New Orleans JAZZED about Engineering Education

Paper ID #14737

The Impact of Museum Outreach

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The Impact of Museum Outreach

Abstract
Museums are organizations dedicated to developing understanding in a broad audience. Science musuems in particular are known for this. The general public believes in the effectiveness of this museum work, frequently turning to these institutions for knowledge and understanding. Further, the public increasingly finds enjoyment in the learning opportunities provided by these institutions. However, these institutions are experiencing increasing difficulty in accessing subject matter expertise, especially in young fields.

Scientists and engineers are strongly motivated to share their understanding of technical subjects with others. Most a driven towards this communication centered outreach by personal desire. This desire is reinforced by professional and institutional requirements. However, these groups are concerned about the effectiveness of their efforts. Their time is limited, and it can be difficult to reach a wide audience.

Developing partnerships between subject matter experts and museums provides a mechanism to resolve both difficulties. Museums gain access to much desired expertise, and scientists and engineers gain access to established mechanisms for reaching a broad audience. Here, an example of this sort of partnership is considered: presentations aiming to improve staff and volunteer understanding of nanotechnology. A single presenter improves the understanding of a museum personnel, who in turn guide visitors to a fuller understanding. This outreach event, and its evolution, are described. A simple survey was developed using standard techniques, and used to assess the impact of these presentations on the audience. Ultimately, the activity was succesful; it is presented here as a guide for those interested in pursuing similar outreach.

Introduction
There are more than 55,000 museums in the world today, double the number there were twenty years ago[1]. Nations around the world believe that these institutions are absolutely vital to society. The Chinese State council recognizes them as a vital to culture, "the spirit and soul of the nation"[2]. The National Science Foundation[3,4] and National Institute of Health[5] spend millions of dollars each year funding programs in science museums. The people of the worlds nations share the feelings of their leaders. Australians overwhelming approve of the work of their Museums[6]. American Museums recieve about 850 million visitors per year[1]. Museums in Japan, Brazil, and a score of other nations guide thousands of citizen scientists in their efforts to understand biodiversity, a project which led to presentations to the United Nations[7]. Across the globe, these institutions act to establish, support, and promote a culture of understanding in the world. For scientists and engineers looking to improve public understanding of science, these institutions can be incredibly effective partners.

The Role of Museums
The primary mission of museums is to engage all members of the public in learning[8]. For museums with a scientific focus, this means connecting the public with both tangible facts and the processes of scientific inquiry. Such engagment promotes a culture of inquiry and discovery. This mission requires inspiring people to ongoing discovery in lifelong learning. Museums have developed, and come to excel at, a number of tasks related to thier mission: youth and adult education, professional development for educators, and public awareness.

Learning within a museum[i] is somewhat different from learning in more formal settings[9]. For many visitors, learning is not their primary motivation for visiting; they are motivated by fun, the enjoyment of the museum[2]. Nonetheless, learning occurs; perhaps inevitably, and certainly by design[10]. Museums present their contents in a way that encourages and facilitates engagement[6,11]. Visitors from all walks of life[12] explore the museum, guided by their whims and interests[13]. During this exploration, visitors connect the contents of the museum to their experiences from outside the institution. In the establishment of these connections, learning occurs. This becomes especially apparent when looking at families, or other groups of visitors. As they proceed through the museum, group members connect with different parts of the exhibits. They share these connections with each other, reinforcing their own learning and enabling the learning of others in the group[14]. Most museums have staff and volunteers available to visitors; these interpreters assist the vistors in unpacking complex ideas (e.g., nanotechnology) by way of analogy and reference, to deepen the visitors understanding[2]. These personnel are often not subject matter experts in the topics they interpret, but they are pationate enthusiasts. The skills to create a framework for learning, refined over many years, are an incredibly valuable asset for many of the museums traditional objectives[6,7]. These skills are also likely to be beneficial in the developing roles of museums[15].

