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Partnering with science centers and museums

Introduction

Much of science learning takes place outside of school in informal learning environments such as libraries, nature centers and museums. These provide important contexts for individuals of all ages to engage in lifelong learning and experience the excitement of exploring and understanding the natural world. In the United States science museums and science centers experience tens of millions of visits each year and are the most widely visited type of museum other than zoos. Studies indicate that designed settings, such as science centers, play an important role in inspiring and maintaining interest in science and technology for people of all ages and they are viewed by some to be an integral part of our nation's science education infrastructure.[1] Unfortunately, chemistry is poorly represented in these settings. It has been reported that less that 27% of science museums feature hands-on activities in chemistry and less than a third offer any chemistry exhibits at all.[2]

Much of the content of science museums is geared towards children. Recent research suggests that childrens' interest in science career prior to secondary school greatly influences their likelihood of getting a bachelor's degree in a STEM field.[3] Exposing young people to enjoyable, hands-on experiences with science and technology as well as providing them with face-to-face contact with researchers may spark the early interest associated with later career choices.

However, two thirds of science museum visitors are adults who are interested in recent science discoveries. Presenting current research topics to the public demonstrates that science is not static, but is a dynamic process of inquiry and exploration to advance scientific understanding. Face-to-face interactions between scientists and lay audiences also humanize scientists in the eyes of the public, and promote better understanding of the value of current research.

NSF-funded researchers and research centers are charged with informing the public about their areas of research but are often poorly equipped to communicate scientific concepts in a way that can be understood by public audiences. Science centers and museums seek to educate and inspire the general public in regard to science and are skilled at communicating science to public audiences. They wish to keep their content current to engage their adult visitors, but are not knowledgeable about current research and often lack the scientific expertise to insure accuracy in their exhibits. Scientists and science centers share a common goal of informing the public about recent advances in science and they bring complementary skills to achieving that goal. Thus, it makes sense for practicing scientists to collaborate with science centers and museums to both find an

audience and learn to communicate their science effectively. These types of collaborations created win-win situations.

The main focus of CENTC's outreach efforts was working with science centers and museums to develop content relating to CENTC research for activities and exhibits. We worked with Pacific Science Center (PSC) in Seattle and Liberty Science Center (LSC) in New Jersey.

CENTC Experience

CENTC's research goals were related to global issues that appeal widely to the general public. There is widespread concern about the use of fossil fuels for transportation, due to the dwindling supply of crude oil as well as the detrimental environmental impact of burning these fuels. CENTC sought to develop catalysts that would enable new processes for efficient, sustainable and environmentally responsible production of chemicals and fuels. Initially our outreach plans focused on school visits, but the proximity to PSC with its innovative programs for disseminating current regional research and an established relationship with UW led us to explore opportunities with them.

Pacific Science Center

Seattle-based Pacific Science Center (PSC; www.pacificsciencecenter.org) is the largest state attraction in Washington, drawing a diverse population of more than 800,000 visitors of all ages each year from throughout the region and the world. In 2007, PSC launched an NSF-funded "Portal to the Public" program to provide mechanisms for scientists at major local research institutions to easily and effectively disseminate their research to the public through a variety of outreach activities. A $2.5 M NSF award funded the research and development of the program that engages scientists and science center audiences in direct face-to-face interactions, promoting an appreciation and understanding of current scientific research.

The Portal to the Public Program earned PSC a 2010 Leading Edge Award from the Association of Science-Technology Centers, Inc. The Portal program consists of two activities. The first activity is directed toward scientists who enroll in the PSC Science Communication Fellowship Course, which provides researchers with skills and ideas for communicating their own work effectively to non-scientists. PSC staff members also work with the researchers to design interactive hands-on activities based on their individual research goals. The second activity in the Portal program targets PSC visitors, and brings trained scientists on-site for programs such as Scientist Spotlight, a monthly weekend program that highlights current regional research.

