progress to collaborative discussion models external to the museum display. What the existing science museum system fails to do by focusing its exhibitions on finished, textbook science, is to recognize the capacity for educating visitors in the process of scientific enquiry.

The presentation of science as a finished set of textbook facts, with unfinished science as an outlier, stands in sharp contrast with accounts of how science proceeds, both in terms of methodology and in terms of social practice. No doubt, exactly how science does proceed is a matter of continuing debate. There is disagreement over what proper scientific methodology is, if such a thing even exists [Godfrey-Smith, 2003]; there is disagreement over the social practices within and surrounding science; and there is disagreement over how such social practices affect the views reached by science and scientists [Fuller, 2006]. But despite these disagreements, the one point on which there is near universal consensus is that science is never finished; there are never "settled facts" in science. We may, for some period of time, agree on some scientific claims, but such agreement is always socially and culturally located. At its core, the view of science as never-finished stems from the view that science is ever changing.

In terms of methodology, one of the dominant views of science — falsification — is as an ongoing set of refutations. Science and scientists are not in the business of providing facts we can know, they are in the business of proposing ways the world might be or is likely to be, and rejecting or refuting the claims that prove to be false [Chalmers, 1976]. Science isn't about proving claims true — which are what we need for finished science — it's about disproving false ones. The rationale for this falsification view is that no matter how well studied, researched, or experimented on a hypothesis is, it could still be false. The studies and experiments may have missed a crucial point or we may not have sufficient theoretical sophistication to ascertain our claims, so the most we can ever rationally claim is that the studied hypothesis is our best current explanation [Godfrey-Smith, 2003]. The upshot of such methodology is that science is in a never-ending state of flux where, hopefully, disproved hypotheses are replaced by ever increasingly likely ones. Thus, theoretically, science is never finished. Of course, falsification is but one view of what scientific methodology is like, but it is a very dominant view, and, more importantly, alternative perspectives share falsification's view that science is never finished. Beyond the methodological views of science, social forces, both internal and external to science, also bring about changes in science.

Leading accounts of the social structures that lead to scientific discoveries likewise present science as a never-finished process, whether we favour a Kuhnian view, Latour's perspective or some other lens [Fuller, 2006]. Kuhn, for example, presents science as proceeding from states of 'normal science' to 'crises'. Under 'normal science', scientists operate within an accepted paradigm and the scientific community largely agrees on what is 'in' and what is 'out' of science. During such periods, we may have seemingly finished science — science that is accepted by the scientific community. But these periods are exactly that: periods. As further research is carried out, settled or finished parts of science are challenged by new findings (think general relativity's challenge of Newtonian mechanics). This leads to a period of crisis where the theories and scientific views held by the scientific community are called into question. The crisis continues until a consensus forms around a new paradigm [Kuhn, 1996]. This shift to a new consensus, this paradigm shift, requires revision of what stands as accepted science. Once a new paradigm has been established, a new period of normal science begins and the cycle starts again. With each paradigm shift, and the associated changes in what is considered as accepted science, we also get a change in which part of science we may consider finished science. As this is an on-going process, what is considered settled science is always in a state of flux, finished science is never finished.

Unfinished Science and Science Communication

The view that science is never finished is neither surprising nor controversial, but it is surprising how such fundamental aspects of the workings of science are left out of museums given the latter's role as science education and science communication institutions. The lack of unfinished science in museums brings up important questions that relate directly to the very nature of science communication. Science communication, once primarily concerned with science literacy and attitudes to science, has shifted to being about engagement with science. The science literacy and public understanding of science movements were largely concerned with the perceived public deficit of knowledge about science — its facts, theories and methods — and later, public attitudes to science. The concern these movement addressed (a concern which still remains for some) is that science is both an important part of our cultural heritage and an essential component of democratic decision making, given the role science plays in so many policy decisions. Hence it is "knowledge with which everybody ought to be familiar" [Bauer, Allum and Miller, 2007]. This led to substantial effort being expended on one-way communication through education, the media or whatever mode was available [Bubela et al., 2009].

The past 30 years has seen a turn away (in theory, if not in practice) from such one-way models of communication, arguing instead for more participatory forms of communication [Bauer, Allum and Miller, 2007]. Under this new model, science communication is not about improving the public's knowledge of or attitudes towards science, it is about assessing and assisting the relationships between science, policy makers and the public at large, and assisting how they communicate with one another [Irwin, 2001; Logan, 2001]. But fundamental to all movements in science communication are concerns about transfer of knowledge, whether that is one-way transfer or two-way. And one of the questions currently being debated is what kind of knowledge do we want to be communicating, and what kind of knowledge should we be communicating?

