

Changed Perceptions About Science Communication: A Case Study of STEM Graduate Students
in Portal to the Public

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ABSTRACT

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Current research in science, technology, engineering and mathematics (STEM) remains largely unavailable to nonscientists. The existing structure of the academic tenure process in universities and STEM graduate training programs further add to the gap as scientists frequently do not have guidance or opportunities to learn effective science communication skills nor pedagogy. Thus, scientists for these and other reasons are sometimes ineffectual communicators of science. Museums endeavor to decrease the separation between public audiences and scientists by bringing scientists into museum spaces and facilitating discussions about current science through exhibits and public programs. The Portal to the Public program at Pacific Science Center in Seattle, WA provides a useful case to study the effects of face-to-face interactions with the public on the scientists involved in science outreach. Portal to the Public provides scientists with professional development opportunities in science communication, and events to engage in dialogue with public audiences. The study focused on the effects of Portal to the Public on master's and doctoral students, who are developing into future science researchers and science educators. Semi-structured interviews were conducted with eleven graduate student scientists who had participated in the program during 2007 to 2010. The results suggest the program positively impacted science communication skills, science teaching skills, and time dedicated to science outreach activities. Surprisingly, Portal to the Public influenced the self-perception of the graduate student scientists in the study. Interest to continue with science outreach in future career stages maybe attributed to positive experiences engaging with public audiences, and positive experiences being mentored by museum educators through the professional development workshops. The study provides evidence that positive science outreach experiences can have a strong impact on emerging scientists' ability to communicate science, and a strong impact on forming an identity as a science communicator.

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PREFACE

Patricia Montaña grew up in southern California and graduated from Occidental College with a Bachelor of Arts in Biology in 2004. After working a few years in a library and public schools, she moved to Seattle, WA to attend graduate school. In 2011 she completed a Master of Science in Biology, followed by a Master of Arts in Museology with a certificate in Nonprofit Management in 2012. Patty's interests in informal science education and education equity while a STEM graduate student inspired her to pursue a career in museums.

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DEDICATION

My thesis is dedicated to my husband, a STEM graduate student, and other STEM graduate students who work tirelessly (sometimes between five to seven years) for the love of investigating new areas of science.

CHAPTER 1: INTRODUCTION

The movement to bring current science to the public is a recent trend in science museums, one that started approximately ten to fifteen years ago with the founding of such initiatives as the Wellcome Wing at London's Science Museum in the United Kingdom (2000), La Cite in Paris, France (2002), the Current Science & Technology Center in Boston's Museum of Science in the United States (2001) and others (Farmelo, 2004). Using museum spaces to bring scientists closer to the public is a more novel idea, with leaders such as the Portal to the Public project, found now in eight United States museums and expanding to more museums in the future. For most of the history of science museums, science was displayed as known facts and collections of "dead" objects, making the dynamic fields of science appear to be "finished." Science museums have transitioned to experimenting with exhibiting "unfinished science" and making the museum a place for dialogue between scientists and nonscientists (Farmelo, 2004). The experiment in museums is to emphasize a public engagement model in place of a deficit model. Such radical changes in museums anticipate benefits for increased science literacy and engagement by public audiences and improved communication avenues for scientists and current science research.

Increasing visitor interactions with current science is a shift towards accomplishing a more visitor-centered space in museums. Many museologists advocate for the academic work done behind-the-scenes in museums and in universities be made more accessible to a greater number of citizens (Farmelo, 2004). The field of science as a whole has come to be seen as a more, "...critically important part of economic and social development" in the lives of all citizens (Durant, 2004). The idea of science being intrinsically part of the fabric of modern culture has changed some traditional science museums from displaying "finished science" to adding exhibits of "unfinished science." In addition, the perception of science as an area of study reserved for academics and the scientific community changed in the second half of the 20th century as science and technology have become of increasing importance and concern nonscientists (Durant, 2004).

The push for addressing current science in such public spaces like American museums is also an effort to tackle the low level of science literacy in the United States. By 2007 the level of science literacy in the United States had risen from previous years and was estimated to be approximately 28% among adults (Miller, 1998; Scientific Literacy: How Do Americans Stack

Up?," 2007). This low percentage poses a concern that citizens may not be able to participate, or effectively contribute, in the practical, civic, cultural, or economic aspects of their lives because of a lack of an understanding of science. The level of science literacy in the United States has been a concern to professional scientific bodies, educators and school systems since at least the 1970s. Although controversy surrounded attempts to define the meaning of science literacy and ways to measure it in the late 20th century, experts agree science literacy encompasses an individual's ability to, "...not only [have] an understanding of a range of scientific concepts and processes, but also being able to apply this understanding, together with one's own experiences and values, to a range of science-related matters in private or civic life" (American Association for the Advancement of Science, 1993; Henriksen & Froyland, 2000). This characterization establishes the expectations that citizens will know scientific facts and concepts, and the knowledge gained can be applied to new learning situations such as academic settings, reading for pleasure, discussions with others, and decisions on legislation during election years.

Novel programs involving face-to-face interactions with scientists to increase public access to science and improve science literacy pose challenges as scientists frequently have trouble communicating science with nonscientists. A common difficulty for scientists is modifying scientific speech for a broad audience because scientists lack practice in speaking without the use of scientific jargon. Another challenge for scientists is centering on one scientific concept and not the details and complexities of current research. The common practice of expressing scientific uncertainty when speaking of science often confuses nonscientists and creates the perception that scientific hypotheses and theories are unreliable (Olson, 2009).

The difficulties many scientists have in communicating effectively with the public are a result of little training in teaching and communicating science. Science, technology, engineering, and mathematics (STEM) graduate students usually do not have teaching or education courses as part of their normal training despite the fact these individuals become future college and university professors, and leaders in scientific research (Tanner & Allen, 2006). This is strikingly different from the hours of teaching experience and a teaching credential required of K-12 educators to teach science and mathematics in the classroom. According to a 2001 survey on doctoral students funded by the Pew Charitable Trusts, many graduates enter doctoral programs because of a high interest in teaching, but feel unprepared to become educators, and feel unprepared for their desired future employment at graduation (Golde & Dore, 2001).

STEM graduate students as emerging professionals have limited opportunities to train as science educators and science communicators. The majority of training in teaching comes from experiences as teaching assistants at the university level, positions that traditionally come without explicit training in teaching strategies and learning theory. One alternative to obtain training in science education and be supported by a research fellowship is to apply for a National Science Foundation Graduate K-12 Fellowship, which is also subject to availability by a student's university and graduate department. Thus, graduate student scientists may need to seek opportunities outside of academia for professional development and public interactions. One way to obtain such opportunities is to join a program through a museum if such a program is available near a student's university. Museums are in a good position to provide such resources as many have been in the business of supporting teacher training and professional development for years (A. J. Friedman, 2009; Melber & Cox-Petersen, 2005). National Science Foundation funded programs in museums, like Portal to the Public, provide an opportunity to instruct graduate students in science communication and education through professional development workshops and outreach events. Master's and doctoral students in STEM gain valuable experiences in speaking to broad audience about their science research. Students also benefit from the guidance and feedback provided by museum professionals experienced in teaching in informal learning environments.

The Portal to the Public project which began as a collaboration between three science museums and an external evaluation organization aims to connect visitors with scientists and lower the barriers to science by: positioning the museum as a forum for dialogue about science, building relationships between museums and scientists and providing professional development resources for scientists so scientists can share their work with public audiences (Portal to the Public Research Report, 2011). All these objectives help emerging science professionals learn and practice skills in audience engagement, and increase the numbers of scientists involved in science outreach activities.

Since endeavors like the Portal to the Public program at science museums in the United States are new, the effect of such programs on the professional development of the scientists that participate, and in particular STEM graduate students, remains to be investigated more thoroughly. One interesting layer to explore is the attitudinal and behavioral changes towards science communication and science outreach years after initially joining well-structured science

outreach programs in museums. Do programs such as Portal to the Public help graduate students become better science educators and science communicators? Do the programs inspire scientists to pursue more science outreach activities? Do scientists think more creatively about how to use or communicate their science? Do such experiences influence a scientist's thoughts on possible employment opportunities? Documenting the thoughts and experiences of STEM graduate student involved with Portal to the Public at Pacific Science Center is a crucial step towards answering these questions and discovering the intended and unintended impacts of the program on scientists.

Few studies have been conducted on graduate students who participate in science outreach programs. The information garnered from this current study is especially valuable for the reason that it records how experiences in science outreach and science communication lead to changes in the self-perception of STEM graduate students, and lead to choices to engage with public audiences in the future. The study of graduate students involved in Portal to the Public at Pacific Science Center consisted of analyzing responses from semi-structured interviews. Eleven individuals from six cohorts involved in the original NSF-funded Portal to the Public program from July 2007 to July 2010 elected to participate in the study. The study aimed to answer the question,

What are the impacts of science outreach activities on STEM graduate students?

Graduate students were asked questions related to their motivations and expectations for the program, participation in science outreach over the ensuing years, and thoughts on how participating in Portal to the Public influenced future career aspirations.

CHAPTER 2: LITERATURE REVIEW

In the past ten to fifteen years the communication of science in museums has taken a novel turn. While science in the past had been presented as a series of facts and concepts, science education in the present has become concerned with the public understanding of current science, current science is sometimes referred to as “unfinished science,” and public engagement with current science.¹ Science museums have positioned themselves to be at the forefront of this new philosophy. Museum programs that bring current science, and scientists, to public audiences have sprung up across the United States. This literature review examines the importance of science communication, particularly with current science, the role of scientists in this endeavor, and the role museums play as spaces for dialogue between scientists and nonscientists.²

In order to understand the importance of science communication, one must start with the reasons for communicating science broadly. First, studies on the United States have shown the

¹Unfinished Science, current science, and science research all refer to science that is under active investigation in the present day.

²Burns et al (2003) defines science communication as, “...the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science and science outreach: awareness, enjoyment, interest, opinions, and understanding...” (Burns, O'Connor, & Stocklmayer, 2003). I have used the definition from Burns et al to inform the use and definition of the following terms in this paper:

Science communication: Communicating topics in science and STEM to public audiences usually by interpreting science topics. Can use many vehicles such as lectures, blogs, podcasts, face-to-face interactions, formal writing, etc...Can be done independently or with organizations.

Science outreach: Scientists, particularly those from university and research organizations, who volunteer time to participate in a program or event that engages public audiences with science and STEM. Usually done in conjunction with informal science education organizations.

Science education: Activities related to the teaching and learning of science and STEM. Can be formal or informal.

While these terms maybe used interchangeably in the text, they have subtle differences. All the terms, in relation to informal science education settings like museums, refer to engaging public audiences in STEM topics.

general public's low level of science literacy. Second, the general public lacks access to current science, thus limiting knowledge and engagement in current research. Third, research scientists face multiple challenges that prevent their participation in science outreach. Finally, research scientists lack opportunities and experience in science education and science communication while pursuing academic degrees, which limits confidence and ability to communicate scientific research to non-peers.

Concerns About Science Literacy

Communicating science is thought to improve the low level of science literacy measured in public audiences. The level of science literacy in the United States has been a concern to large professional scientific bodies, educators and school systems since before the 1970s (American Association for the Advancement of Science, 2000; Gruenberg, 1935). In the words of Jon D. Miller, a long-time researcher of science literacy, "We should take no pride in a finding that 70 percent of Americans cannot read and understand the science section of the New York Times" ("Scientific Literacy: How Do Americans Stack Up?," 2007). Although controversy surrounded attempts to define and how to measure science literacy in the late 20th century, experts now agree on a unifying definition. Authorities in the field consider science literacy to mean an understanding of science concepts, an ability to analyze science presented through various media, and a transfer of knowledge to new learning situations outside of formal schooling, particularly science policy issues.

Educators, scientists, and institutions side with multiple arguments for science literacy. Henriksen and Froyland list four arguments for science literacy: practical, democratic (civic), cultural, and economic (professional) (see Appendix A). Museums and institutions writing standards for science education have traditionally upheld the practical argument, often described as the "top down" approach to learning (American Association for the Advancement of Science, 1993; Hein, 2006; Yahya, 1996). The "top down" approach views the public's role as learning information deemed important by experts. Political scientists, like Jon D. Miller, believe governments and schools have a civic responsibility in generating a scientifically literate society that can function well when discerning policy issues on stem cell research and climate change (Miller, 2010). This perspective is also shared among educators, who are of the opinion that an increased percentage of science literacy will benefit the whole fabric of a democratic society, as

well as individuals. The cultural argument, a view that science is a social practice and part of our cultural heritage is relatively new and one not favored by museums and schools in the past (Coffee, 2007). Economically, individuals with science, math and engineering skills have better chances for employment and greater pay (National Science Board, 2012) and therefore will strengthen national economies in the 21st century. Whatever the argument used, the current technological age has reinforced the worry that the United States has not reached a satisfactory level of proficiency in basic sciences (Miller, 2010), and society is at risk at not functioning well in any of the areas of concern in the four arguments.

The importance of science communication also stems from the public's lack of access to current science and little personal connection with scientific researchers. "Scientific research is and always has been very much a minority pursuit," with less than one in one-thousand people in Western countries actively involved in scientific research (Mayfield, 2004; Pyenson & Sheets-Pyenson, 1999). Since relatively few individuals have careers in science research, most of the general public cannot name a living scientist because they do not know of one. "Just 18 percent of Americans know a scientist personally, according to survey data, and even fewer can name the government's top science agencies... When polled in late 2007 and asked to name scientific role models, 44 percent of people [could not]... among those respondents who were able come up with specific names, the top selections were either not scientists, or not alive: Bill Gates, Al Gore, Albert Einstein" (Mooney & Kirshenbaum, 2009).

A Call to Action: Advancing the Involvement of Scientists in Science Outreach

While knowing a scientist would create personal connections with the public and humanize science professions, these are not common reasons given by scientists who are in support of greater science communication. A largely held viewpoint is science communication would subsequently lead to public and congressional support for federal funding of research (Marincola, 2003; Mayfield, 2004). This is also part of the "top-down" approach mentioned earlier, whereby scientists decide the relevant information to communicate to the public, and scientists as the experts decide what areas of research deserve attention and funding. However others would interpret this more positively as scientists advocating for areas of crucial research and providing expert counsel.

Other perspectives by prominent scientists view the communication of science as more than increasing general scientific knowledge. In a 2007 editorial, Alan Leshner, chief executive officer of the American Association for the Advancement of Science and executive publisher of *Science*, wrote, “Efforts that focus simply on increasing public understanding of science are not enough, because the problem is not merely a lack of scientific comprehension” (Leshner, 2007). Leshner made the distinction between teaching knowledge and increasing public engagement when speaking to public audiences about science. He described public engagement as scientists participating in dialogue with fellow citizens on scientific findings and listening to public concerns about science topics. He also noted the public may have an abundance of knowledge (partly because an abundance of science content can be found on the world wide web) but may disagree with scientists due to mistrust, religious conflicts and cultural conflicts. Other scientists have chosen to call science outreach and science communication a moral imperative, advocating for more “civic scientists” that engage with local communities, and become involved with policy initiatives within government (D. P. Friedman, 2008; Marincola, 2003; Merenstein, Bowdy, & Woolley, 2001). Increasing the public’s knowledge and understanding of scientific topics – such as controversial topics – may not be a silver bullet as scientists thought before. Rather, the goals for science communication may need to be more varied than resolving an absence of content.