PSC established the Portal To Current Research space that uses digital media, graphics, objects and interactive displays to showcase current research being carried out by local

scientists. Topics change several times throughout the year and content is developed in collaboration with scientists involved in the research projects presented.

University of Washington – PSC Collaboration Paws on Science

In 2009 University of Washington (UW) initiated a program with PSC to bring active UW researchers to the Center to engage one-on-one with science center visitors about current ongoing research. The program, Paws on Science, was an annual 3-day science festival-type event that was featured annually through 2016. PSC staff offered training in effective communication techniques to the visiting scientists as well support for development of hands-on activities related to the research.

We attended the first Paws on Science and took advantage of the workshops on communication and hands-on activities. At our booth at PSC we offered a hands-on version of "elephant toothpaste". This fun activity demonstrates the power of a catalyst to speed up a reaction by several orders of magnitude. This was an extremely popular activity, attracting many kids and their parents as well. This is the key goal of attractive activities – to bring people to you to engage in conversation. Bringing adults to our booth gave us the opportunity to share with them the importance and goals of CENTC research. Another activity was called, "What Comes from Oil", was intended to communicate how many common items are actually made from chemicals that are derived from petroleum. A basket contained items such as acrylic and wool yarns, cosmetics, plastic toys, paper and paint. Visitors were asked to identify those products that are made from chemicals derived from crude oil. Many expressed surprise at the wide array of common items were made from petrochemicals. This observation led us to consider a more wide-reaching forum for communicating this information to the public.

Figure 1. Paws on Science - Elephant Toothpaste

CENTC - Pacific Science Center Partnership

Chemists: Catalysts for Change

We approached PSC's Meena Selvakumar, Acting Vice-President of Strategic Programs, to discuss potential opportunities to reach a larger and broader audience to with the message that dwindling petroleum reserves will have a significant impact not only on transportation fuels, but also the manufacture of common items that have great economic

importance. As described above, PSC had developed a NSF-funded program, Portal to the Public, which encourages informal science education organizations to work with local researchers in STEM fields. In addition, an ancillary program, "Portal to Current Research," had been initiated. Portal to Current research used a dedicated space in PSC to present ongoing research by scientists in the Puget Sound region.

In 2010, NSF's Chemistry Division issued a Dear Colleague Letter inviting proposals for supplements to existing awards for projects to enhance broader impacts in recognition of the International Year of Chemistry, 2011. CENTC partnered with PSC and submitted a proposal to develop a Portal to Current Research exhibit that focused on educating visitors about the use of crude oil in the production of many common items such as make-up, medications, food additives and synthetic fabrics. An integral part of the project was to train all CENTC graduate students and postdocs in effective techniques for communicating science to the general public.

Project Goals

- Create an engaging science experience for visitors to increase their awareness of the importance of chemical research, particularly in catalysis, in addressing daunting contemporary problems
- Create opportunities for the public to interact with active research scientists
- Communicate ongoing findings of NSF-funded, regional research
- Put a human face on chemistry and chemists

Planning Process

CENTC staff, faculty and students worked with the PSC exhibit development team to develop content for the exhibit. The first step in the planning process was to articulate a broad, overarching statement to guide the story line, "Chemists here in Seattle are creating better chemical reactions to address major social issues like dependence on oil." As content was developed we continually referred back to this statement to ensure that the content was aligned with the stated story line. PSC staff directed the project in consultation with CENTC personnel who contributed to the creative process and ensured that the content was accurate.

Vocabulary was targeted to the sixth grade level and each piece of text was limited to 150 words. Staff from PSC visited CENTC laboratories to see what conducting our research was like – who were the scientists, what equipment was used, what was the process. As non-scientists, they could better predict what aspects of the labs might be interesting to Science Center visitors.