Critical Science Literacy

While both textbook scientific facts and (less commonly) accepted scientific methodology have long been the object of communication, the pathways and processes by which these facts and methods get created and become accepted have not. This has led to calls for a shift in focus in what we communicate away from aiming to increase awareness of textbook fact and such like — what might be called “classical science literacy” — and towards what has been termed “Critical Science Literacy” [Priest, 2013; Matthews, 2009]. Critical science literacy, like classical science literacy, is concerned with increasing awareness and knowledge. The knowledge that proponents of critical science literacy argue we ought to make increasingly public is knowledge about the culture of science. It is “the kind of everyday, tacit knowledge of “how things work” that members of a culture take for granted but outsiders can find mystifying” [Priest, 2013]. The motivation for critical science literacy is that simply knowing textbook facts is insufficient for evaluating the validity and robustness of scientific claims.

The argument for critical science literacy is that having the skills to carry out such evaluation, especially in the current internet-driven information-rich climate, is essential; or at least it should be considered an essential component of science literacy. Science literacy is about increasing knowledge and we ought to be cognisant of the different forms knowledge takes; knowledge as data (facts), knowledge as information (organized, related set of facts) and knowledge as understanding (making sense of the information, including its context) [Davenport and Prusak, 1998; Machlup, 1983]. Critical science literacy, then, is concerned with increasing skills; its focus is on epistemic capacity, not epistemic content. Critical science literacy is about increasing the capacity of individuals to understand, assess, and make sense of science and scientific claims rather than being about increasing the amount of science or scientific claims individuals know.

In order to promote the skills required for evaluating scientific claims, proponents of this view argues that the sociological and philosophical underpinnings of scientific processes ought to be made more public, more explicit [Matthews, 2009]. Making the sociological and philosophical underpinnings of scientific processes more public is where communicating unfinished science, the many ways science can be unfinished, and the many reasons it might be unfinished, comes in to play. Unfinished science, because it is not yet settled, shows the complexity, messiness and sociality that exists in science [Priest, 2013]. This is no trivial task; not all examples from science are good at making the complexity of science and the scientific processes explicit. These complexities are conceptual, theoretical and practical, and if we want to increase the capacity of individuals to understand, assess, and make sense of science, then all of these needs to be communicated. Part of what we need to communicate in order to increase critical science literacy is the idea that much of science is about what could be, about potential, rather than about what is or “facts”. Textbook science can’t show these since textbook science presents science as “facts about the world”. Moreover abstract explanations don’t always make a good case and don’t always provide good learning opportunities [Bybee, 2002]. We know this; that’s why institutions that use examples and exhibits such as museums are valued as effective communicators. Real world examples are good at helping make sense of complex conceptual issues, and this is where unfinished science needs to step in [Schwan, Grajal and Lewalter, 2014].

Unfinished science provides us with a rich set of examples to draw from to show, describe, and explain the sociological and philosophical underpinnings of science called for by proponents of critical science literacy [Meyer, 2010]. Unfinished science, because it is undisputedly in a state of flux, makes considerations of the messy, difficult, social and cultural aspects of science unavoidable. Whether it’s water policy or string theory that is being presented, the not-yet-settled nature of unfinished science prohibits us from presenting a science as a set of accepted and undisputed facts. It demands that we present the disputes, the not-yet-accepted stage that scientific hypotheses and theories go through. This also allows us to show how seemingly accepted science is borne out of and shaped by the disputes, disagreements, and uncertainty they emerge from; that seemingly accepted textbook science cannot be separated from the sociality of science and from its philosophical underpinnings. If, as the proponents of critical science literacy argue, we want to increase the awareness and knowledge of "how science works", of the sociological and philosophical underpinnings of scientific processes, then unfinished science ought to feature much more prominently in our science communication institutions, such as museums and science centres, as they are more than useful examples; they are current exemplars of the scientific processes.

Conclusion

Science communication has, amongst its many objectives, the aim of increasing science literacy. But this literacy can come in many forms, from knowledge of scientific facts to knowledge of scientific processes, knowledge of scientific methods to knowledge of the workings of the scientific community. Science literacy can also be presented in a variety of forms, from blogs to newspapers, from museums to public events, from films to radio shows, to name just a few. In this paper, we focused on the museum as a prominent mode of informal science education opportunities and as a place that aims to generate science literacy. As institutions of authority, museums not only present information about science, but also shape the way society perceives science as an activity and scientists as a community. We have argued that museums present a misleading picture of science by focusing on objective, finished science when science is in fact dynamic, fluid and always unfinished. Drawing from discourses in the philosophy and sociology of science, and from recent moves in science communication more generally, we have argued that museums ought to present a fuller and more complex picture of science, its processes and its sociality. More specifically, we would like to see unfinished science — often messy, socially complex and value laden — sit along side objective, text-book science as a staple of the museum's repertoire because unfinished science can provide exemplars of the full scientific process. Unfinished science provides examples for the fullness of science because science is, in fact, always unfinished.

Acknowledgments

The authors are grateful to Joan Leach for engaging discussion on the topic and insightful suggestions for the manuscript. We are also indebted to thoughtful reviewers whose comments helped improve the manuscript.

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How to cite

Hine, A. and Medvecky, F. (2015). 'Unfinished Science in Museums: a push for critical science literacy'. *JCOM* 14 (02), A04.

ISSN 1824 – 2049. Published by SISSA Medialab. http://jcom.sissa.it/.