Since 1997 the National Science Foundation (NSF) has called on scientists to communicate current science to non-peers by requiring an outline of science outreach activities, called “Broader Impacts,” in the submission of research grant proposals. According to a 2007 NSF document on representative activities for the broader impact criterion, scientists can address how to “Advance Discovery and Understanding While Promoting Teaching, Training and Learning,” “Broaden Participation of Underrepresented Groups,” “Broad Dissemination to Enhance Scientific and Technological Understanding,” or “Benefits to Society” (National Science Foundation, 2007). While these categories within “Broader Impacts” are vague, NSF has provided examples of activities that establish ties with public schools, museums and community groups, encourage mentoring young scientists, and promote the training of emerging scientists in teaching and communication skills. Currently, NSF has revised and simplified the official wording of “Broader Impacts” due to extensive confusion within the science community (National Science Foundation, 2011b). Now NSF does not recommend specific activities, but advises scientists to draft a description of outreach that best fits the NSF mission and vision, an

aspect of which is "...to continue activities that help foster a scientifically literate society, one whose members embrace a new culture of lifelong learning" (National Science Foundation, 2011a).

Challenges Scientists Face Communicating Science

NSF and science societies are presumed to represent the views of the science community on science outreach and science communication, but individual scientists may have divergent attitudes. Some scientists feel indifferent, and many who may be interested experience multiple challenges to participating in science outreach activities and science communication (see Appendix A). The challenges range from believing public audiences might not find research interesting, to time pressures in laboratory work, to a lack of professional advancement incentives to participate in activities outside of the laboratory (Paola, 2004). A survey of tenured faculty, graduate students, and postdoctoral fellows in physics, astronomy and biology conducted by Ecklund et al (2012) provides support for these challenges in addition to describing other challenges, ...“commonly cited barriers [are] time, funding, knowledge, training, and institutional disincentive. There is also a widely perceived ‘Sagan Effect’ or a professional stigma attached to spending too much time translating one’s research to the broader public” (Ecklund, James, & Lincoln, 2012).

The academic research culture largely does not support outreach activities and presents one of the largest challenges to communicating science research to public audiences. Scientists frequently experience what can be described as peer pressure. Studies and individual accounts have shown scientists fear being viewed negatively or fear being criticized if time and efforts are spent away from research activities (Ecklund, et al., 2012; Poliakoff & Webb, 2007). The phrase “Sagan Effect” commonly refers to the belief that science outreach and communication will diminish productivity in science research and will lead to being negatively viewed by other scientists. Carl Sagan, the prolific writer of astronomy research and media savvy science communicator was denied admittance to the National Academy of Sciences 1994 by a vote from his peers. The Academy thought Sagan was an inadequate researcher, and doubted his seriousness as a science professional (Olson, 2009). But scientists need not fear a decrease in research productivity. Carl Sagan, Stephen J. Gould and other researchers have published many scholarly articles during the time they participated in science outreach and communication

activities (Shermer, 2002). Though the years have passed and the calls for scientists to communicate to public audiences have increased, the “Sagan Effect” is still prominent in the halls of academia.

Furthermore, science outreach, communication activities, and teaching have little to no effect on the tenure process at universities, thus offering scientists few incentives to participate (Anderson, et al., 2011; Paola, 2004). Tenure-track scientists are primarily measured by the grants awarded and articles published, and feel time pressures to fulfill tenure requirements (Tanner & Allen, 2006). Time spent away from laboratory duties is thought to hinder research productivity. The pressures have led to what is called as a “leaky pipeline,” or when scientists leave the academic track for reasons related to the demands and inequities found within the academic culture. Academia has been shown to have biases against gender, family and race in addition to prejudice towards time spent in education activities. One of the most prominent factors to cause women to leave the “pipeline,” and not obtain professorships when compared to men, is having children (Wolfinger, Mason, & Goulden, 2008). Numerous scientists and authors have called for reforms to include rewards for training in pedagogy and time spent on outreach activities (Golde & Walker, 2006; Leshner, 2007; Paola, 2004) especially when scientists are in their formative years as graduate students in STEM.

Paucity of Teaching & Communication Experiences for STEM Graduate Students

A misalignment exists between motivations to attend graduate school and graduate training in the sciences. In a study conducted by the Pew Charitable Trusts (2001) on graduate students in the sciences and humanities, a strong desire to teach in college classrooms was a common motivation to attend graduate school. But training in education and communication is largely unavailable or discouraged. Moreover, emerging scientists may need to develop a broader skill set that includes communication and teaching as a way to secure employment away from the laboratory bench since, “In the biological sciences, 40% hold faculty positions 10 years after receiving their Ph.D. Another 40% are working as scientists in other settings: industry (23%), government (11%), and other sectors (7%). Twenty percent are not working in science fields” (Golde & Dore, 2001).

While universities and the National Science Foundation recognize the need to increase the exchange of ideas between scientists and nonscientists, and the need to better prepare

graduate students to become successful educators, the current model of graduate education is not equipped to produce scientists ready to speak with public audiences. Scientists in graduate school have few professional development opportunities to learn how to teach and communicate science. Teaching assistantship experiences provide some training, but graduate students are frequently not given preparation in pedagogical techniques, curriculum development, or tools for public engagement. Rather most STEM graduate students must discover how to teach through trial and error and must come across more formal resources in teaching and communication through their own initiative (Ciaccia, 2011; Tanner & Allen, 2006). In addition, few universities offer courses specifically in science communication and fewer science departments in the United States have science communication coursework integrated in their programs (Pearce, Romero, & Zibluk, 2010).

Just as the academic culture exerts pressure upon tenure-track faculty, emerging scientists experience similar challenges to participating in public outreach. Time dedicated to professional advancement in research is more favored, “Many young colleagues are enthusiastic about discussing their work with the public, but they also are under tremendous pressure to stick to the bench, secure hard-to-get research grants, and publish rapidly and repeatedly in high-quality journals. Many even feel that the culture of science actively discourages them from becoming involved in public outreach, because it would somehow be bad for their careers” (Ecklund, et al., 2012). Thus an incongruity exists between graduate training, future employment opportunities, and expectations from national science organizations.

Some academics think the solution to the problem of STEM doctoral education lies in restructuring the current academic system to include science teaching and science outreach as part of STEM graduate programs and to include rewards for such activities. To harken back to Alan Leshner (2007), “If science is going to fully serve its societal mission in the future, we need to both encourage and equip the next generation of scientists to effectively engage with the broader society in which we work and live.” One such measure to create an avenue for pedagogical training was the NSF Graduate K-12 Fellowship (GK-12) program, now in its final year, “NSF developed the GK-12 program recognizing that, in addition to being competent researchers, STEM graduate students must be able to communicate science and research to a variety of audiences”(National Science Foundation). Graduate students interested in gaining experience in teaching can apply for a GK-12 fellowship if one is available in their department.

GK-12 provides a stipend equivalent to the predoctoral research fellowships offered by NSF, and requires students to dedicate 15 hours per week in activities related to teaching (National Science Foundation). GK-12 Fellows are immersed in public school classrooms and mentored by experienced science teachers; they learn how to develop science lessons, and learn how to communicate their research and general science topics to young audiences.

An evaluation of the first ten years of the GK-12 program, performed by Abt Associates, found significant effects on the professional development of graduate student fellows. The evaluation recorded the responses of 662 graduate students and found these individuals were more active in communication and education activities in STEM than their peers (Gamse, Rhodes, & Carney, 2010). The report showed that GK-12 Fellows participated more in explaining STEM concepts to non-technical audiences, were more likely to receive a teaching award and more likely to think of career goals that included teaching obligations (Gamse, et al., 2010). Contrary to fears that time spent in education and communication-related activities reduces research productivity, GK-12 Fellows were found to finish master's and doctoral degrees within a normal timeframe (Gamse, et al., 2010). One additional benefit to graduate students is that teaching and communicating science significantly improves research skills in the laboratory such as hypothesis testing, experimental design, and analytical thinking (Feldon, et al., 2011).

Building relationships with science museums and other informal learning organizations is another approach to help STEM graduate student develop teaching and communication skills. The collaboration between the St. Louis Science Center and Washington University, supported by a National Science Foundation Integrative Graduate Education and Research Traineeship, "...sought to produce [graduate student] scientists who were trained to be effective informal educators...through workshops developed and led by [the science center]" (Webb, et al., 2012). The workshops provided instruction on science communication skills, and building interactive displays on neuroscience. Overtime, the graduate students reported becoming more comfortable speaking about neuroscience research with public audiences. The "Science Squad" program developed by the Biological Sciences Initiative at the University of Colorado, Boulder also had similar positive results. STEM graduate students placed in K-12 classrooms learned inquiry-based teaching skills and expanded their understanding around issues related to education (Laursen, Liston, Thiry, & Graf, 2007). The experiences in both examples proved positive for the STEM graduate students involved.

The Portal to the Public program (PoP) in the United States recruits scientists to speak about current research with public audiences. The objectives of PoP are to: build relationships between museums and scientists, provide professional development to scientists to prepare scientists to share their work with public audiences, and create face-to-face public programs where scientists and public audiences interact (Portal to the Public, 2011). The PoP program started in 2007 with a grant from NSF and aimed to build a model to bring scientists into informal science education in science museums. The PoP program has grown from three museums in the beginning, to eight in the present, and many more museums in the future. PoP provides professional development elements to scientists, which can take place in a workshop setting. During the workshops scientists learn from museum educators, and scientists practice facilitation skills, questioning strategies, invitations to participate, and how to adapt to different audiences (Portal to the Public, 2011). The face-to-face programs with public audiences makes the museum a forum for dialogue between visitors and scientists and is a crucial component to PoP. The PoP program at Pacific Science Center holds large-scale, themed research weekends and a monthly Scientist Spotlight as its face-to-face programs. Pacific Science Center also has the largest proportion of STEM graduate students of all the PoP museums. The graduate students have been shown to benefit from PoP by developing teaching skills through their experiences with the workshops and face-to-face public programs (Portal to the Public Research Report, 2011).

Bringing Current Science & Scientists into Museums

Portal to the Public and other programs in museums offer approaches to diminish the gap between scientists, current science and public audiences using interactivity and a public engagement model of communication. Museums are places that access diverse public audiences. Museums are places of life-long learning, reaching people who have finished formal schooling, and students who are learning outside of formal classroom settings. Museums are free-choice learning environments where the learner can decide to pursue a topic of science that appeals to them.

Approximately 90% of an individual's lifetime is spent outside of the classroom in learning situations such as family experiences, information searches through online media, museums and more (Bell, et al., 2009; Brandsford, et al., 2005). Thus informal learning

environments, such as museums, present an important and sizable portion of the overall education of individuals and are frequent places of learning in the form of school field trips, and family outings (Bell, et al., 2009). To the visitor, museums are, “rich with real-world phenomena, these are places where people can pursue and develop science interests, engage in science inquiry, and reflect on their experiences through sense-making conversations” (Bell, et al., 2009). Museums offer unique atmospheres where people can focus their attention on topics of their own choosing in a space where they encounter tangible objects unavailable otherwise, (Glick & Samarapungavan, 2008).

While education has been at the core of the mission of many science museums, (Hein, 1998), the idea that museums could play a powerful role in inquiry-based learning is a new addition (Henriksen & Froyland, 2000; Ucko, 1985). At its founding in 1969, the Exploratorium in San Francisco, California, was a leader in science education research. The Exploratorium aimed for visitors to experience science in an interactive way, which was the opposite of the accepted model of the time. “...[T]he old model of the science museum, [where] visitors looked at displays of artifacts and instruments, and read the signs to decipher what was in the glass cases. But at the Exploratorium and other new museums, exhibits were taken out from behind glass and set up so that visitors could interact and play with them” (Klages, Librero, & Bell, 1995). Many science museums have since increased the interactivity of their exhibits and programs, plus launched new programs that display current science and built face-to-face interactions with scientists using the public engagement model of science communication as a foundation.

Displaying current science in the museum is a recent trend, one that started in the early 2000's with the ingenuity of the Wellcome Wing at London's Science Museum in 2000, La Cite Des Sciences et De L'industrie in Paris in 2002, and the Current Science & Technology Center in Boston's Museum of Science in 2001 (Farmelo, 2004). The PoP programs followed this trend and added a novel facet by bringing scientists into the museum to converse with public audiences. By bringing scientists into museum spaces, many museums consciously decided to abandon traditional communication models in favor of models that placed scientists (experts) on equal footing with public audiences (nonscientists), “...the climate of opinion is that there is an urgent need to move from a ‘monologue’ model of communication, with scientists lecturing the public on what it should know, to a ‘dialogue’ model, in which scientists meet the public in

forums that are evenhanded, giving nonspecialists much more time to air their concerns and share them with the ‘experts’” (Farmelo, 2004). Museums transformed from using information delivery models, such as the deficit model, to the public engagement model that focused on increasing public participation in science. “The public participation activities are often driven by a commitment to ‘democratizing’ science – taking control of science from elite scientists...and giving it to public groups through some form of empowerment...although the exact nature of this empowerment has yet to be clearly defined” (Brossard & Lewenstein, 2010). The structure of PoP, with its professional development elements for scientists and face-to-face public programs connecting public audiences with scientists in a forum setting, offers an evolution of science education and science communication standards and sets an example for the use of the public engagement model of science communication.

Increasing access to current science and bridging the academic culture with public audiences has a bright future. The Portal to the Public program will quickly increase to twenty-three museums across the United States in the near future with continued funding from the Institute for Museum and Library Services. Individual academic scientists and science research organizations more frequently voice support for the involvement of scientists in public outreach and communication through publications and editorials in peer-reviewed journals. Evaluations of scientist and STEM graduate student involvement in science education and outreach show positive outcomes; scientists demonstrate increased comfort and facility speaking about science and current research, and the public shows increased engagement. Still challenges persist in integrating science education and communication opportunities with STEM graduate student training, but change is occurring. The successes of Portal to the Public and other programs promise to continue transforming the relationship between science, scientists and public audiences.

CHAPTER 3: METHODS

Why? Where?

The Portal to the Public (PoP) program at Pacific Science Center (PSC) in Seattle, Washington was chosen as an exemplar of a science outreach program that involves STEM graduate students in dialogue with public audiences. PoP has the benefit of being well defined, well supported and in a museum setting. The informal education setting allows scientists to immerse themselves as agents of current research in a free-choice learning environment and allows scientists to access museum educators who have expertise in public engagement. The present study enquired about the intended and unintended effects on STEM graduate students attributable to the PoP program.

What is Portal to the Public (PoP)?