The education of youth is one of best known functions of museums[3,11]. Many people have fond memories from their youth of field trips to local museums. Trips of this sort are an important part of youth education. They provide necessary experience and practice that can not be accomplished in a classroom[12,16]. Students learn to apply their knowledge, both facts and principles of inquiry, to informally structured activities. These activities helps to bridge the gap between the accumulation of facts and the development of true understanding[13,17]. There is a direct link between the self-driven learning in museum settings and the practical understanding of science[18]. There is also a seemingly simple, but incredibly important, function of these trips: students enjoy them[2]. Enjoyable museum experiences can have an incredible impact upon an individuals attitude toward science, leading many to pursue science-related careers[5,11,19]. Alongside the development of youth, many museums also work to develop teachers in K-12 education[2,3]. Many museums have professional development programs for teachers[9], providing lessons and curriculum materials to supplement visits, as well as stand alone programs for use in classrooms. Such materials are one of the ways in which museums not only enable success in conventional science education, but also connect those formal systems with the community at large[20].

Naturally growing from this focus on education, science museums are an incredible resouce for public awareness and engagment. “Public” is a can refer to a variety of large groups; leaders in and out of government, news and mass media, the adult populace at large, and the aforementioned children and educators[21]. There is, of course, some overlap among these groups. Individuals and groups, frequently desire to know more about a subject, or to engage in discussion about it[6,21]. Indeed, this sort of self-directed educational pursuit is increasing in

[i] Hereafter in this paper, “museums” refers more narrowly to those instititutions associated with science and technology. This limit is a consequence of the author’s interests, rather than a fundamental constraint. Many museums outside of this limit (e.g., History Museums) have a similar role and prominence in culture and education. They are simply beyond the scope of this article.

popularity as a leisure pursuit[12]. Overwhelmingly, people worldwide turn to museums as part of meetings these desires[6]. Over their long history, museums have established a much deserved reputation as a source of information and understanding on complex topics[7,20]. This extends even to topics percieved to be contentious, such as climate change, or very new, such as nanotechnology[20,22]. Museums are seen as a critical resource for information, understanding, and discussion[7], an opinion which cuts across many divisions: nation, socioeconomic status, education[20]. Museums have earned this reputation because of their long history of making the understanding of complex material accessible to all[6,20,23]. The combination of exhibits, outreach, and communciations expertise, in the hands of devoted staff and volunteers, have created a forum in which all people can take part in the issues of the day[7,23]. Perhaps unsurprisingly, the weight of this respect also gives a measure of power: Museums can (and do) affect the state of public knowledge about science, and the attitude of the public towards science and technology[12].

Outreach and the Academy

While the success of museums at pursuing their mission is notable, they still encounter are a number of issues. Reductions in outside funding have, in recent years, made it difficult for museums to maintain maintain or expand the services they offer[5]. These reductions also limit the number of subject specialist that can be maintained as staff. Museums can be slow to adapt to the technologies of newer specialites, such as biomedical implants, due the difficulty in fitting unconventional artifacts into conventional catalague and exhibit structures[24]. Closed-access journals and esoteric specialty conferences make it difficult for museums to obtain the latest information[25]. Unlike many public interest groups, museums often don't recieve free or heavily discounted access to such articles. While these difficulties have not prevented museums from pursuit of their mission, they have limited their success. For similar reasons, some science professionals do not have access to education journals[25]. The difficulties caused by paywalls, cutting edge specialties, and the ever deepening specialization of science can be largely ameliorated by increased collaboration with universities partners, especially faculty and student researchers[15,23,26,27]. Who better to elucidate the nuances of novel science and technology than the researchers developing it?

That appears to be the broad consensus of many stakeholders, including funding agencies[3], museums[25], universities, and the scientists[28] themselves. The initial impetus for this focus on outreach is likely the scientists themselves. Surveys from professional societies suggest that most practicing scientists and engineers feel an obligation to share their knowledge, and to increase the general understanding of their discipline[28]. This urge goes beyond simple duty; scientists and engineers regularly call upon each other to share their excitement along with their knoweldge[21]. Such is the importance placed upon this out-of-discpline communication that young scientists are all but expected to have interdisciplinary and outreach experience[29]. Universities, museums, and other partners are developing programs expressly to facilitate the acquisition of this experience[30]. Such collaborations creature unique opporunites for the edification of the public, and for developing understanding[3,7,28].