Communication Training

Communicating science to the general public is essential in order for citizens to be informed about basic science so they can make informed decisions on subjects such as

climate change. Public understanding (or misunderstanding) of science can influence policy and funding. However, very few scientists receive any training in the effective communication of scientific concepts to the lay public. A significant component of this partnership was for PSC Portal to the Public instructors to provide such training to CENTC graduate students and postdocs. All graduate students and postdocs participated in a half-day program during the 2010 annual meeting. A selection of UW CENTC researchers and staff took part the Science Communication Fellowship Course, a more intensive program that involved three sessions and included assistance with developing pertinent hands-on activities. These scientists visited the exhibit periodically to engage visitors in the activities and provide the opportunity to speak face-to-face with researchers involved in the projects included in the exhibit.

Chemists – Catalysts for Change

The resulting multi-media exhibit titled, "Chemists – Catalysts for Change", on display 10/23/11 – 2/3/2012, included interactive activities, videos, text and artifacts. Content included a simple introduction to what chemistry is, explaining atoms, molecules and chemical reactions, and the fact that everything is comprised of chemicals from air to food to the human body. Basic descriptions of chemical reactions and catalysis were also provided. A timeline illustrated the history of society's growing dependence on oil. Another area exhibited a Lucite box filled with colorful items including clothing, cosmetics, paint and medication that are all made from oil. An explanation of catalysts and catalysis was an introduction to the presentation to three current CENTC research projects: converting natural gas to liquid, using glycerol to make useful products and obtaining useful building block chemicals from biomass. To put a more human face on the research enterprise, photos of local CENTC scientists with brief bios that included professional as well as some personal information were included in the exhibit. In addition CENTC scientists were available in the exhibit space periodically, offering hands-on activities and the opportunity for visitors to ask questions about the exhibit.

Figure 2. Portal to Current Research exhibit. Chemists Catalysts for Change

Figure 3. Scientist Spotlight

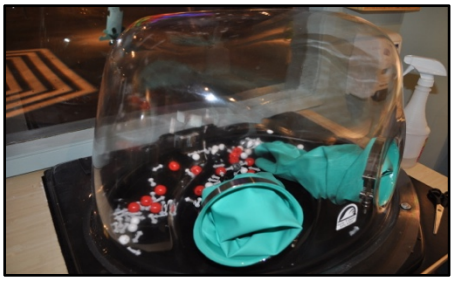

Figure 4. Glove box activity

Exhibit content was supplemented with interactive activities. In one, visitors used a ball and stick molecular model set in glove-box facsimiles to construct molecules that ranged from simple (methane) to more complex (glucose). An interactive multi-touch table invited visitors to select photos of a number of CENTC scientists and hear anecdotes about their interest in chemistry, favorite chemical reactions or other information that would help to demonstrate that scientists are people like everyone else. Featured scientists were young and old, male and female, and from diverse ethnic groups to show that anyone can be a scientist. One area of the exhibit was for viewing videos. Visitors could select from six different videos including interviews with local scientists, the elephant toothpaste reaction and a virtual tour of UW chemistry labs.

Outcomes

PSC's professional evaluators observed and interviewed visitors to the exhibit to determine to see how they interacted with different components of the exhibit and to assess what the learned from it. Visitors spent the most time at the molecule boxes, video space and the surface table, but ranked the surface table significantly lower in terms of interest and satisfaction. Almost 60% of visitors reported that they had learned at least one new fact about chemistry and over 90% recalled that chemistry is used to make useful things. More than half remembered the basic elements of chemistry and the purpose and benefits of catalysis. These were the messages that we had hoped to convey. Suggestions for improving the exhibit were primarily to include more hands-on activities and to add more layered scientific content to appeal to a wider range of visitors. An observation that we made of how visitors interacted with the visit was that there was great interest in the multi-touch table but that the content was not engaging and. We also overheard visitors wondering exactly what the statement that certain products "come from oil" actually meant.