“Portal to the Public is a program designed to assist informal science education (ISE) institutions as they seek to bring scientists and public audiences together in face-to-face public interactions that promote appreciation and understanding of current scientific research and its application.” (Pacific Science Center)

The Portal to the Public project, and the Portal to the Public programs at science museums have been funded by grants from various federal agencies. The National Science Foundation (NSF) provided the initial funding for the project that started in July 2007. The original grant was instrumental in creating the PoP National Network, a consortium of eight museums across the country that implemented the PoP program, though each in its distinctive way with PSC being the leader and primary investigator. PSC has continued to receive federal funding to support the operational structure of the Portal to the Public National Network and the dissemination of the framework and programs to other science museums in the United States.

Science centers with PoP have each developed unique PoP programs that aim to connect visitors with scientists and complete the original three objectives of the grant:

1. Combat barriers to outreach through building partnerships between museums and science and research organizations.
2. Train and provide resources in informal science education to scientists.
3. Provide a forum for face-to-face interaction between scientists and the public (Portal to the Public Research Report, 2011).

The program was designed to have four main components that would address each of the three objectives listed above. First, STEM professionals (referred to collectively here as “scientists” for convenience) from such diverse backgrounds as university professors, physicians, nurses, engineers, and graduate students would be invited to work with the museum and thus links would develop between museums and current science research. In PoP a scientist is an individual with, “. . . a science-based career and some degree of professional expertise that they can share with public audiences” (Portal to the Public, 2011). Second, scientists participating in the program would learn about informal learning environments and strategies on speaking to the public in informal education settings through professional development experiences provided by the museum. Third, scientists who had received instruction on informal learning would engage with the public in dialogue through a public program at the museum. Fourth, PoP would evaluate the performance of each of its main components and the effectiveness of the program for the scientists, museums and the public. The information gleaned from such research would support a professional learning community of museums, informal science learning institutions and interested professionals.

At PSC, PoP has evolved since its inception to have a program structure unique from other PoP museums. The staff at PSC has created professional development workshops focused on audience engagement, and public programs with face-to-face interactions between scientists and visitors. The professional development workshops and public programs for scientists have been crafted into a formalized “Science Communication Fellowship” program with clearly stated requirements and benefits for scientists (“Fellows”). To become a Fellow, a scientist participates in four professional development workshops, “. . . focused on building the skills to effectively engage public audiences. Scientists refine key messages related to their areas of expertise and practice simple techniques for talking science with non-scientists.” With the help of museum staff, scientists build a hands-on educational activity based on the scientist’s research to be used at PSC public programs, or at other outreach events. Fellows also agree to volunteer at PSC for three events per year. Note that during the earliest stages of PoP at PSC the Fellows program had not yet been created, and therefore people who attended an early workshop series and created an activity did explicitly join the program to become Fellows. This means scientists prior to 2009 did not have a well-defined set of expectations and commitments as they began the workshops and activity development.

PSC has four recurring public programs that highlight the work of local researchers and scientists: Polar Science Weekend, Life Science Weekend, Paws-On Science: Husky Weekend, and Scientist Spotlight. Polar Science Weekend, Life Science Weekend, Paws-On Science: Husky Weekend, collectively called “Research Weekends,” take place once per year and are large-scale events. Scientist Spotlights occur more frequently, on a monthly basis and are small-scale events with only a handful of scientists. Science Communication Fellows are exclusively featured at Scientist Spotlight programs. All scientists are welcome to volunteer at other Research Weekend events since professional development workshops are not required for participation. Those scientists who have received support from the professional development workshops can join the Research Weekends to exhibit their hands-on activity to visitors who attend the museum.

The Portal to the Public NSF grant and an NASA grant helped fund the professional development and activity development workshops for the first six cohorts of scientists between 2007 and 2010. These cohorts, with names in chronological order and appropriate abbreviations are: Molecular and Cellular Biology Fall 2008 cohort (MCB 2008), Cohort B Fall 2009, Molecular and Cellular Biology Fall 2009 cohort (MCB 2009), Earth Revealed Spring 2009, Polar Science Weekend Winter 2009-10 (PSW 2009-10) and Polar Science Weekend Winter 2010-11 (PSW 2010-11).³

Subjects and Sampling Procedure

Because the research statement aimed to understand the experiences of graduate student scientists in PoP, a list of individuals was gathered to include scientists who were graduate students (Master’s or Ph.D.) at the time they participated in one of the six cohorts described above. All the graduate students on the list were enrolled at the University of Washington in Seattle, WA and not other universities. To further determine appropriate study subjects, the following two selection criteria were used:

- A graduate student participated in four professional development workshops and developed an activity.

³ A NASA (National Aeronautics and Space Administration) grant funded both Polar Science Weekend cohorts.

- A graduate student volunteered, at minimum, for one public program with face-to-face interactions with museum visitors (such as Research Weekend events).

These criteria were chosen to include graduate students from any year in a Master's or Ph.D. program, and from any STEM-related field. Other science-based professionals were excluded because these individuals would not share common experiences with graduate students. The selection criteria yielded a possible 43 subjects to contact.

PSC initiated the first contact with the graduate students by email. The email introduced the researcher of the study and alerted them to wait for further information from the author. The 43 students were subsequently contacted by the researcher by email and informed of the purpose of the study, the topics to be discussed in the interview, and when the interview period would be conducted (Appendix B). Interested individuals were asked to reply to the researcher to schedule interviews from April 17th to May 7, 2012. Graduate students who did not reply to the previous emails were contacted a third time, again by the researcher. Potential study subjects were contacted multiple times to increase the sample size, and obtain an even representation of cohorts, gender, and year as possible. Because individuals elected to take part in the study, the final list of study subjects is not a random sample of the 43 possible subjects. Individuals involved in this work and their responses characterize the experiences of STEM graduate students who felt positively about their time with PoP. However, their degree of involvement in PoP, and their opinions of the program are not homogeneous. The individuals in the study come from all six cohorts.

Interview Methods

The subjects in the study were interviewed either in-person, by telephone or by Skype using a semi-structured interview. Interviews were conducted in private, and not in groups. The flexibility of the semi-structured interview allowed the researcher to ask questions in different ways, or to rephrase questions if needed (Diamond, 2009). The interview format also allowed the researcher to pursue interesting lines of thought, or ask for more explanation of particular experiences or opinions. This qualitative approach was selected as a way to allow subjects to freely express their opinions and recollections during the interview and provided the researcher the liberty to listen and interact with the subject in a way that was more conversational.

The interviews were digitally recorded, and stored on a password-protected folder to safeguard the subjects' answers. The subjects' names were not used in the recorded interview as a step to protect the person's identity. In the invitation email, each subject was informed of the steps to ensure the anonymity of their answers, and asked to contact the author with questions. On the day of the interview, each subject was informed again as to the steps to be taken to maintain the privacy of their answers, and each individual was asked to communicate any concerns or questions. A verbal agreement to participate in the interview was recorded for each interview conducted.

A copy of the interview instrument can be found in Appendix C. The topics covered during the course of the interview included:

- Purpose of the study
- Academic background
- Motivations & expectations for participation with Portal to the Public
- Outreach activities after participating with Portal to the Public
- Professional plans for the future
- Thoughts on how the Pacific Science Center can help the professional development of other scientists & graduate students
- Additional thoughts and opinions

Graduate students were questioned about personal motivations and expectations for PoP. Graduate students may have different motivations and expectations for joining science outreach programs than scientists further in their careers. Asking about each student's outreach activities after finishing the professional development workshops and one outreach event at PSC was to discover if the PoP experiences led to more volunteer activities in science within the museum or with other organizations, as well as to ascertain changes in attitude or awareness concerning science outreach opportunities. The graduate students were asked to describe their professional plans, and if the experiences with PoP influenced professional choices in science, or prepared them for future careers as educators and communicators of science. Lastly, students were asked to share thoughts of how Portal to the Public and the Pacific Science Center can help scientists – such as graduate students – with professional development in science communication.

The audio files from the interviews were transcribed in full using a transcription company then reviewed for fidelity to the original recording. The text was examined first for themes and relevant quotes to inform a coding rubric, then analyzed for key phrases and common opinions between individuals. The quotes printed in the results section characterize the thoughts and

opinions of individuals and groups of individuals. Correlations between responses and gender, or responses and cohort are noted in the result and analysis sections.

One key source, the Report of the Discussions and Findings of the Portal to the Public Synthesis Meeting January 2008, was used to establish an understanding of the initial objectives of the program on scientists and STEM graduate students and will be referred to in the Analysis section (Portal to the Public, 2008).

Interview Length

Interviews ranged from twenty to forty-eight minutes, and averaged thirty-one minutes.

The Public

The phrase, “the public,” is used repeatedly to refer to the audiences the graduate students engaged with at the museum and in other science outreach activities. The students commonly used the phrase “the public” to refer to their audiences and to refer to nonscientists in general. The public is not uniform; it is composed of various communities with distinct levels of education, socio-economic position, gender, age, ethnicity, and desire to engage with science. The publics the scientists engaged with in conversation at Pacific Science Center are not defined in the study.

CHAPTER 4: RESULTS & DISCUSSION

Demographic Description of Subjects

The sample of eleven individuals interviewed consisted of eight women and three men. The ratio of women to men in the population of eligible graduate students is twenty-seven to sixteen, and thus the sample is not representative of the gender ratio of the population. The study subjects come from the following STEM departments and programs, as determined by the graduate program conferring the degree to the individual: Molecular and Cellular Biology Program, Astronomy, Oceanography, College of Forest Resources (renamed the School of Environment and Forest Sciences in 2011), Earth and Space Sciences, and the School of Aquatic and Fisheries Sciences. Individuals in the study were enrolled in the three most common graduate programs in Portal to the Public, but not all the graduate programs from the students eligible to participate in the study (Table. 1).

Master's and doctoral students in the study participated in Portal to the Public when in the first to fourth year of graduate school (Figure. 1). The individuals primarily sought a doctorate as the highest degree. Students in programs that combined a Master's degree and a Ph.D. degree were recorded as Ph.D. students since the doctorate was the highest degree pursued (Figure. 1). No fifth year, or final year Ph.D. students, participated in the study.

A total of 114 individuals were recorded as having gone through the Science Communication Fellowship program as of May 2012. Science Communication Fellows are asked to volunteer for three events per year at Pacific Science Center after finishing the professional development workshops and developing an activity. 54% of Fellows are professional scientists (university faculty, researchers, etc...), and 46% are STEM graduate students at the University of Washington (Figure. 2). Thus graduate students are a large proportion of scientists in PoP at PSC.

A summary of responses for most interview questions is shown in a matrix in Table. 2 and Table. 3. The names of individuals have been replaced with letters to maintain anonymity. STEM graduate departments, fields of study, and years in Portal to the Public are not listed, as these pieces of information would lead to the identification of the graduate students. Most professional development workshops had a theme, or STEM concentration, which are here referred to as "cohorts." Graduate students in the study spanned the first six workshop cohorts

supported by the first National Science Foundation grant cycle (Figure. 3). The two Molecular and Cellular Biology cohorts in 2008 and 2009 were almost exclusively filled with students from the molecular and cellular biology program (MCB) at the University of Washington. Three out of the eleven students in this study came from MCB. The largest cohort, “Earth Revealed” had four graduate students in the study.

Motivations

The graduate students in the study had multiple motivations for joining PoP (Figure. 4). Seven graduate students joined PoP because of an interest in engaging with the public about science. These students used words such as *interest in science communication, teaching or science outreach* to describe their motivations, and expressed a need to gain experience in these areas. Another large motivation for four students was teaching assistantship credit or laboratory rotation credit. However, three out of the four students who chose PoP to fulfill graduate school requirements, such as a teaching assistantship, also chose PoP because of an interest in gaining outreach experience. PoP at Pacific Science Center has a special relationship with the Molecular and Cellular Biology Program (MCB) at the University of Washington. MCB requires students to complete an “alternative TAship” in the second year of the doctoral program. Participation in PoP satisfies the alternative to a traditional teaching assistantship position at the university. In the past, MCB students in cohort from the years 2008-2009 were funded by the National Science Foundation grant at little charge to the MCB program. Currently, MCB funds two students per year to join PoP to complete the alternative TAship requirement. A correlation was noted between cohort year and teaching assistantship/laboratory credit. Graduate students from the three cohorts spanning fall 2008 to fall 2009 were motivated to join PoP because of a teaching assistantship/laboratory credit (a ratio of four out of five students from fall 2008-fall 2009), but students in later cohorts did not express this as a motivation.

“...I did it because I’m interested in science outreach and communication with the public. So, that was my motivation. It was a [teaching assistantship] requirement, but a choice within a requirement.”

An equally important motivation for many students was “to do something fun” with their science that engaged them as scientists outside of the laboratory. The museum appeared to be a

place where this desire could be achieved. Some graduate students felt a wish to share their research with others. The sharing and educating of others (referred to as “nonscientists” by one student) was both very rewarding and personally meaningful. Students repeatedly articulated the need to share and educate others about current research as a way to convey the importance of scientific research and get the public interested and excited.

“I was interested in getting a little bit of formal training on learning how to talk to the public. It’s also very personally rewarding to get out there and talk to people and see people excited about what you’re doing.”

“I really like interacting with nonscientists. I think it’s really fun and it reminds you about why your work is important and why it’s interesting and where it fits into the bigger picture of things.”

A small subset expressed dissatisfaction with their graduate school experiences, and wanted to gain experiences outside of the academic realm. Three students expressed a lack of personal fulfillment in conducting research, and one of the three wanted to discover how people learned science. The dissatisfaction stemmed from feeling inside an “ivory tower,” removed from the public, unable to share science with others, or removed from “real world questions.” A possible gender bias was noted here. The three that expressed dissatisfaction with graduate school were all women. None of the three men in the study articulated comparable thoughts during the course of the interviews.

“I think, at the time, I was really just frustrated with grad school... there was no balance between applied and real world questions and this kind of ivory tower thing. So it seemed like a really good opportunity to just take a break from the heavy thinking that I was doing inside of graduate school and make it a little bit more fun and just to start talking about what I was doing.”

Expectations

A majority of graduate students felt their expectations were fulfilled (Figure. 5). Six students gave a strong affirmative that their expectations were fulfilled, and one out of the six felt they had achieved more than they expected. The expectations the students had prior to entering the program were: to learn new techniques in communicating science to nonscientists, and to have help from museum staff in developing activities and translating science concepts for broader appeal. In the interviews, the students said they had learned new techniques in the professional development workshops. In addition they affirmed that they achieved the goal of

knowing how to engage an audience through creating an activity and interacting with the public. Three thought the museum staff served as good models and were very helpful when students found it difficult to interpret science concepts.

“My expectations were to really learn how to communicate my own science and what I do in a laboratory to someone like my grandparents who have very little background knowledge in what I do...”

Two felt they benefited somewhat from the program and only certain expectations were fulfilled. Both thought the workshops and programs were fun and good, but that the program was not geared appropriately for scientists. Instead the program better suited people who may not have advanced training in the sciences and wished to interpret current science to the public, and the program did not address how to talk about ethical issues with the public. One individual critiqued the program by saying the quick interactions with the public simplified current research to a point the sciences were not well represented.

“I’m not sure that it was a perfect match for what I ideally wanted to get out of it...The workshop would have been better designed for interested members of the public who were interested in volunteering as interpreters, not scientists looking to bring your science to the public.”