There are, in fact, many reasons for the prevalence of this desire to share understanding, even setting aside the pressure from outside groups. Scientists can directly benefit from this activity, as the prestige and promience of their work is elevated not only in the public mind[26], but in the eyes of their peers[15]. There are also indirect benefits; a more informed and better understanding populace can increase the support for ones discipline[18]. Younger scientists and students

especially can benefit from outreach work[31]. The act of communicating specialist knowledge, in plain language to non-specialists, is a learning experience in and of itself. This communication deepens the understanding of both parties.

Armed with university[7] and financial support[3], and cognizant of the personal and public benefits[15,18], the only remaining question is of specifics. What work can be done? For those with an inclination to educational research, museums can provide an excellent laboratory for the study of human learning. Many already are engaged in this sort of work[31]. There is also room for contributions to the development and evalulation of the practices in the design of outreach programs[27]. For those less directly involve in educational research, there are numerous practical projects. Musuems often need to call upon outside advisors when developing exhibits[25], and are often lacking in advisers working on the cutting edge of young fields[32]. Experts from all disciplines can contribute ideas for exhibits and components of special events[20]. There are numerous special science days hosted at museums which beneft from demonstrations and brief talks by scientists actively researching the topic. This is especially prevalent in nanotechnology[22] and chemistry[21], where museum events have become an incredibly important venue for dialogue between scientists and the public[33].

Ultimately, there is a great great need and a great opportunity. Scientific research is more specialized than ever before, as disciplines deepen and proliferate. Budgetary issues in public education mean that, across the globe, people are receiving less formal science education than generation in the recent past. Simultaneously, new science and new technology are having incredible impacts on peoples lives, requiring them to make decisions on topics about which they are ill informed. But there is hope; people are reaching out, striving for the understanding that they believe is needed. By and large, they are looking to science museums to fill that need. These institutions are capable of communicating complex scientific understanding to the public. They are capable of partnering with scientists, combining research and outreach. They have incredible institutional experience in making these multidisciplinary collaborations work. It is in this combination of talents that these institutions are unique, and it is this combination that makes them excellent partners for researchers looking to share their understanding.

An Example Case

Museums are an excellent venue for developing understanding and for engaging in discussion of complex topics. Their work in this area has had a positive impact on the lives of hundreds of millions of people. However, there is plenty of room in the discussion for more voices. There is a critical need for specialists and subject experts in all fields (especially in young areas of study) to share their knowledge, their understanding, beyond the academy. It has been amply demonstrated that everyone benefits when this sort of understanding is available to all; people are empowered to make informed decisions about medicine, technology, and myriad other subjects.

As many of the previously referenced materials shown, understanding is gained not just by accumulating information, but by connecting it to personal experience and the lives of others. Museums are effective at guiding this connecting, as has been shown. To close this paper, the author will adopt a part of this method, and relate an example experience from their work with the Museum of Natural History and Science in Cincinnati, OH.

The author's involvement with the Museum of Natural History and Science began in 2012. This institution hosts a variety of science based special events are held each year: NISE Nanodays, ACS Chemistry week, etc. During Nanodays, discussions of nanotechnology, specifically carbon nanotubes and their synthesis (part of the authors ongoing research), arose spontaneously with a number of staff, volunteers, and visitors. During these discussions, a possible trend appeared. Many of those engaged in discussion had plenty of technical savvy, either from personal studies or their formal education. They also had a number of questions about nanotechnology that they had not been able to answer through their own investigation. The talks with the museum's visitors provided an opportunity to help develop public understanding of nanotechnology. It also helped develop the authors understanding, improving their ability to communicate these concepts to a lay audience.

Among the staff and volunteers, there was an additional sentiment. Many felt that their own studies had not adequately prepared them to interpret nanotechnology concepts for visitors. Nanotechnology is a young field, so older volunteers had not encountered it in their formal studies. Younger volunteers and the staff were more familiar with it in the abstract, but the focus of their work lay in very different areas. Many felt that an opportunity for them to learn more about the critical concepts would improve not only their experiences, but also those of the visitors; especially in the context of special events like Nanodays.