CENTC – Liberty Science Center Partnership

Dear Colleague Letter

Shortly after this exhibit, a Dear Colleague letter was issued from the NSF Division of Chemistry and Center for Advancement of Informal Science Education (CAISE) soliciting proposals from Centers for Chemical Innovation for projects involving partnerships between the CCI and an informal science organization. Based on our own observations and results of the evaluation of our PSC exhibit, CENTC proposed a project to develop an appealing multi-touch table activity that could provide more layered content and would teach users about the chemicals derived from crude oil and how they are used to manufacture familiar items. We proposed to partner with Liberty Science Center (LSC) in Jersey City, which draws about 650,000 visitors each year. They had already been thinking about supplementing their "Energy Quest" exhibit with information about the use of petrochemicals in the manufacture of economically important and ubiquitous materials and products. LSC was a good partner for us because the project could involve CENTC researchers in that region.

Activity Development

The development team included the LSC project manager, two CENTC alumni, both of whom were teaching at The College of New Jersey (TCNJ) at the time, and students from the TCNJ chemistry club. LSC contracted with Randi Korn & Associates, Inc. (RK&A) to conduct a front-end evaluation to guide the development of the multi-touch table activity. RK&A interviewed visitors in the "Energy Quest" exhibit at LSC – the space in which the multi-touch table would be displayed. There was a strong interest in using a multi-touch table to learn the pathways by which building block molecules are used to make more complicated molecules used in everyday products. Based on the results of their interviews RK&A suggested simplifying chemistry content as much as possible, limiting technical terminology and making the activity multi-user and using people's curiosity about unexpected products coming from oil to draw in users.

"Molecule Magic: Turning Crude Oil into Useful Stuff"

The CENTC team provided the concept and the content and contracted with Blue Telescope Studios, an interactive multimedia developer to create the activity. The resulting product, "Molecule Magic: Turning Crude Oil into Useful Stuff", displayed an array of colorful images of common items derived from petroleum, such as lipstick, a Barbie doll, aspirin and a Lego brick. There were four work stations that could be used simultaneously. After selecting an item, users were guided through the process of creating the main component used in each item. Users were guided to create the larger molecule by connecting the smaller ones. A stream of petrochemical building block molecules "flowed down the table" and users would select a molecule and drag it to their station. Once the molecule was successfully completed, the final molecule and it's name appeared at their station with the message, "Congratulations! You have made polyethylene, a main component in Barbie dolls".

The multi touch table was installed in the "Energy Quest" exhibit at LSC in the fall of 2013 and is still a popular activity.
https://www.youtube.com/watch?v=1qWpZu

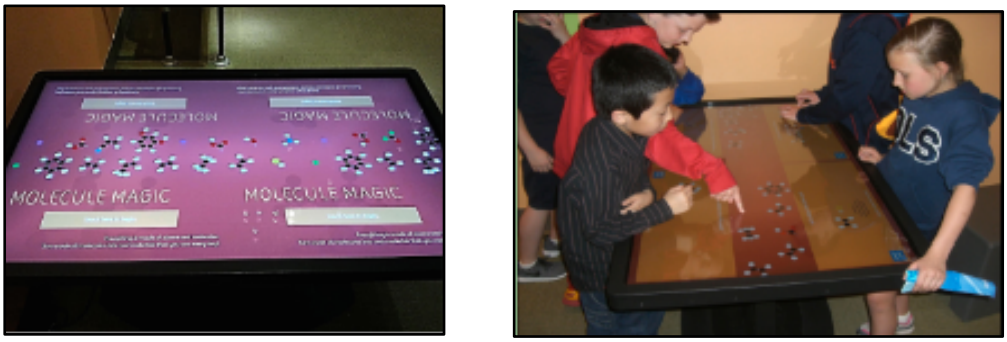

Figure 5. Molecule Magic

Chemists – Catalysts for Change 2.0

CENTC and PSC partnered again in 2016 to develop an improved version of the earlier Chemists – Catalysts for Change exhibit. Over the years since the 2011 exhibit, PSC learned a lot about making the exhibits more effective and working with scientists. We incorporated several interactive elements to the space, including the multi-touch table game, "Molecule Magic", a push-button-activated electrical demo of what a catalytic converter does, a glove box for build-a-molecule, and others.