Two students did not have clear expectations prior to starting the professional development workshops and so could not describe what they anticipated from the program. However, both expressed achieving more than planned.

“I had no idea what it was when I first started...I have participated many times since then, but that wasn’t part of the original thing that I expected. I didn’t plan at the beginning to be involved for so many years, but I am.”

The student who thought the program was unsuccessful felt disappointed in their experience; the disappointment was mainly due to a misalignment between their research interests and the theme of the cohort that they joined.

Impact on Science Communication & Teaching Skills

A majority of graduate students, eight, felt the PoP workshops and event experiences had a positive impact on their communication and teaching skills (Figure. 6). The workshops helped the scientists think about science from a novice’s perspective, and enabled them to translate science vocabulary and concepts to attract the interests of the public.

“The workshops helped me to more easily put myself back in the shoes of someone who is young and just learning about science.”

Many had used the tools learned in the workshops in situations outside of the museum such as teaching assistantships, lectures, conference presentations, and other STEM outreach experiences. One student remarked experiencing success when using the inquiry-based techniques in teaching classes at the university, but less success when the same techniques were used in professional presentations to other scientists.

“The training that I went through in order to develop the activity for the Science Center had a lot of emphasis on audience considerations and on asking questions. And, these are things that I now try really hard to bring into my own teaching and in my own work when I’m presenting science to colleagues...It doesn’t transfer over perfectly...I would say that my teaching has improved dramatically. When I’m talking with other scientists...what I learned in the Portal to the Public program doesn’t translate quite as easily as it does to my teaching, but I still try to emphasize questions when I am giving a scientific lecture to my peers...”

One graduate student stated a strong personal impact as a result of the PoP program. The elements learned and the positive experiences with visitors led to a path in science communication and away from laboratory research.

“Yeah, absolutely. They just really made me fall in love with the whole idea of science communication and so essentially, shaped my career...”

But two individuals felt that the skills learned and the experiences at the Research Weekend events did not translate well beyond the museum setting, or were not conducive to deeper and more meaningful conversations about current science.

“I think that they’ve certainly helped. Just getting out there on the floor at the Pacific Science Center gave me a lot of practice in interacting with people...I think that there is a downside to that in that it’s a little bit too easy to distill what you do down into a couple of brief sound bites and not be prepared to give a really meaningful discussion to somebody about what you do. So, that was always a little bit dissatisfying.”

More individuals echoed this opinion in response to other questions during the course of the interview indicating possible imperfections in the program’s current form.

Ten graduate students were asked if their frame of mind about science communication had changed due to the workshops, the responses were mixed. Six said yes, while four said no. The question elicited few thoughts on how or if an individual’s perception of science

communication changed. The open-ended wording of the question may have caused the confusion. The subjects had much more to say and had an easier time reflecting on the impact of PoP on their science communication and teaching skills than if their perceptions about the field of science communication had changed. Those that responded reflected on becoming more enlightened and informed about effective communication,

“I started expanding my thoughts about what communicating science was.”

The majority of those that felt their perspective change discovered the difficulty in communicating science to others. The subjects commented how the nature of communication was dissimilar to their prior knowledge of science communication. For instance, communicating science was described as more than talking or explaining science to others (not didactic, nor a lecture). Instead effective communication elicited personal connections and interest.

“ Yes. I had always assumed that science communication meant explaining to people what you did...but it’s more getting them to care about what you do.”

One of the graduate students came to realize science communication could be taught and learned, and was not an inherent quality found in some.

“I always thought maybe there were a few people that were really, really good at talking to the general public and those were the ones who are working at science centers but I think I realized that pretty much any scientist can go through certain trainings like this and learn how to communicate more clearly.”

Of those that said no to the question, one person came into the program believing the importance of communicating science to the general public; thus their opinion, though unchanged, was supported by the program,

“I don't think too much. I think I've always felt it's an important thing and liked doing it.”

Two individuals stated the workshops had not changed their ideas about science communication but did not explain their ideas further. One person felt the change came from direct interactions with the public not the workshops. This person referred to him/herself as a science communication agnostic through the professional development workshops, but experienced a transformation after directly interacting with the public; this scientist later became very dedicated to the program and its objectives.

Continued Science Outreach Activities

Two out of eleven graduate students stopped volunteering in science outreach altogether, either at PSC or other organizations primarily due to work and school obligations, but not a diminished interest in science outreach (Figure. 7).

“No, I have not as of yet. Pretty much my excuse would be that I'm just trying to finish up my degree as quickly as possible...”

A majority, nine out of eleven, continued to participate in science outreach. Eight volunteered with PSC after they had finished the professional development workshops for a period of time between six months to four years (Figure. 7 & 8). Seven out of the eleven study subjects volunteered with PSC for two or more years (Figure. 8). Of the four students who were motivated to join PoP because of a teaching assistantship or laboratory credit, three continued to volunteer at the museum and one did not volunteer at PSC after finishing the professional development workshops and one public program.

Seven volunteered with other organizations or participated in other types of science communication and/or science outreach programs, such as through various University of Washington STEM departments (Figure. 7). Volunteer interest at PSC and in other organizations is related to the students' inherent interest in science outreach, as well as positive experiences from their time in PoP.

All the graduate students agreed their approach to communicating science to a broad audience was altered by PoP. Their knowledge of the public's level of science understanding was better informed through their engagement with the public. The scientists stated they felt better able to gauge the public. The graduate students thought more about their audiences, and felt enabled to independently discover more about potential audiences by asking questions prior to doing an event, or asking the visitors probing questions about interests in science.

“I feel like my expectations on what the general public as a whole knows about science are further refined, so I have a better gauge of who my audience is when I go. I mean, often people know a lot more than you think they do...so I think I make a bigger effort to kind of gauge or ask questions when I'm speaking. ”

“They certainly have. One of the things that I now do whenever I'm asked to give a public presentation...is I actually ask about how many people are going to be there, what are their backgrounds, are they an interactive crowd or do they just want me to talk at them for an hour? What are you guys looking for? Which is

something that I learned in the Portal to the Public program, and I never would have dreamt of doing before.”

Eight of the eleven scientists mentioned specific ways they changed their communication strategy when speaking with nonscientists about their research. Because of the PoP program, the scientists said they now focus on conveying the “big picture,” rather than details, talk about smaller concepts not scientific terminology to the public. They also used tools taught to them by the museum staff like asking questions rather than lecturing, using a “hook” to interest the public in their topic, and helping the public in self-discovery. Many felt capable translating concepts from their research to reach nonscientists.

“Just thinking about the ways that you get people hooked into a scientific concept. You get them to see big pictures, get them to see basically the sexiness of it.”

“I feel like that the workshop just helped in making you continue to think about more fun ways to interact with people, and also ways for people to think about how to make the experience for the person on the other side exciting. The workshop talked a lot about helping people discover things themselves instead of telling it to them. And that really stuck with me.”

Professional Plans for the Future

Participation in PoP increased the graduate students’ awareness of employment opportunities and volunteer opportunities. Most felt their network of opportunities increased within the museum, with a few of the scientists feeling they were more aware of opportunities with outside organizations (Figure. 10). One student specifically mentioned meeting other scientists involved with science outreach through the Research Weekends, like the annual event Paws on Science. Other graduate students actively sought volunteer opportunities, or were frequently approached to participate in outreach by other organizations because of the new “science communication network,” and because persons in their university department know of their involvement with PoP.

“I’d say just being plugged into the science communication network. I hear about outreach activities by email. People ask me about them because I’ve done them. I’m approached by other people and I learn about other activities probably more than I would otherwise.”

Two scientists voiced that the experiences with PoP piqued their interest in a career at a museum or doing some kind of science communication career in the future. One person actively

asked museum staff about such career opportunities, and about the work environment and responsibilities in a science museum.

“It has increased a lot. It was like connecting with a different network. Participating in Portal to the Public made me realize what it implies to have a job there and what is the difference between having a job in a museum and volunteering in a museum to present science. So people at the Pacific Science Center have been great at answering my questions because I ask them about careers.”

The other scientist felt they would be happy to work in a museum or a museum-type organization, but thought this prospect was not realistic as a traditional career in academic research. This individual described this desire to do science communication as a full-time career as “pie in the sky.”

Six out of eleven did not feel they became aware of employment opportunities through their experiences in PoP (Figure. 9), in contrast to the nine that felt they had become more aware of volunteer opportunities (Figure.10). Four out of the nine became aware of volunteer opportunities only within PSC, and not with outside organizations. Two graduate students felt they had not gained awareness of either volunteer or employment opportunities. Interestingly, some graduate students articulated becoming more aware of science outreach because of PoP, as one student replied they might not have paid attention to requests or announcements for science outreach opportunities if they had not become involved in PoP.

“I don’t think it has done too much from a career development standpoint in terms of informing me about new jobs or anything like that. I think that I understood that there were employees at museums and science centers who do this work fulltime...It’s certainly opened my eyes to the amount of volunteer potential that is out there.”

“I don’t know about employment opportunities. Volunteer opportunities I think I hear about because they have an email list that they send out about what’s going on at the Pacific Science Center.”

The graduate students were split evenly between those that felt their future career choice influenced by the experiences in PoP, and those who did not feel their future career choice impacted (Figure.11). A subset of those who replied “no” came to graduate school with specific ideas about their desired career track as research professors or educators, which did not alter due to PoP. One student in the study expressed a desire to have a career in science communication

and science outreach prior to engaging in PoP and so PoP would not have changed this preexisting desire.

“I don’t think so. I think that science communication will be – I just assumed that is part of whatever job I will have in the future.”

“I don't think probably too much. I think a lot of those decisions end up coming from the research side of what I do, not the outreach side of things. So I don't think it's probably had a big influence in that area for me.”

A possible gender bias was noted. While one-third of men (one man) in the study felt PoP influenced their career choices (two men replied their career choices were not influenced), four out of seven women replied that their career thoughts and aspirations were influenced.

The experiences in PoP helped five students with professional advancement. One student thought the experience in science communication at the museum would aid in entering the field of science communication instead of scientific research if the person wanted to change occupations.

“Portal to the Public helped me get a feel for what is out there and it makes me feel confident that it’s something I could do if something I wanted to do didn’t work out. Or, another really amazing opportunity came up in the field of science communication I have a solid record of experience in that field.”

Two others attested that their time in PoP helped them switch to their current employment, or graduate program of study. One person in the study was no longer a graduate student, but employed as a science reporter, and had chosen to forgo the doctoral degree in favor of a career in science journalism. The experiences in PoP as a second year doctoral student provided work experience for a science writing internship and thus helped the transition to another career. Another doctoral student had been in a STEM program while participating in PoP, but after the experience switched to study learning sciences. The experiences in PoP nurtured this graduate student’s interest to study how people learn science and provided a way to exit one graduate program and enter another.

“I think so. I think it came at the time when I was considering switching fields and I think the fact that I had a positive experience with it definitely influenced me to switch over...it supported that transition for me from one career pathway to another.”

Three of eleven graduate students felt an interest in museum education work because of their experiences in PoP and because of their exposure to museum staff with science degrees. One person felt more enlightened about the day-to-day activities because of relationships fostered with museum staff, but also felt a job in museum education might not be a correct fit. This person rather saw a future participating in science outreach as part of their job as a scientist.

“It [PoP] gave me a lot of clarity about what it meant to have a job in outreach and consider maybe that is not what I want to do. I want to talk to the public but not necessarily work in museums institutions. It made me realize I want a job that has, that gives me the opportunity to go to museums and volunteer there and present my science.”

Another student felt their ideas for career choices was strongly impacted by PoP, and had a positive vision as a science educator at a museum. But the job market in science communication and museums appeared too unfamiliar and the person felt an uncertainty for how to achieve this particular career goal. Though this person has frequently dreamed about working at a science center, the individual has chosen to pursue the traditional academic route and look for a post-doctoral position at a research institution.

“I’m probably going to start looking for postdocs in the next six months or something like that to continue doing scientific research. But, I’d say about once a week I have a conversation with my spouse about, ‘Well, it’d be great if we could get jobs doing science communication.’ ”

The third person strongly impacted by their relationship with museum staff and PoP had never considered a career in a museum, but is very interested in learning more about science museum education careers.

“In talking to other people who run the Portal to the Public program I really like what they do and they also have science backgrounds and they have learned a lot of education tools. That’s something I never really would have thought of is working in a science center or a museum setting. I’m interested in looking at that.”

When asked what jobs these graduate students would most like to have in the future, the common response was a professorship at a college or university. Six responded a professorship at a college or university and three wished to work in research outside of academia. Three mentioned they were interested in science outreach/science education careers.

Though the majority felt their experiences in PoP did not change their ideas for possible careers, the evidence suggests PoP has influenced and changed how these graduate students

imagine their professional responsibilities as scientists. Ten out of eleven graduate students felt they will continue to do science outreach or science communication in some form as part of their future career (Figure.12). They expressed a duty and a personal interest to connect with the public even without formal support as such received by the museum. Some picture themselves as leaders of science outreach initiatives such as heading a National Science Foundation science education grant at a university, creating a “Science on Tap” series if one did not exist in the community, or researching the relationship between the public and controversial scientific topics. Others want to be involved developing science curriculum, or become facilitators between science topics and the public as an educator or a writer of popular science journal articles. The individual who answered no to the question had never contemplated participating in science outreach after graduate school. The interview was the first time they had thought about the possibility. In all, the majority of the graduate students felt passionately about their role as science communicators.

“I think that has definitely is something that has crossed my mind that in the future I would really enjoy possibly doing...Because after doing Portal to the Public it kind of gave me a better idea of what exactly is entailed in that...I would definitely say that [Portal to the Public], you know, that piqued my interest and it is something that I do think about.”

“No matter what career path I head down, if it’s hunting for faculty spots at a university or something more along the lines of doing stricter science communication, either way I’m going to be doing science communication. It’s going to be part of my career. Even if I were to obtain a faculty job at an institution I would still be looking for opportunities to either partner with nearby science museums. Or, if I’m in some remote part of the country where that’s not an option, I envision myself setting up things like a Science on Tap series where I can get people from the university talking about their science to the public just at a local restaurant or bar...”

“Not as my career top title, but maybe as part of my career subtitles. I do think that it's something that if you're working for a university that is a really good service to the university is having those kinds of interactions with the public...I imagine it will continue to be part of what I like to do as one of the many things that keeps me busy, but not probably the main one.”

“I think it’s definitely a huge part of what I want. What I want to do is teaching at a university or being involved with a science center or a museum or aquarium...I would imagine developing activities or curricula but most of the time interacting with visitors, directly, as more of a facilitator in communication.”

Preparation For Teaching

Nine of the graduate students felt the professional development workshops and programs at the museum had prepared them for a career teaching science, but the majority had reservations. Three felt completely positive that the training they received through PoP had prepared them to teach science to others. Six felt prepared to teach science to nonscientists, but felt the lessons learned at the museum had limited application and usefulness outside of the museum setting. One individual thought the program had neither contributed, nor detracted from their teaching ability. One person did not comment on the question.