Such an opportunity arrived a few months later. The museum coordinates an internal lecture series attended by many staff and volunteers. During these lectures, presenters with specialist knowledge introduce their work and field to the audience, followed by time for questions. The opportunity to introduce this audience to some of the basic concepts in nanotechnology was provided to the author. Further discussion of a number of past, current, and near future applications that various types of nanomaterials (nanoparticles, e.g.) was also encouraged. The questions afterward ranged from clarifications of the relative size of nanomaterials to the particular thermal stability characteristics of carbon nanotubes. Overall, the presentation was well received. The staff and volunteers reported, informally, personal satisfaction with the event. They felt that their own understanding of nanotechnology was improved, and that they would be better equipped to field questions that visitors to the museum might have.

Due to the positive response from attendees, a second event was scheduled on a related topic: The origins of atomic theory. This presentation had a similar goal to the first: provide museum volunteers and staff with a foundational understanding of the topic, which would in turn allow them to improve the understanding of visitors. After this presentation, attendees were asked to complete a short survey about the presentation; the survey questions, and aggregated responses, can be seen in Figure 1. The survey was developed using well documented principles for Likert style surveys[34,35,36,37,38], though due to its short length some techniques for reducing bias were deemed more cumbersome than the benefits they would provide[39,40,41]. While the sample size is small, the results show good enough separation to be valid. The survey shows two things. First, the vast majority of respondents felt better informed about the topic after the presentation. Second, that many (about half) felt that attending the presentation made them better able to assist visitors with questions about this topic.

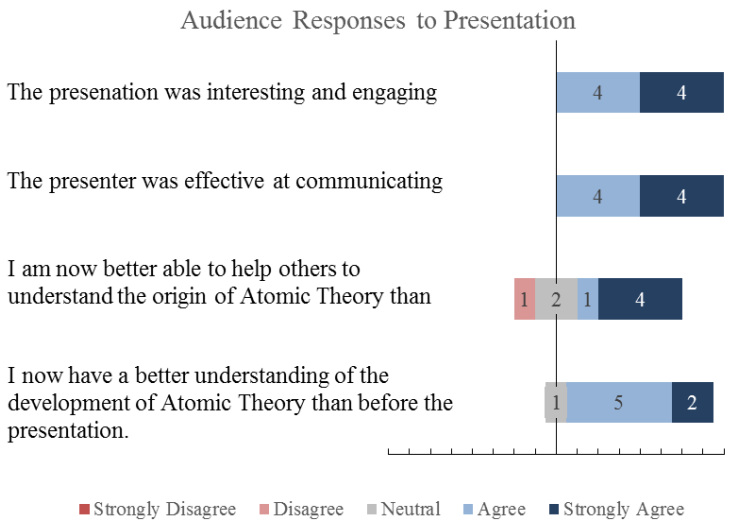

Figure 1: Questions and results of the audience survey following a presentation on the origins of atomic theory. Survey participation was voluntary, with a total of eight respondants.

Conclusions

By partnering with an organization that is devoted to spreading understanding to everyone, a researcher can leverage their knowledge into a profound impact. Museums are such organizations, and are generally eager to enable such communication. A researcher partnering with a museum can work with staff and volunteers. These, in turn, work with visitors, creating a multiplying effect for the researcher. Limited though the experimental data presented here is, it resoundingly supports this conventional wisdom. Interested researchers can reach out to volunteer coordinators to find and create opportunities of this sort. Conversely, museums looking for this sort of expertise can try reaching out to faculty directly, or contact a universities public relations department (which often knows which faculty are interested in this sort of public outreach).

Fairly or unfairly, we are accustomed to measuring our outreach efforts in terms of impact. Museums impact millions of minds each year. Millions of people, of all ages and levels of education, who can have a clearer understanding of our complicated world. If, of course, we are willing to make the effort to share our understanding with others. A significant impact, by any measure, and all thanks to the efforts of some of our most venerable (and rightly venerated) institutions.