Evaluation

PSC evaluators tracked and interviewed visitors to the exhibit. Visitors spent significantly more time in this exhibit than in the previous one. Again, the glove box and the touch table were the most popular areas of the exhibit and visitors spent nearly twice as much time at these elements than they had in the 2011 exhibit. Adults were most engaged with the Molecule Magic game. Almost 80% of guests were satisfied with their experience in the space and 27% were "extremely satisfied." We were particularly interested in determining whether the Molecule Magic game actually fulfilled our goals for it: 1) Small molecules combine to make more complex molecules and 2) Petrochemicals are used to make many common products. 86% of guests had an understanding of the first concept and 68% understanding of the second. The respondent's reported degree of understanding of these concepts correlated with the number of molecules they had created in the Molecule Magic activity. The feedback about the Molecule Magic games reveals that it is very effective in engaging visitors with the concepts. Many visitors talked about the use of oil and some were struck by the number of products made of oil and recalled that CENTC scientists are looking for ways to decrease the use of oil. Results of the evaluation showed that the exhibit was effective in achieving its intended goals.

Figure 6. Chemists – Catalysts for Change (2.0)

Lessons Learned

- CCIs and other research centers have resources that are valuable to ISE organizations – staff and scientists.
- Science centers offer a venue and audience for outreach activities.
- Formal instruction in effective communication benefits scientists; these skills may be applied in many contexts other than science museums.
- Don't be afraid to contact potential science center partners directly.

- Be prepared with a specific story that you would like to tell.
- Center staff can serve as primary contact for science center and facilitate meetings between science center staff and scientists.
- Formative evaluations are important for crafting scientific information that is appropriate for the intended audience.
- Be clear about expectations and roles. Final product may not be what researchers envision; it is a collaborative process where each side makes contributions based on their expertise.
- Having iterative exhibits is an advantage for both parties. Ideas for improving design, storytelling, and exhibit development improve with experience. Thus, researchers can refine and strengthen their message through the lifetime of a Center.

Resources for Communicating Chemistry in Informal Environments

Portal to the Public - http://popnet.pacificsciencecenter.org/

Over 40 informal science institutions have adopted the Portal to the Public model for connecting their visitors to local current research. These organizations form the Portal to the Public Network (PoPNet) dedicated to sharing ideas and strategies for scientist engagement with public audiences, providing communication workshops and help scientists to develop hands-on activities to engage the public. Researchers who are near a PoPNet institution is near you, it would be a tremendous opportunity for your researchers to learn about communicating with the general public and for providing a forum for your outreach. Many feature programs that bring in local researchers.

National Alliance for Broader Impacts (NABI) - https://broaderimpacts.net/

NSF-funded NABI is a community of practitioners sharing ideas and practices to advance broader impacts and demonstrate the societal benefits of research. Areas of interest include partnerships, citizen science, social media, evaluation and innovative approaches to broader impacts.

Center for the Advancement of Informal Science Education (CAISE) https://InformalScience.org

CAISE is a collection of project, research, and evaluation resources designed to support the informal STEM education community in a variety of learning environments.

Crone, W.C. 2006. Bringing Nano to the Public: A Collaboration Opportunity for Researchers and Museums. NISE Network [online].

http://www.nisenet.org/sites/default/files/BringingNanoToThePublic_Guide_May10.pdf

A booklet describing how researchers can get involved with museums to communicate their research to the public.

Effective Chemistry Communication in Informal Environments

https://www.nap.edu/read/21790/chapter/1 - v

A report, published by the National Academy of Sciences, based on a survey of research and review of effective practices in science communication, informal learning, and chemistry education stresses importance of evaluation at the outset of program development and creates a framework for effective chemistry communication.

Communicating Chemistry: A Framework for Sharing Science: A Practical and Evidence Based-Guide

https://www.nap.edu/catalog/23444/communicating-chemistry-a-framework-for-sharing-science-a-practical-evidence

Based on above report from National Academy of Sciences, describes a framework comprised of five essential elements to guide the design of chemistry communication events.

Acknowledgments

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