The graduate students stated learning more about teaching and science communication through PoP than through their graduate programs, but thought the techniques learned in PoP would not be useful in other settings, such as the university.

“...it would not prepare me to have my own – to run my own class or have a group of students that I interact with for a long time.”

Many university courses have large student bodies and require contact over a quarter or semester with individuals. The experiences at the museum were mostly one-on-one, with young children, and of short duration (usually described as communications lasting seconds, or a few minutes). One student continued to feel a lack of knowledge of how to creatively deliver scientific information, and also uninformed as to the literature available on how people learn science.

“There weren’t a lot of little modules where we talked about being creative and how to develop interactive projects to draw people in, not a lot of hard facts or hard information on how can you best interact with the public, or help educate the public.”

Of the six graduate students who expressed reservations, only one expressed a sense of empowerment of being able to use the teaching techniques learned in PoP and adjust them for different audiences.

“Yes, I think it did...if I want to explore other settings I can try to go through a similar process. For instance they don’t prepare you to giving talk to people in an auditorium. I have never done that, but I recognize in my mind that that is a

different setting and now I know I can think about my public first and prepare accordingly.”

The three graduate students who expressed only positive opinions that their PoP experiences prepared them for teaching thought the program laid a good foundation in teaching skills and greatly benefited them. Two shared the opinion they would not have independently developed the teaching and communication tools learned in the workshops if they had not joined PoP. One student had been a teaching assistant before and after the professional development workshops and noticed a remarkable difference in their teaching style as well as in the end of the quarter evaluation reports from students. This graduate student felt an immense sense of satisfaction in having taught well because of transferring inquiry-based education techniques to an introductory-level science course at the University of Washington.

“So it’s impacted my teaching skills fairly dramatically in that I now shy away from how I was taught to teach, which was to stand at a black board and derive things, or stand next to a power point presentation and just talk for an hour. I now incorporate...asking questions to the students, or students asking questions to me. I also incorporate whenever possible...hands on activities, laboratory activities. I spend a lot of time thinking about how to keep the students engaged and things like that that I would never have thought of prior to going through the training program.”

This anecdotal evidence that PoP may have improved teaching skills in a formal learning environment is interesting, but the design of the present study cannot assess the teaching skills of this individual or of the other study subjects.

Changed Perspectives on Professional Development

Eight agreed that professional development workshops like those at the museum were very valuable because of the opportunity to learn new skills not cultivated as part of normal graduate school training. Effective communication and the presentation of science are absent from normal STEM curriculums, but the students recognize these skills as important to their professional training and the training of other scientists.

“The world doesn’t just work like it does in the lab or the institute. There’s different skills that are useful outside the lab. And, honing those is worth your time, even if you don’t use them on a daily basis as a grad student. So, I do think it’s valuable.”

“Making the time for those kinds of professional development are, I think, really, really important to be successful after you graduate because you don’t really get a lot of that in grad school unless you find it on your own.”

Thoughts on Improvements to PoP

Graduate students were asked an open-ended question for thoughts on improving PoP for future scientists. The suggested improvements and changes varied. The students wished to extend their experiences – expressed as “moving on to the next level” – and wished for more constructive criticism from museum staff. The desire to “move to the next level” was described as time to create new activities because new ideas to communicate science emerged over time, or the scientists became bored repeating the same activity. Two students wanted partners when making activities for Research Weekends, and two wanted the opportunity to communicate in different venues with more exposure to talking with different age groups and audiences about current research.

“...I was the only person from my lab to go and do this workshop, whereas I didn’t realize a lot of people came in like groups of two or three. It seemed like a lot of work for me to take on by myself. It would have been helpful to know that it was something a little bit more like a group effort.”

“We don’t get a lot of teenage students, and I feel like there’s a whole demographic there that’s missing out on this fantastic opportunity to talk with people who aren’t that much older than them doing things that maybe they want to do.”

“One of the most challenging things...is just time. I had this activity, and I did it a few times on the floor, and then I wanted to fix it because I wanted to make it better or do something a little different and just coordinating getting follow up support from people in Portal to the Public...was difficult...probably because there wasn’t the support built in for that in the program.”

Suggestions for making PoP more helpful for graduate students yielded more consistent responses. Eight had suggestions for improvements geared specifically for graduate student scientists. Three felt the program was fine in its current form. Of those that had suggestions, half felt an academic value of some kind should be attached to PoP for all graduate students (Figure.

13. The term academic value refers to a teaching assistantship, research assistantship, or course credit understood as obligatory activities in graduate programs. The interviewees' suggestions paralleled requirements to fulfill graduate degrees.

“When I think about all the people I know who are doing it the only other grad students I know who are doing it are either people who did get teaching credit for it or people whose departments have an established outreach group as kind of an extra curricular thing that you get credit for...I think getting TA credit for it would help lower the barrier for graduate students...”

The interviewees thought an academic value would allow more graduate students to join PoP and decrease a stigma associated with STEM graduate students dedicating time to informal science education and science outreach. Academic value has the benefit of showing that participation in science outreach has professional worth. Academic circles, some students felt, did not understand the time spent away from laboratory and research activities. One student directly encountered criticism to his/her involvement at the museum.

“In my own experience, the only impediment that I experienced to my participation in the program was from people more senior to me in the department who have sometimes a somewhat negative view of science communication...if this were something akin to a research assistantship that we do here at the university, or the teaching assistantship that we do here at the university, that was more integrated into sort of the framework that the University of Washington has, then it might change some of the minds of the people who were frowning on my participation. Because, to them it was something that I was volunteering to do when I could have been working on research, and ‘you weren’t getting paid to do it, so why are you doing this?’ I could see that [TA/RA] lending a lot of credibility, especially in the eyes of people who I feel are a little resistant to graduate students engaging in science communication.”

The experience of this one graduate student is supported by research from articles published on the professional development of doctoral students. As described in the literature review, STEM graduate students face direct and indirect pressure from academic advisors and faculty members to eschew volunteering and science education/outreach activities and instead concentrate all efforts on research activities (Ecklund, et al., 2012; Golde & Dore, 2001).

Due to time constraints, only eight out of eleven graduate students were asked to comment on professional development opportunities they would like the museum to create or address. Two wished for a workshop that addressed career opportunities for graduate students interested in pursuing careers in science communication and outreach.

“Having a graduate student oriented workshop with different career opportunities, knowing what is out there for us after graduate school in terms of informal science and communication careers.”

Others had suggestions similar to responses for previous questions. Four individuals expressed a desire to do science outreach events different from Research Weekends. The graduate students wanted the opportunity to speak to older age groups in the museum, speak to larger groups, or help the museum in a different capacity altogether. Students felt ready for new challenges, and outreach activities better suited to their strengths.

“Just giving people other opportunities to do things. Maybe we all need to start with doing the thing on the floor because obviously that’s where they need people to do it, but a lot of people don’t want to do it. But, then giving people other opportunities to do things other than that so that they can kind of find the niche that works best for them and develop the skills that they’re most suited to using.”

ANALYSIS

The graduate student scientists interviewed reported that participation in Portal to the Public had positive effects on science teaching and science communication skills, increased their awareness of volunteer opportunities, and had a correlation to increased time spent undertaking science outreach. A quick review of the data shows a majority of the graduate students felt satisfied volunteering for the museum through Portal to the Public and approved of the program's format and objectives. But the influence of the program is more powerful and more intriguing. Due to PoP, the scientists changed their self-perception as communicators of science, and adjusted their outlook on their future role as professionals after graduate school.

PoP changed how scientists approached communicating science to a broad audience. The tools learned in the professional development workshops were remembered and practiced between six months to four years after the initial exposure to inquiry-based techniques in education. In some cases the techniques were translated to new situations such as other outreach programs, university classrooms, and scientific conferences. The students recognized their communication strategies had changed because of PoP. They acknowledged the program resulted in them becoming more adept at speaking to an audience of nonscientists about scientific research, plus the scientists were better able to engage nonscientists, usually children, in conversation.

Participation in PoP impacted the time scientists invested in volunteer activities. Few stopped volunteering for the museum within one year of joining PoP. A majority of the graduate students in the study continued to volunteer at the museum years after finishing the professional development workshops – seven continued to volunteer two to four years after starting the program (Figure 8). In addition, scientists searched for other opportunities to engage with the local community and contributed to the science outreach efforts of other organizations in the City of Seattle, such as the University of Washington's Program on Climate Change, the Burke Museum, Seattle Public Schools, and the Ocean Inquiry Project.

Lastly, participation in PoP altered the self-perception of scientists, the way in which the scientists viewed themselves as professionals, and changed their aspirations for the future. A majority felt motivated to continue science outreach activities as part of a future job with the support of an institution, like a museum, or independently. Half of the graduate students felt the experiences inspired them to seek or consider careers in science outreach. Through the

experiences in PoP, communicating science to nonscientists became personally meaningful to the scientists, or nurtured an existing desire to be involved in informal science education.

Another interesting theme that surfaced referred to the positive aspects and limitations of the program. A majority of the scientists felt PoP was filled with positive experiences and met their expectations for learning how to communicate current science with the general public. However, a common response articulated was that the audiences they engaged with at the museum, plus the lessons learned in the professional development workshops were limited. The scientists mainly engaged with young children, and some parents. Shared views amongst the scientists were wishes to have varied experiences with the public and varied experiences in the museum: to have contact with older age groups, learn how to communicate with large groups of people, have deeper and more meaningful conversations with the public and explore other communication avenues.

Furthermore, many scientists felt the tools learned in the workshops were helpful, but the tools did not transfer flawlessly to the university teaching environment, or to science communication venues different from the museum's Research Weekend events. The training and outreach experiences appeared museum specific and were not seen as transferable skills. This is an important criticism to take into account, as these scientists (and others in the PoP program) have or will have teaching obligations in a university setting. Adjusting the current professional development modules, providing further instruction on teaching strategies or educating the scientists on learning is imperative to achieve long-term outcomes that will be valuable for the scientists. Further work investigating the prominence of these opinions amongst all scientists in the PoP program will be worthwhile.

An examination between responses and gender and responses and cohort revealed possible correlations. A gender bias was not found for the majority of responses to the interview questions, except for the influence of PoP on career choices and general graduate school dissatisfaction. More women (four out of seven) than men (one in three) in the study articulated their thoughts on careers in the future were changed due to PoP. All the individuals who expressed frustration with graduate school research, or the structure of graduate school – collectively referred to as dissatisfaction – were women. None of the men in the study expressed similar opinions. The correlations written here are possible and not absolute. A gender bias cannot be concluded given the overall sample size, and the low ratio of men to women. To better

analyze correlations between gender and experiences in PoP, a future study would need a larger sample size, and an equal participation of women and men.

A correlation was found between cohort and motivation. Individuals from the three earliest cohorts, not the last three cohorts, were the only students who stated gaining a teaching assistantship or laboratory credit as motivations for joining PoP. Another correlation was found between suggestions for improvements and cohort. Later cohorts more frequently said they would like more time to revise activities or create new activities. Obtaining more feedback from museum staff was not correlated with cohort, but was expressed in both early and later cohorts.

Correlations due to field of study, laboratory at the university, and year in graduate school were not possible due to the sample size.

Study Revealed Portal to the Public Achieved Initial Programmatic Objectives

In January 2008, 43 experts in informal science education, scientists and researchers gathered at Pacific Science Center for the first Synthesis Meeting. The group identified the field's opinion of what objectives should be achieved through the Portal to the Public grant, and delineated expectations for best practices, impacts, and evaluation. Expectations of the program written in the documents from the Synthesis Meeting, are compared to the data gathered when relevant to the scope of this study.

Those attending the Synthesis Meeting correctly surmised that PoP – and the professional development workshops made available in the program – would be of interest to graduate students.

“One group noted there seemed to be a greater interest in professional development among younger scientists and wondered if the reason was that they did not know where to find professional development opportunities elsewhere. A target group for professional development might be early-career scientists and graduate students, since their development will have long-term effects and implications.” (Portal to the Public, 2008, p. 15)

Graduate students in the study said they did not have professional development opportunities in science communication and education available to them at the university. PoP and similar programs offer a service and fulfill a need in the science community. Moreover, the study gives evidence that PoP does have long-term effects and implications on scientists. The graduate student scientists interviewed were greatly affected by their experiences. The knowledge they

gathered has changed how these individuals teach and communicate science and the time they dedicate volunteering in science outreach. In all likelihood, the lessons learned through PoP will continue to have ramifications in the future when these scientists teach at a university become student advisors, and independently participate with outreach programs.

Theme Six from the meeting articulated the goals for professional development, “Scientists will benefit from professional development focusing on effectively communicating current research to public audiences, and ISEs are well-suited to provide this service” (Portal to the Public, 2008, p. 4). This goal was met since the majority of graduate student voiced positive experiences, and stated they had learned a great deal about effective science communication from PoP staff. The museum, as an informal science education setting, provided skilled professionals that served as mentors plus provided a good setting for scientists to practice their newly acquired communication skills. On a related note,

“Most groups noted that impacts on scientists should also be considered. Both parties, scientists and audience, are changed as a result of engaging interactions. One potential impact on scientists is to provide a ‘reality check’ (i.e., explaining his/her work to a public audience gives the scientist an appreciation for what level of understanding or concern public audiences have about his/her work).” (Portal to the Public, 2008, p. 10).

The evidence points to scientists becoming more informed as to the public’s level of understanding and finding that as experts, communicating science to novices was challenging. Furthermore, this study shows the graduate students achieved two of the three professional impacts listed in “Section on Insights Regarding Professional Development of Scientists”: increased communication skills with public audiences, and increased understanding of public audiences (Portal to the Public, 2008, p. 13).

The wish to impact scientists’ (particularly academic scientists) perceptions toward education and science outreach was also achieved.

“There was also mention of the need for a greater level of understanding of scientists’ attitudes toward education. Within university culture, there is an important opportunity to change how education and outreach are viewed and valued. ISEs can have a positive impact through meaningful partnerships.”(Portal to the Public, 2008, p. 6)

Due to the joining the PoP program, graduate students had a more positive view towards the museum and towards education. Also, meaningful partnerships were established between the graduate students and the museum. Most students were motivated to continue volunteering with the museum and felt a strong commitment to communicate science to the public thus supporting the idea that, "... face-to-face experiences build a relationship between scientists and public audiences, which develops interest amongst involved parties for future science programs of all types" (Portal to the Public, 2008, p. 12). Nonetheless a broader impact within STEM departments at the University of Washington may not have been achieved. One student interviewed was confronted by a STEM faculty member and given negative criticism concerning his/her involvement with PoP. This study was unable to account if other students in the study or at the university experienced similar clashes with professors. The students' suggestion for PoP to institute academic credit (such as a research/teaching assistantship) as a way to facilitate other graduate students joining informal science education activities suggests the students in the study view their peers to be blocked in some way from participating in PoP. Students might need a "credible reason" for their activities outside of the laboratory to be accepted by their departments and advisors.

Students commonly referred to the skills they learned through PoP as not transferable to other science education and communication environments, thereby opposing the expectations that, "ISE communication skills may be broadly transferrable to a range of explanatory experiences (e.g., communicating with grantors, peers, media and students.)..." (Portal to the Public, 2008, p. 14). This hope for the program was not achieved but may be remedied with additional professional development modules, and resources that illustrate how inquiry-based techniques can be applied to laboratory classrooms, lectures, and other explanatory experiences germane to scientists.