References

[1] "Templers of Delight," The Economist, 21 December 2013.

[2] "Mad about museums," *The Economist,* 21st December 2013.

[3] A. J. Ingram, "Science Museums as Partners in STEM Education:," in *Testimony to the U.S. House of Representatives*, 2013.

[4] "Museums bring the nano world to the masses," *Materials Today,* vol. 8, no. 12, p. 25, 2005.

[5] P. B. Jarreau, "SciLogs," Spektrum der Wissenschaft Verlagsgesellschaft mbH, 9 August 2013. [Online]. Available: http://www.scilogs.com/from_the_lab_bench/science-museums-should-aim-beyond-education-to-citizen-science/. [Accessed 10 January 2015].

[6] F. Cameron, "Contentiousness and shifting knowledge paradigms: The roles of history and science museums in contemporary societies," *Museum Management and Curatorship,* vol. 20, pp. 213-233, 2005.

[7] I. Miaoulis, "Cognoscenti - The Role Of Museums In The Public Understanding Of Science," 90.9WBUR - Boston's NPR news station, 29 October 2012. [Online]. Available: http://cognoscenti.wbur.org/2012/10/29/science-museums-miaoulis. [Accessed 11 January 2015].

[8] D. Chittenden, "Commentary: Roles, opportunities, and challenges—science museums engaging the public in emerging science and technology," *Journal of Nanoparticle Research,* vol. 13, pp. 1549-1556, 2011.

[9] M. Morentin and J. Guisasola, "The role of science museum field trips in the primary teacher preparation," *International Journal of Science and Mathematics Education,* pp. 1-26, 2014.

[10] N. S. Stroud, Teaching and Learning Science in a Museum: Examining the role of attitudes toward science, knowledge of science, and participartory learning in an astronomy internship for high school students, Columbia University, 2008.

[11] Nanoscale Informal Science Education Network, "Small Steps, Big Impact: An Online Guide for Museum," Nanoscale Informal Science Education Network, 2010.

[12] "Oregon State News & Research Communications: Surveys confirm enormous value of science museums, “free choice” learning," Oregon State, 7 April 2011. [Online]. Available: http://oregonstate.edu/ua/ncs/archives/2011/apr/surveys-confirm-enormous-value-science-museums-%E2%80%9Cfree-choice%E2%80%9D-learning. [Accessed 10 January 2015].

[13] l. Ramey-Gassert, H. J. I. Walberg and H. J. Walbergy, "Reexamining connections: Museums as science learning environments," *Science Education,* vol. 78, no. 4, pp. 345-363, 1994.

[14] K. M. Ellenbogen, J. J. Luke and L. D. Dierking, "Family Learning Research in Museums: An Emerging Disciplinary Matrix?," Wiley InterScience, 2004.

[15] "Museums need two cultures," *Nature,* vol. 446, no. 7136, p. 583, 2007.

[16] S. Cavanagh, "Lessons At The Museum," *Education Week,* vol. 27, no. 41, pp. 20-22, 2008.

[17] J. Griffin, "Learning science through practical experiences in museums," *International Journal of Science Education,* vol. 20, no. 6, pp. 655-663, 2007.

[18] O. M. Castellini, G. K. Walejko, C. E. Holladay, T. J. Theim, G. M. Zenner and W. C. Crone, "Nanotechnology and the public: Effectively communicating nanoscale science and engineering concepts," *Journal of Nanoparticle Research,* vol. 9, pp. 183-189, 2007.

[19] C. Rix and J. McSorley, "An investigation into the role that school-based interactive science centres may play in the education of primary-aged children," *International Journal of Science Education,* vol. 21, no. 6, pp. 577-593, 1999.

[20] R. J. Semper, "Science Museums as Environments for Learning," *Physics Today,* vol. 43, no. 11, pp. 50-56, 1990.

[21] H. M. Free, "Public outreach," *Journal of Chemical Education,* vol. 75, no. 12, p. 1533, 1998.