Point fourteen in the "Section on Effective Strategies and Best Practices for Achieving Maximum Impact" states, "Offer a range of ways for the scientist to reflect, self-evaluate, and get feedback on their face-to-face interactions with public audiences" (Portal to the Public, 2008, p. 14). The PoP program at PSC from 2007 to 2010 did not accomplish this program design element. Most graduate students from early and late cohorts stated not receiving adequate feedback on their progress as communicators, or the effectiveness of their interactive activity. Students from later cohorts ("Earth Revealed" and both Polar Science Weekend cohorts)

repeatedly voiced wanting time to reflect on their experiences during Research Weekends and time to revise their activity with help from the museum's staff. (See the Recommendations section for an alternative model addressing this need for students who are Science Communication Fellows.)

In connection, groups at the Synthesis Meeting, "... suggested creating a "hierarchy" of diverse professional development experiences starting with broad, introductory-level workshops and materials and ending in mentorship, practice and immersion in informal environments. This range of scalable options can be matched to individual scientists' needs, interest, and programs" (Portal to the Public, 2008, p. 14). The graduate students in the study are asking for this scalable option. A need for varied and more challenging volunteer opportunities have been explained as desires to create new activities, boredom from using the same activity, wishes to understand more about learning, curiosity about the museum's staff and exhibits, and a curiosity about careers in outreach. An expansion of initial workshops could be done using the seminar format as discussed in the Recommendations section.

Implications of Findings

Museums with programs that bring scientists in conversation with the public may benefit from the study findings. Programs like PoP have deep impacts on the scientists the program trains. The study establishes that the STEM graduate student population has a need to be taught teaching and communication skills through well-defined and well-supported programs and museums are excellent places for graduate students to learn and practice these skills. Museum educators function as good mentors and mediators, helping scientists translate concepts in current science research for diverse audiences.

The evidence shows graduate students are a pool of experts willing to commit years to the museum after experiencing meaningful public interactions, and developing good relationships with museum staff. Graduate students can become ambassadors of the program to university STEM departments, and bring other graduate students into the museum through personal recommendations. Graduate students can become advocates for science outreach programs now, and in the future, thus diminishing obstacles between the public and access to science and technology.

Limitations to Generalizing Study Results

While the data provide insights to the dramatic impact that may be achieved through well-defined programming and positive experiences in science outreach, the study findings cannot be applied to programs dissimilar to Portal to the Public. PoP at PSC has dedicated staff working with scientists in the professional development workshops and in developing hands-on activities. The PoP program has grown to be well-defined. Other programs that bring scientists in contact with the public may not have a framework akin to PoP and may not use graduate students scientists. Therefore, the experiences of the graduate students described in this study may be unlike the experiences of scientists in other programs.

The study results may not be generalizable to other populations of scientists such as tenured faculty, industry researchers, or those in other science-based fields. Furthermore, programs like PoP may not help or be of interest to all scientists. Scientists with an existing interest in science outreach will be more receptive to instruction on learning and engagement provided by the museum, and open to conversing with non-scientists of diverse age groups and backgrounds.

CONCLUSION

Current research in science, technology, engineering and mathematics (STEM) remains largely unavailable to nonscientists. The existing structure of the academic tenure process in universities and STEM graduate training programs further add to the gap as scientists frequently do not have guidance or opportunities to learn effective science communication skills nor pedagogy. Thus, scientists for these and other reasons are sometimes ineffectual communicators of science.

Calls for change within science communities and informal science education communities have resulted in the creation of programs that bring scientists and current science closer to public audiences. The National Science Foundation Graduate K-12 program has immersed numerous STEM graduate students in public school classrooms to learn teaching and communication skills. In museums, the creation of Wellcome Wing at London's Science Museum in 2000, La Cite Des Sciences et De L'industrie in Paris in 2002, and the Current Science & Technology Center in Boston's Museum of Science in 2001 started a trend to bring current science to public audiences using a public engagement model of communication. Portal to the Public programs across the United States soon followed, creating a model to engage science-based professionals in informal science education at science museums. The Portal to the Public program at Pacific Science Center provides professional development to scientists to prepare scientists to share their work with public audiences and create face-to-face public programs where scientists and public audiences interact.

This present study on the effects of Portal to the Public at Pacific Science Center on STEM master's and doctoral students provides a useful case study on the impacts of science outreach activities on emerging scientists. STEM graduate students are an important population to study because experiences in Portal to the Public, and thereby communicating science to public audiences using a public engagement model, may have enduring effects.

Semi-structured interviews conducted with eleven graduate student scientists who had participated in the program during 2007 to 2010 showed Portal to the Public positively impacted science communication skills, science teaching skills, and time dedicated to science outreach activities. For many graduate students Portal to the Public was their first exposure to learning effective science communication, teaching techniques, and inquiry-based practices.

But graduate students felt Portal to the Public had certain limitations. Graduate students expressed a lack of meaningful conversations between the scientists and the public. The interactions in a museum are swift and heavily focused on children. Graduate students who had volunteered for a long period of time felt the communication experiences lacked variety. The students wanted to have other science outreach experiences, as well as learn more about effective communication, and learning. Finally, graduate students thought the communication skills they learned at the museum would not be effective in other education environments; to be specific Portal to the Public would not prepare them to teach in a higher education setting. This is within reason. More than half of the graduate student subjects plan to become professors in STEM and will be leading and developing courses for undergraduate students. Therefore, Portal to the Public and other programs that serve as science communication resources to STEM graduate students can learn to explicitly describe and demonstrate the links between learning in informal and formal learning environments. In addition, it is important to establish continued professional development to those scientists that become captivated by how public audiences learn science. Museums can provide academic literature on learning that may be unfamiliar to scientists and connect scientists to different avenues of science communication at the museum through internships, blogging, podcasting, exhibit design, etc... Thus, museums may need to plan for ongoing, multi-year relationships with scientists that remain stimulating and fruitful for all parties.

Remarkably, Portal to the Public influenced the self-perception of STEM graduate students in this study and affected their identity as scientists. The experiences with staff at the museum and with the public had a strong impact on how the individuals viewed their future careers as science professionals. Five of ten graduate students became inspired to pursue or think about careers in science outreach and science education. The majority, ten of eleven, felt passionately about continuing science communication activities in the future because of their experiences in Portal to the Public. Many expressed plans to join science outreach programs, or to independently lead science communication/science teaching projects if one did not exist as part of their future employment.

Interest to continue with science communication in future career stages maybe attributed to positive experiences engaging with public audiences, and positive mentoring experiences with museum educators. These causative results inform the field of museums, and other organizations

involved in science outreach, that STEM graduate students – and perhaps other scientists – can become transformed through their experiences with the public. Portal to the Public may be a part of effectively achieving the calls for reform in STEM graduate education and the STEM academic culture. Ongoing work and larger studies with STEM graduate students in Portal to the Public will help determine effects, if any, on changing perceptions about science communication within greater science communities.

Interesting avenues for future work could include studies using a random sample of scientists in Portal to the Public to determine if the findings in this study are common. Researching whether other STEM graduate students at Pacific Science Center and other Portal to the Public museums share the same effects on their teaching skills and professional plans could also prove fruitful. Ascertaining why the program may not work for some graduate students will be helpful and informative. Interviewing STEM graduate students after five to ten years would be a step to determine long-term impacts of the program and further document participation in science outreach activities. Since the study focused on STEM graduate students, knowing more about the effects of Portal to the Public on senior scientists and university faculty could determine if other scientists have increased their time volunteering in science outreach programs. Finally investigating correlations due to gender would be interesting and require a larger pool of study subjects. The present study had three men and could not effectively ascertain if some responses were gender biased. Yet a recent study found that a significantly larger percentage of scientists – graduate students, faculty and post-doctoral fellows – from biology and physics backgrounds involved in outreach are female (Ecklund, et al., 2012). In all, Portal to the Public provides a fountainhead of questions for future investigation on the effects of science outreach experiences on STEM scientists.

CHAPTER 5: NONPROFIT MANAGEMENT CERTIFICATE PROJECT

A portion of the nonprofit management certificate project from the Evans School of Public Affairs at the University of Washington is presented as the fifth chapter of this thesis considering recommendations for the Portal to the Public Program at Pacific Science Center.

The Importance of Evaluation in Museums

“...the demand is that the American museum provide some verifiable added value to the lives of those it serves in exchange for their continued support...to earn its keep, it must be something more important than just an orderly warehouse or popular soda fountain.” –Stephen Weil, 1999

Evaluation in the American museum, though traceable to the early 20th century, was not a common practice in the museum field (Hooper-Greenhill, 2006). But in the 21st century, evaluation has come to be an intrinsic part of museum operations due to an internal drive to measure performance, and external pressures from funders to see evidence of outcomes. Funding agencies view evaluation as essential and expect museums to be held to the same standards as other nonprofit organizations. The acceptance of financial support from such government agencies like the National Science Foundation requires an evaluation plan of the museum program or exhibition sponsored as well as the subsequent free-access publication of the evaluation report through avenues like InformalScience.Org (National Science Foundation). Though evaluation is challenging with respect to time and resources, the information garnered assesses the value of the institution, and can be used to feedback into an institution to improve museum programs and exhibits.

In 1999 museum scholar Stephen Weil wrote of two immense changes affecting the American museum. One was a shift in focus. Traditionally, the primary occupations of museums were to collect objects and provide a space for academic research. After the American Association of Museums published seminal papers in the 1980s and 1990s, the purpose of museums was redirected to include education and the visitor experience (American Association of Museums & Hirzy, 1992). In essence, museums became visitor-centered. The second major change, related to the change in focus, was the pressure to show donors the outcomes and impacts that sprung from museum programs (Weil, 2002). The social-enterprise model and the development of the United Way of America’s outcome-based evaluation changed the status quo for all nonprofits, and museums were catching-up with the changing environment in the late

1990s (Weil, 2002). Weil challenged the museum field to reconsider the worth of museums and to carefully decide the beneficial outcomes a museum would like to measure to report back to donors and to the public (Weil, 2004). He cautioned museums from relying on worth from the point of view of a prestigious pedigree, a museum's mere existence, or good intentions as sufficient factors to determine great value (Weil, 2002). But, the organizational structure of museums at the time combined with museum staff expectations created an atmosphere that was unaccustomed to assess performance, and unaccustomed to share information with those outside of the institution walls (Weil, 2002). Presently, the existence of online databases for museum evaluation reports and guides for conducting evaluation studies has made sharing and conducting evaluations easier.

Evaluation creates better programs and exhibits through numerous fundamental ways. The gathering of opinions from audiences served by the museum connects the museum to the public and affixes a value to the views of visitors. The purpose of evaluation can be used to point out flaws in the design, content and the accessibility of museum products. Information gleaned from one study can help the museum plan for future programs and exhibits. Evaluations that are published in journals inform the field as a whole, and other institutions that may not have the resources or familiarity with evaluation work.

C.G. Screven described five areas in museum evaluation studies, albeit he concentrated on exhibits. One area focuses on understanding the role of the museum as a place of informal education. Measuring the knowledge visitors have prior to a visit, as well as visitors' learning styles informs the museum of the make-up of their audiences. The second, on measuring the patterns of behavior of visitors within the museum space provides a window to understand the museum as a social space, the time spent in a gallery, and the visitor usage of the services at a museum. A third area aims to measure the impact of an exhibit on a visitor's continued interest in a subject, or a change in attitude or misconception. Evaluations can also measure the effect of the design of an exhibit on the communication of ideas to visitors, and can point out parts of an exhibit that may be confusing. Finally, evaluation has an iterative purpose; performing evaluations can improve methods for future evaluations, plus the continuous evaluation of programs and exhibits helps determine short-term and long-term impacts and outcomes (Screven, 2004).

5 Areas of Evaluation

1. Visitor Education: measure learning styles, attitudes, knowledge, language skills
2. Patterns of Behavior: measure where visitors go, whom they come, time spent, label reading, fatigue, family and social behavior, return visits, use of services, preferences for exhibits
3. Impact of Content: measure the understanding of exhibit messages, impact of visits on visitor attitude, behavior, misconceptions, and interests
4. Exhibit Design: measure how the presentation format, objects, spatial layout, media, noise, and general design affects attention, comprehension and way-finding
5. Development of Evaluation Methods: improving methods of evaluating the visitor experience, and measuring the short-term a long-term impacts of museum programs and exhibits (Screven, 2004)

Outcomes function to measure the return on investment, measure accountability for resources donated by grantors, and to ensure an organization's products have served a community need. The information derived from evaluation studies gives an indication as to the return on investment, and can help to determine "success." But in museums, the return on investment in the traditional sense of money earned per dollar spent gives a superficial picture of the effect of a program or exhibit. Many areas of evaluation, as described above, would be better defined as providing evidence for the social return on investment, or outcomes that cannot be measured easily in dollars. "Social Value is created when resources, inputs, processes or policies are combined to generate improvements in the lives of individuals or society as a whole" (Emerson, 2001). Measuring the revenue derived from a program and the attendance at a museum are important factors, but these two measurements by no means afford a complete representation of the services a museum offers to its audiences. Revenue and attendance do not shed light on the impacts of the educational services the museum may provide nor the role of a museum in its community as a force of social good.

Purpose Of The Program Analysis

This analysis of the Portal to the Public program (PoP) at Pacific Science Center (PSC) is an extension of a Museology Master's thesis. The broad goal of the thesis was to examine the question, "*What are the impacts of science outreach activities on STEM graduate students?*"

using PoP as a case study. The impact on visitors was not measured. Instead the scope was turned inwards to the scientists who are learning to communicate their research to a broader community in Seattle, WA. Interviews with graduate student scientists and staff at the museum revealed some barriers to entry into the program and interest among graduate students to continue with professional development workshops. The following manuscript delineates recommendations considering STEM graduate student needs.

Interviews conducted with graduate students revealed 3 key areas for improvement. These areas can be divided into accessibility into the program, representation of STEM fields and graduate student wishes to learn more about science outreach, education and communication. Outside of grant-funded workshops, participation in PoP appears largely limited to graduate departments that pay for their graduate students to attend the program, and to departments that have a system to provide teaching assistantship credit or laboratory rotation credit to students that engage in recognized science outreach activities. From the list of eligible study subjects, some graduate departments are overrepresented, and many STEM fields at the University of Washington are not represented in PoP. Graduate students in the study expressed wanting to continue with professional development in science communication. Some of the questions identified as being of top consideration are:

Questions

- How can PoP train graduate student scientists from a variety of STEM fields?
- How can PoP provide additional professional development to Science Communication Fellows?
- How can PoP add more value to its program and thereby have the participation of scientists in science outreach gain more acceptance within the research-university culture?