[22] A. L. Chun, "The shifting roles of museums," *NATURE NANOTECHNOLOGY,* vol. 9, p. 724, 2014.

[23] L. Bell, "Engaging the Public in Technology Policy: A New Role for Science Museums," *Science Communication,* vol. 29, no. 3, pp. 386-398, 2008.

[24] T. Söderqvist, A. Bencard and C. Mordhorst, "Between meaning culture and presence effects: contemporary biomedical objects as a challenge to museums," *Studies in History and Philosophy of Science,* vol. 40, pp. 431-438, 2009.

[25] Institute for Dynamic Educational Advancement, "Science museums are disconnected from new science research," Institute for Dynamic Educational Advancement, 25 April 2011. [Online]. Available: http://www.idea.org/blog/2011/04/25/science-museums-are-disconnected-from-new-science-research/. [Accessed 12 January 2015].

[26] K. M. Vandiver, J. M. Bijur, A. W. Epstein, B. Rosenthal and D. Stidsen, "A Museum Learning Lab," *The Science Teacher,* vol. 75, no. 4, pp. 41-43, 2008.

[27] N. W. Feinstein and D. Meshoulam, "Science for What Public? Addressing Equity in American Science Museums and Science Centers," *Journal of Research in Science Teaching,* vol. 51, no. 3, pp. 368-394, 2014.

[28] D. R. Johnson, E. H. Ecklund and A. E. Lincoln, "Narratives of Science Outreach in Elite Contexts of Academic Science," *Science Communication,* vol. 36, no. 1, pp. 81-105, 2014.

[29] e. a. Jasanoff S, "Conversations with community: AAAS at the Millennium," *Science,* vol. 278, pp. 2066-2067, 1998.

[30] A. C. Payne, W. A. deProphetis, A. B. Ellis, T. G. Derenne, G. M. Zenner and W. C. Crone, "Communicating Science to the Public through a University–Museum Partnership," *Journal of Chemical Education,* vol. 82, no. 5, pp. 743-750, 2005.

[31] L. J. Rennie and T. P. McClafferty, "Science Centres and Science Learning," *Studies in Science Education,* vol. 27, no. 1, pp. 53-98, 1996.

[32] B. o. C. S. a. T. Committee on Challenges for the Chemical Sciences in the 21st Century, Beyond the Molecular Frontier: Challenges for Chemistry and, Washington,: National Academies Press, 2003.

[33] M. H, "What about the audiences? Tailoring PUR programs for museum visitors," in *Creating connections: museums and the public understanding of current research*, Walnut Creek, Altamira Press, 2004.

[34] R. Likert, "A technique for the measurement of attitudes," *Archives of Psychology,* vol. 140, pp. 1-55, 1932.

[35] N. Reid, "Thoughts on attitude measurement," *Research in Science & Technological Education,* vol. 24, no. 1, pp. 3-27, 2015.

[36] M. S. Matell and J. Jacoby, "Is There an Optimal Number of Alternatives for Likert Scale Items? Study I: Reliability and Validity," *Educational and Psychological Measurement,* vol. 31, pp. 657-674, 1971.

[37] M. S. Matell and J. Jacoby, "Is there an optimal number of alternative for Likert-scale items," *Journal of Applied Psychology,* vol. 56, no. 6, pp. 506-509, 1972.

[38] J. Jacoby and M. S. Matell, "Three-Point Likert Scales Are Good Enough," *Journal of Marketing Research,* vol. 8, no. 4, pp. 495-500, 1971.

[39] D. Watson, "Correcting for Acquiescent Repose Bias in the Absence of a Balanced Scale," *Sociological Methods and Research,* vol. 21, no. 1, pp. 52-88, 1992.

[40] J. C. Chan, "Response-order effects in Likert-type scales," *Educational and Psychological Measurement,* vol. 51, pp. 531-540, 1991.

[41] L.-J. Weng and C.-P. Cheng, "Effects of response order on Likert-type scales," *Educational and Psychological Measurement,* vol. 60, no. 6, pp. 908-924, 2000.