Marketing

PoP is publicized through a variety of web-based avenues (including the PSC website, Facebook, and Twitter) community newsletters, and email lists, and contacts with local science organizations (NWABR, Gates Foundation, science outreach coordinators, and partners on other grants). PoP publicizes equally across all audiences, and does not make targeted efforts towards graduate students at the University of Washington. Graduate student scientists hear of the

program from friends, advisors, departments with special partnerships with PSC, and through one-time workshops offered for Research Weekends.

In the past, the participation of graduate students, and other scientists in PoP professional development workshops was funded by federal grants and no payment was necessary. A special relationship with the Molecular and Cellular Biology (MCB) graduate program at the University of Washington enabled many graduate students from that department to be in PoP at almost no cost to the department with the benefit of providing the student with a Teaching Assistantship credit. Currently, MCB pays \$2,000 each for two graduate students per year to participate in PoP should a student elect the program as an alternative to their teaching requirement. Thus, many of the graduate students in the past four years have been from the molecular and cellular biology field.

Interest in participating in PoP is high, and the demand far exceeds the capacity of the program. 161 individuals are on an interest list to join future professional development workshops, and staff frequently receive letters of interest from scientists (Vukajlovich, 2012). Current funding will support two or three cohorts per year for the next three years. At the moment, joining PoP requires a \$2,000 fee for one person to take part in the Science Communication Fellowship program, which pays for staff time during and after professional development, individual consultations, materials, and overhead costs. This fee is equivalent for professional scientists and graduate students. The maximum number of scientists per cohort is 15 individuals, totaling 30 to 45 scientists per year. While PSC would like to scale-up the program, this would require hiring new staff as the current staff is overburdened. One limitation to hiring is funding from the federal government is time-restricted which results in an unstable hiring environment, one that does not guarantee employment beyond one to two years (Vukajlovich, 2012).

A Problem of Access

The population of interest in the evaluation, graduate students, do not have the personal funds, nor in many cases, the grant money to provide the \$2,000 fee for PoP. This creates an unfortunate barrier to entry. The ability of the Molecular and Cellular Biology program at the University of Washington to pay for two students to be in PoP, in addition to a stipend, is very

rare. Furthermore, the recognition of science outreach as an alternative to a Teaching Assistantship is equally rare at the University of Washington.

Consideration of Alternative Approaches For Continued Graduate Student Participation

Option A: Maintain Status Quo, Subsidize PoP When Federal Grants Are Available

During the first NSF grant cycle from 2007 to 2010, the participation of many graduate students was subsidized. This creates a tenuous situation. When the funds run dry, the program needs to rely on other federal grants, and fees to continue the program. Another disadvantage to this arrangement includes a lack of resources to foster the growth of continuing Science Communication Fellows. This option does not require any programmatic or operational changes.

Option B: Maintain Status Quo, Charge A \$2,000 Fee per Scientist

When federal funds diminish and subsidization is not an option, a \$2,000 fee is implemented to maintain the program. While the fee supports staff, and ensures the continuation of science communication workshops, it creates a barrier for many graduate students. Many graduate students at the University of Washington support themselves through Teaching Assistantships, and some through Research Assistantships. Adding a cost to science outreach becomes prohibitive and may result in less graduate student participation in the future, or PoP only including students from those programs with the money to pay the fee. This option does not require any programmatic or operational changes.

Option C: Institute Differentiated Pricing

A differentiated pricing scheme could pay for the implementation of PoP, with the benefit of eliminating the barrier based on price. Given the \$2,000 per scientist and a 15 person maximum per professional development workshop cohort, the total cost to the museum is \$30,000 per cohort of scientists. Professional scientists—those not in graduate school—may be asked to pay a \$3,000 fee. In this argument the individual funding situation of professional scientists is unknown, but professional scientists are assumed to earn more than STEM graduate students and perhaps have research funding set aside to fulfill NSF “Broader Impacts.” A maximum number of 10 professional scientists would pay for 5 graduate students to attend PoP for free, which results in 15 graduate students trained over the course of three cohorts.

Differentiated pricing allows for internal subsidization of the program. This allows graduate students who have neither the personal nor research funds, nor an accommodating program to still participate in PoP. The price increase may lessen interest from professional scientists. However, the strong popularity of PoP and its market dominance could preclude this disadvantage. This option requires minimal operational changes.

Option D: Start A University Course Open To All STEM Graduate Students

Collaborating with the University of Washington to create a course in science communication could increase the diversity of STEM fields within the Science Communication Fellows of PoP. This measure also furthers the marketing scope of PoP to individuals at the University of Washington who may not know of the program. Most graduate students and scientists hear of the program through word of mouth and personal recommendations (Vukajlovich, 2012). From 2008-2010, 13 distinct graduate programs and departments have been represented in PoP in contrast to the 65 separate STEM graduate programs that granted degrees in 2011 (The Graduate School, 2010-2011). Earth and Space Science, and the Molecular and Cellular Biology graduate programs have had the most graduate students in PoP. Engineering, Computer Science, Chemistry, Biology, the School of Aquatic and Fisheries Science, and Forestry each have very low representation (2 individuals from the fields of engineering, 1 Computer Science, 2 Chemistry, 1 Biology, 1 School of Aquatic and Fisheries Science, 3 Forestry). The bias is a result from the special relationship with MCB, and the “Earth Revealed” PoP program that recruited scientists who studied earth science or astrophysics.

This option requires collaborating with a professor at the University of Washington, or a PoP staff person hired as a part-time instructor through a STEM program. In addition, negotiations with the university registrar must be made in advance to have the new course be part of offered classes. “New courses can be submitted for review by the University Curriculum Committee up until the deadline for the month prior to the start of the desired academic quarter. Example: The deadline for Winter quarter would be the December meeting deadline...” (Office of the Registrar University of Washington, 2012b) This option would pay for some portion of the operational costs of PoP because the instructor would be paid a salary. But, PSC overhead would not be paid directly, and some portion of the tuition would be siphoned to pay for the university’s

overhead fees. This option requires extensive operational changes and may not provide the funds needed to support PoP.

Option E: A University Course for Science Communication Fellows

Obtaining a course at the University of Washington for existing Science Communication Fellows would be a relatively simpler process than Option D. Many STEM graduate programs offer “Seminar” courses for 1 credit or variable credits per quarter, and are graded on a credit, no credit basis. Collaborating with a faculty researcher involved with PoP would allow a Science Communication Seminar for PSC Fellows to be put on the registrar list of classes. A PSC staff person would not need to be hired as an instructor by the university. The proposed seminar would be publicly listed on the University of Washington Schedule of Classes and email alerts would be sent to Science Communication Fellows. The use of flyers to advertise new courses in STEM is frequently used, and flyers for the new seminar would be distributed and posted in STEM graduate departments.

A seminar would add more value to the Science Communication Fellow program by addressing a need for community. In the study, many graduate students mentioned they liked meeting graduate students from other departments and becoming friends. Fellows who had participated for a number of years and had members of their original cohorts drift away felt less compelled to continue. A course could add a social element to PoP, it could also sustain Fellows for longer periods of time. In this seminar format graduate students can cover and explore topics in learning sciences, educational psychology, pedagogy and audience engagement. The seminar format can take the form of one or all of the following: a reading group, activity development, activity revision and exploration of other science communication options. The seminar can be graduate student organized with guidance from PSC staff and the collaborating faculty member, which would not require museum staff presence at all the seminar meetings. This strategy has precedent as the seminar attendees, including STEM graduate students, organize some STEM seminars at the university. In this format, the leader(s) of the seminar organize the logistics of the class calendar and encourage attendees to sign-up to lead weekly presentations and discussions on a pre-selected topic. Thus, responsibility is allocated while maintaining a participatory (non-lecture) format.

Graduate students may wish to read research conducted on how people learn science, the longitudinal studies on science literacy and evaluation studies on museum exhibits and programs in order to inform their interactions with public audiences. Graduate students may be interested leading discussions on books like, *Creating Connections: Museums and the Public Understanding of Current Research*, *Don't Be Such A Scientist: Talking Substance in an Age of Style*, *Learning Science in Informal Environments: People, Places, and Pursuits* and *Communicating Science*. Additionally, students expressed wanting to know about other science communication avenues. The seminar would be a good opportunity to explore learning how to engage larger audiences, and practice responses when the public has ethical concerns about animal testing, genetically modified organisms and evolution. Students can practice writing science pieces for targeted age groups, plus learn about the format, software skills and technicalities involved with blogging, podcasting, and video production. Finally, the seminar would be an opportunity to openly converse about employment opportunities in science education, outreach and communication.

An academic benefit for the student would be receiving course credit towards their degree requirements. As part of the seminar, graduate students can be asked to do a public presentation of their work with PoP. A public presentation would disseminate the experiences in PoP to various STEM departments, and graduate students would obtain recognition of their work communicating science with the public. A presentation also extends the PoP brand to more student and professors, and shows science outreach as a serious and worthwhile endeavor. This option requires some operational changes.

Program Recommendations & Implementation

I recommend Option E and put forth Option C for the museum staff to ponder. These two options have many benefits for the museum and the graduate student scientists, and are the easiest to initiate. While Option D is interesting and has many benefits, the steps needed to see it to fruition are many. The museum would be dependent on the hiring of a staff person as a part-time instructor by a graduate department in addition to the approval of a new course by the University of Washington Registrar. The denial of beginning steps would prevent the museum from being able to proceed further.

Implementing Option C: Differentiated Pricing

Step 1: Publicize the price increase starting Winter 2013 through recognized avenues.

Step 2: Look for graduate students on the interest list who declined engaging in PoP because of the previous \$2,000 fee.

Step 3: Send an appeal for graduate students to apply to PoP in STEM departments that do not have a system in place to pay for the fee.

Step 4: Review applications, and select students from STEM graduate programs that have had low representation or who have not been represented in PoP previously. Since PoP professional development workshops sometimes have a theme, such as the current “Genetics” theme, ensure that the students’ research fit the theme well. For the Genetics theme I would look at applications from the following STEM departments that have research laboratories focused on genetics and human health:

- Genome Sciences
- Biology
- Neurobiology & Behavior Program
- Pathobiology
- Public Health Genetics
- Bioengineering
- Biochemistry
- Bioethics and Humanities
- Immunology
- Microbiology
- Pathology
- Pharmacology
- Rehabilitation Medicine
- Medicinal Chemistry
- Epidemiology

Implementing Option E: A University Course For Science Communication Fellows

Step 1: Contact an interested STEM graduate department at the University of Washington (e.g. College of the Environment, Oceanography) that will have a faculty member sponsor a seminar for the museum.

Step 2: Initiate the process of renaming an existing seminar section as the “Science Communication Seminar for Science Communication Fellows.” Renaming an existing seminar is simpler than creating a new course. The submission of a syllabus is not required. Complete a course change application form with the new seminar title, all other course information will be the same. Please see the “Course Change Instructions” (Office of the Registrar University of Washington, 2012a).

Step 3: If a new seminar section is needed, initiate the steps to request for the addition of a new

course. A new course offered for more than one quarter requires the submission of a syllabus in addition to the curriculum application. The sponsoring department may have copies of pre-filled forms. Again, a faculty member collaborator would be listed as the official instructor of the new seminar.

Step 4: Wait for approval by the curriculum review committee.

Step 5: Once the course is approved, Fellows may easily add the seminar to their schedules.

Step 6: Depending on the majority interests of the Fellows, the seminar can have a variety of themes. The theme can be: revisions on the activity used at the museum, prototyping a new activity, reading a science communication book, reading research conducted on science learning, exploring new science communication media, or discussing employment in science education, outreach and communication. PSC staff can help direct students to resources for these themes. If the seminar will focus on discussing literature, PSC staff can create a reading list, or pick a book for the Science Communication Fellows.

Step 7: Graduate student attendees elect who will be the leader(s) for the quarter and handle the logistics of the course such as email reminders, the course calendar, and scheduling weekly or bi-weekly discussion leaders.

Step 8: Together, fellows and the PSC staff can determine if the seminar will meet weekly or bi-weekly throughout the quarter. PSC staff can inform the attendees which dates during the quarter they can attend the hour-long seminar. The schedule of these meetings will be at the discretion of the students and PSC staff.

Step 9: Students can arrange when to present their work at the museum to their respective departments, and if they wish to partner with other Fellows to give joint presentations for multiple departments, in the style of a “Fellows Symposium.” Students may feel more comfortable giving joint presentations especially if they are the only individual in their department to participate in PoP. A symposium style event has the added value of showcasing the fact many scientists at the University of Washington regularly participate in science outreach.

Step 10: At the end of the quarter, the museum can email the sponsoring faculty member the Fellows who received credit, and those that did not. The faculty member will then submit the grades to the university.

Nonprofit Management Conclusion

Portal to the Public participation fees may be cost prohibitive to graduate students who do not have the personal funds, nor the financial support from their department or laboratory, but who wish to be involved in a structured science outreach program. Thus, the recommendation to initiate a differentiated pricing scheme whereby professional scientists pay \$3,000, and thus subsidize the enrollment of graduate students, has been outlined for the museum's consideration. Ten scientists will need to be recruited per cohort to pay for five graduate students to attend Portal to the Public workshops per cohort. An additional benefit to this recommendation is the potential increase in interest from many more STEM departments, consequently leading to more science fields represented at public events at the museum. Potential problems can include deciding which graduate students to accept into the program and if an increase in price for professional scientists is possible.

A more realistic recommendation addresses the graduate student need for community building, continued professional development opportunities and recognition of science outreach activities within the academic culture at the university. In my study some graduate students felt less compelled to continue in Portal to the Public because some of their friends stopped volunteering. In addition, time spent outside of a laboratory to do science outreach is not widely accepted in academic circles despite many scientists, and the National Science Foundation, acknowledging the need to communicate science more broadly. Many graduate students in Portal to the Public have been happy to meet and become friends with other scientists interested in public outreach. The formation of a "Science Communication Seminar for Science Communication Fellows" would construct a social and creative atmosphere, give time for fellows to share their experiences at the museum, enable a space for these individuals to critique and refine their activities and time to explore other communication strategies. Fellows, with guidance from the museum staff, can develop reading groups to cover books and research studies on science learning, pedagogy and communication. As part of the seminar, Fellows can give a symposium style presentation of their activities in Portal to the Public, therefore providing public recognition of their work, and extending the Portal to the Public brand to more STEM departments at the University of Washington.

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Appendix A: Arguments for Science Literacy & Challenges Scientists Face Communicating Science to Public Audiences

Arguments for Science Literacy	
Practical	People need an understanding of science to handle everyday life in a science – and technology – dominated society.
Democratic (Civic)	People need an understanding of science to relate to the many complex science-related issues that confront citizens of modern democracies (and to make informed policy choices).
Cultural	Science is part of our cultural heritage and has profoundly influenced our view of the world and [ourselves]...knowing something about the objects and phenomena in the world that surrounds us is a source of joy and fulfillment.
Economic (Professional)	A scientifically literate workforce is necessary for a sound and flourishing economy in most countries.

A list of the four arguments advocating for science literacy in communities and countries as written by Henriksen, E. K., & Froyland, M. (2000). The contribution of museums to scientific literacy: Views from audience and museum professionals. *Public Understanding of Science*, 9(4), 393-415.

Challenges Scientists Face Communicating Science to Public Audiences
A perception that the public would not be interested in current science
Communicating science to non-scientists requires over-simplification
Time pressures
Lack of incentives
Fear of negative perception and criticism by peers, or the “Sagan Effect”
Unfamiliarity with science outreach and communication opportunities in surrounding communities

Science researchers face multiple challenges preventing their participation in science outreach and communication. The most commonly cited challenges are a fear of negative perceptions and criticism, the lack of incentives, and time pressures. The list above references challenges written by Chris Paola in *Creating Connections*, and those in a study by Ecklund et al (Ecklund, et al., 2012; Paola, 2004).

Appendix B: Letter of Introduction to the Study Distributed to Potential Subjects

Dear Friend of the Pacific Science Center:

This is a follow-up to the email request sent by Dana Vukajlovich from the Pacific Science Center. You are being contacted because you participated in a professional development workshop and a science outreach activity as part of the Portal to the Public grant at the Pacific Science Center between the years 2007 and 2011. The Pacific Science Center is collaborating with me on a research study for my Master of Arts degree in Museology at the University of Washington. The focus of this study is to help us understand the efficacy of the program for graduate students. We would like to know if the program has affected your science teaching and communication skills, and the influence of the program on your professional and academic life years after your participation. This opportunity to gather information on your experiences with Portal to the Public will be valuable and will inform the development of the program for future scientists.

If you agree to join the study, you will be interviewed either in-person, Skype, or by telephone. All interviews will be digitally recorded, transcribed, and stored on a password-protected folder to safeguard the respondents' answers. Your name will not be included in the recorded interview. This step is to respect your privacy and to protect your identity should the transcription of the audio file be shared for research purposes. Please be assured that your responses will remain anonymous. Those at the Pacific Science Center will not be able to connect your name to your answers and opinions. Any quotes that will be used in my thesis paper will be quoted as from "a graduate student."

The topics to be addressed in the interview are:

- Purpose of the research study
- Your background
- Motivations & expectations for your participation with Portal to the Public
- Your outreach activities after participating with Portal to the Public
- Your professional plans
- Your thoughts on how the Pacific Science Center can better help the professional development of other scientists & graduate students

Please send me a quick "I am interested," and times when you are available to be interviewed to pmontano@_____, or call XXX-XXX-XXXX by **April 16, 2012**. The interviews will take place from April 17 to May 7, 2012. Your responses will be greatly appreciated, and will be very instructive as a means to improve existing programs.

Please contact me if you have questions or concerns about the study. I will be glad to clarify any points.

I look forward to speaking with you! Thank you again for your interest in helping the Pacific Science Center.

Sincerely,
 Patricia A. Montano
 University of Washington
 Candidate M.A. Museology
 Candidate Nonprofit Certificate Program, Evans School of
 Public Affairs

Appendix C: Interview Instrument

Academic Background

- 1) What year in graduate school did you participate in Portal to the Public? (For example, I was a 2nd year Ph.D. student.)
- 2) Tell me about the science you study and some activities you have done with the Pacific Science Center (such as professional development workshops, programs, etc...)

Motivations and expectations for your participation with Portal to the Public at the Pacific Science Center

- 3) How would you describe your motivations to attend the workshops and participate in the activities at the Pacific Science Center and Portal to the Public?
- 4) In thinking about your motivations, would you say your expectations were fulfilled? If not, why and in what ways?
- 5) How do you feel your experiences have impacted your science communication and teaching skills?
 - a) Career advancement or improvements in teaching skills could be motivations
 - b) Let the subject reflect on their frame of mind before and during the workshops.
 - 5B) Did your frame of mind about science communication change during the workshops?

Outreach activities after participating with Portal to the Public

- 6) After your initial participation in professional development workshops and programs at the Pacific Science Center, have you continued to be involved in science outreach programs with this museum, or with other organizations? If so, could you please state with what organization and please describe your experiences?
- 7) Have your experiences with the Pacific Science Center altered the way you approach communicating science to a broad audience? If so, please describe how?

(Such as in how you plan a presentation, or how you think about your audiences)

Professional plans for the future

- 8) How and to what extent have your experiences with the Pacific Science Center & Portal to the Public increased your awareness of other employment opportunities & volunteer opportunities to communicate science?
- 9) Did your experience with Portal to the Public influence your career choices, such as for job applications for post-doctoral study, faculty positions, or other?

If the individual is currently not a student:

 - Can you tell me about your current job?

If the person is a student:

 - What job would you most like to have in the future?
- 10) Have you considered making science communication and/or science outreach part of your career as a science professional? If so, or if not, could you please explain.
- 11) How has participating in professional development workshops and programs at the Pacific Science Center prepared you (or not prepared you) for a career that includes teaching science to non-scientists?

(Teaching science could mean in the academic sense of college classes, or in other ways such as industry or policy when speaking or writing about science to non-scientists.)

Thoughts on how the Pacific Science Center can better help the professional development of scientists & graduate students

- 12) Has your experience with the Pacific Science Center changed your view of professional development and your need for it?
- 13) Reflecting back on the training and support you received from staff at the Pacific Science Center, are there improvement or changes you would suggest?
- 14) Are there ways the Portal to the Public program could have been more helpful for graduate students?
- 15) What professional development opportunities would you like the Pacific Science Center to create, or address?

Additional thoughts and opinions

- 16) What other thoughts, suggestions or opinions would you like to share concerning Portal to the Public &/or the Pacific Science Center?

Appendix D: Tables & Figures

Eligible Subjects and Study Subject Sample by STEM Graduate Department/Program Conferring Degree

Portal to the Public Graduate Students Eligible to Participate in the Study	STEM Graduate Department/Program Conferring Degree												
	MCB	Astronomy	Chemistry	Oceanography	Bio-engineering	Electrical Engineering	Computer Science	Biology	CFR	ESS	Atmospheric Sciences	SAFS	Total
Count	10	3	2	5	1	2	1	1	3	10	4	1	43
%	23.3	7.0	4.7	11.6	2.3	4.7	2.3	2.3	7.0	23.3	9.3	2.3	100%
Study Subjects	3	1	0	3	0	0	0	0	1	2	0	1	11

MCB – Molecular and Cellular Biology Program, an interdisciplinary graduate program. Students work in laboratories affiliated with other STEM departments at the University of Washington, and earn a degree in MCB.

CFR – College of Forest Resources, now restructured and renamed the School of Environment and Forest Sciences in the College of the Environment.

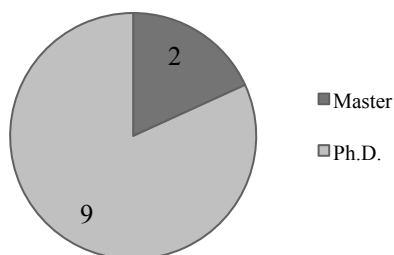
ESS – Earth and Space Sciences Department, part of the College of the Environment.

SAFS – School of Aquatic and Fisheries Sciences, part of the College of the Environment.

Table 1. Of the graduate students that participated with Portal to the Public, a total of 43 graduate students were deemed eligible for the study according to two criteria: students attended four professional development workshop series, created an activity and attended, at minimum, one public program with face-to-face interactions with museum visitors. Eleven of those students agreed to be part of the study.

STEM Study Subjects Described By Graduate Degree Sought and Year

Graduate Degree Sought



Year in Graduate School (Ph.D. or M.S.)			
Year 1	Year 2	Year 3	Year 4
2	5	3	1

Figure 1. Graduate students in the study primarily sought a doctorate (Ph.D.) as their highest degree. Students in Ph.D./M.S. programs were recoded as Ph.D. students since that was the highest degree pursued. A majority of the students in the study were in their second year of graduate school when they joined Portal to the Public. No fifth year, or final year Ph.D. students, participated in the study.

Pacific Science Center Science Communication Fellows

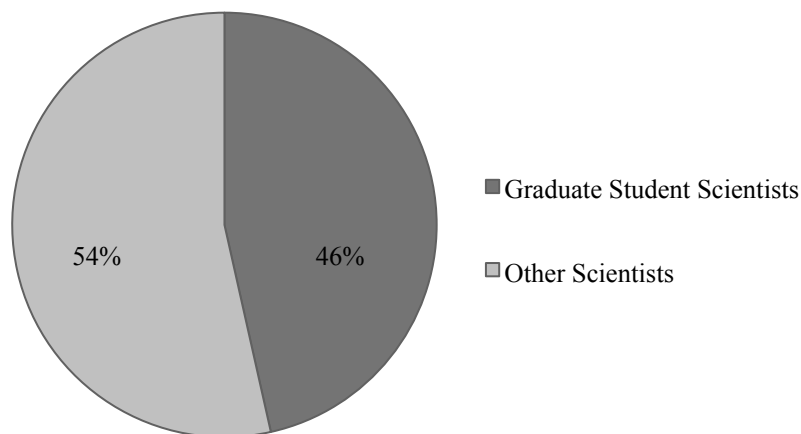


Figure 2. Scientists who participated in the professional development workshops and developed an activity can dedicate time to volunteer for three events per year at the Pacific Science Center and thus become “Science Communication Fellows.” Since 2008, slightly more than half of the scientists trained as Fellows are professional scientists (university faculty, researchers, etc...). 46% are STEM graduate students at the University of Washington. (A total of 114 individuals were recorded as Fellows as of May 2012. Some individuals in this total may no longer be active at the museum).

Table 2. Matrix of Study Subject Responses Part A

Scientist	Graduate Degree Sought	Year	Motivation (multiple responses)	Expectations Fulfilled (Y/N/Unclear)	Impact on communication and teaching skills (positive, negative, neutral, positive w/reservations)	Outreach Activities	Altered communicating science (Y/N)	Awareness of jobs and volunteer opportunities in science communication/science outreach (Y/N)
A	PhD/Master	2	- TA credit - Interest in science outreach	Unclear expectations. Surprised involved for years.	Positive	PSC & other organizations	Yes	Yes, both
B	PhD	2	- TA credit - Interest in science communication	Yes	Positive	Stopped volunteering	Yes	Yes, both
C	PhD/Master	2	- Interest in science communication. - Personally rewarding.	Yes with reservations. Workshop did not help with the type of science communication this individual was interested in.	Positive, but wanted deeper conversations with the public	PSC & other organizations	Yes	No, jobs. Yes, volunteering
D	PhD	3	- Laboratory credit	Yes, more than expected.	Positive, but skills did not translate into formal teaching environments	PSC & other organizations	Yes	Yes, both
E	PhD	2	- TA credit - Interest in science outreach. - Dissatisfied with graduate school.	Yes	Positive. Shaped career in science communication.	Other organizations	Yes	Yes, both
F	Master	1	- Advisor recommended. - Dissatisfied with graduate school. - Interest in science communication. - Fun.	Yes with reservations. Individual felt less motivated to volunteer without a partner.	Positive. Used tools as a TA.	PSC	Yes	No, both
G	PhD	3	- Initially not interested. - Volunteered with a friend.	Unclear expectations. Experience exceeded expectations.	Positive. Used tools as a TA. Inquiry in professional lectures ineffectual.	PSC	Yes	No, both
H	PhD	2	- Fun. - Likes science museums.	No	No Impact	PSC & other organizations	Yes	Yes, jobs. Yes, volunteer opportunities at PSC.
I	PhD	4	- Interest in science communication. - Interest science museums. - Fun.	Yes	Positive	Stopped volunteering at PSC	Yes	No, jobs. Yes, volunteer opportunities at PSC.
J	PhD	3	- Fun. - Personally rewarding.	Yes	Positive	PSC & other organizations	Yes	No, jobs. Yes, volunteer opportunities at PSC & other
K	Master	1	- Interest in science education.	Yes	Positive	PSC & other organizations	Yes	No, jobs. Yes, volunteer opportunities at PSC.

Scientist	Influenced career choices? (Y/N/)	Science communication/outreach in future career? (Y/N)	Improvements or changes	How PoP can help graduate students	Suggestions for professional development
A	—	Yes	Talk to different age groups: pre-teens & teens.	TA credit	Workshop on career opportunities in informal science education and science communication.
B	No	Yes	Did not like museum staff teaching style. Did not like workshop teamwork exercises.	no suggestions	—
C	No	Yes	More help from staff communicating technical knowledge to the public.	Opportunities for different types of science communication with the public. Different audiences. Different venues.	Opportunities for different types of science communication with the public. Different audiences. Different venues.
D	Yes	Yes	Diary to document experiences.	Class or academic credit.	Opportunities for different types of science communication with the public. Different audiences. Different venues. Voice preparation.
E	Yes	Yes	no suggestions	TA credit	—
F	No	No	Work with a partner	no suggestions	—
G	Yes	Yes	Observe scientists at the museum interacting with the public.	TA/RA credit	Workshop on career opportunities in informal science education and science communication.
H	No	Yes	Other volunteer opportunities at PSC.	no suggestions	—
I	Yes	Yes	More help from museum staff. Feedback. Time to revise activity. Time to create new activities.	no suggestions	Workshop delving deeper into subject of science learning, and why communicating science is difficult.
J	No	Yes	More feedback from museum staff. Time to create new activities.	more feedback from staff	Workshop addressing how engage larger audiences.
K	Yes	Yes	Work with a partner. Workshop geared towards this person's science better.	Workshop on career opportunities in informal science education and science communication.	Shorter workshops

Table 3. Matrix of Study Subject Responses Part B

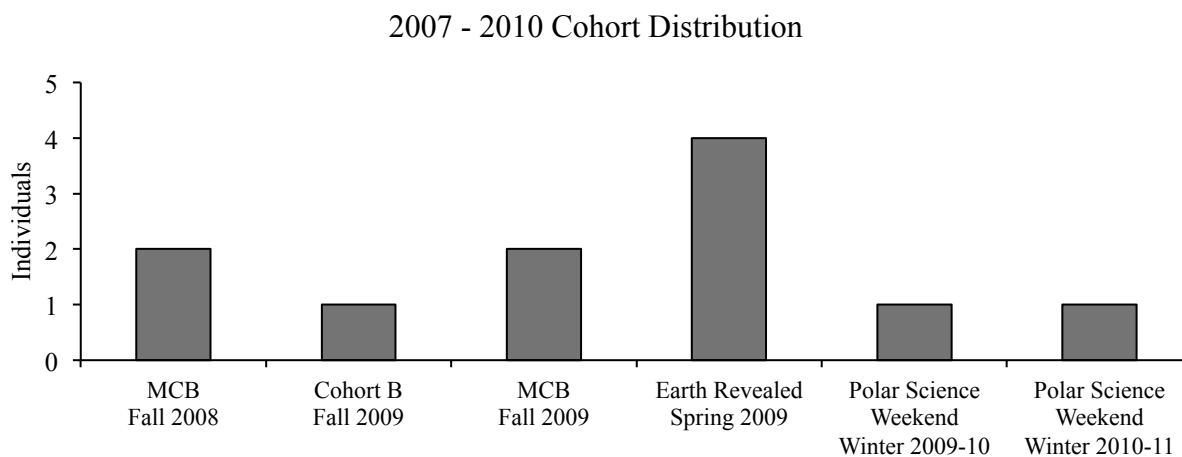
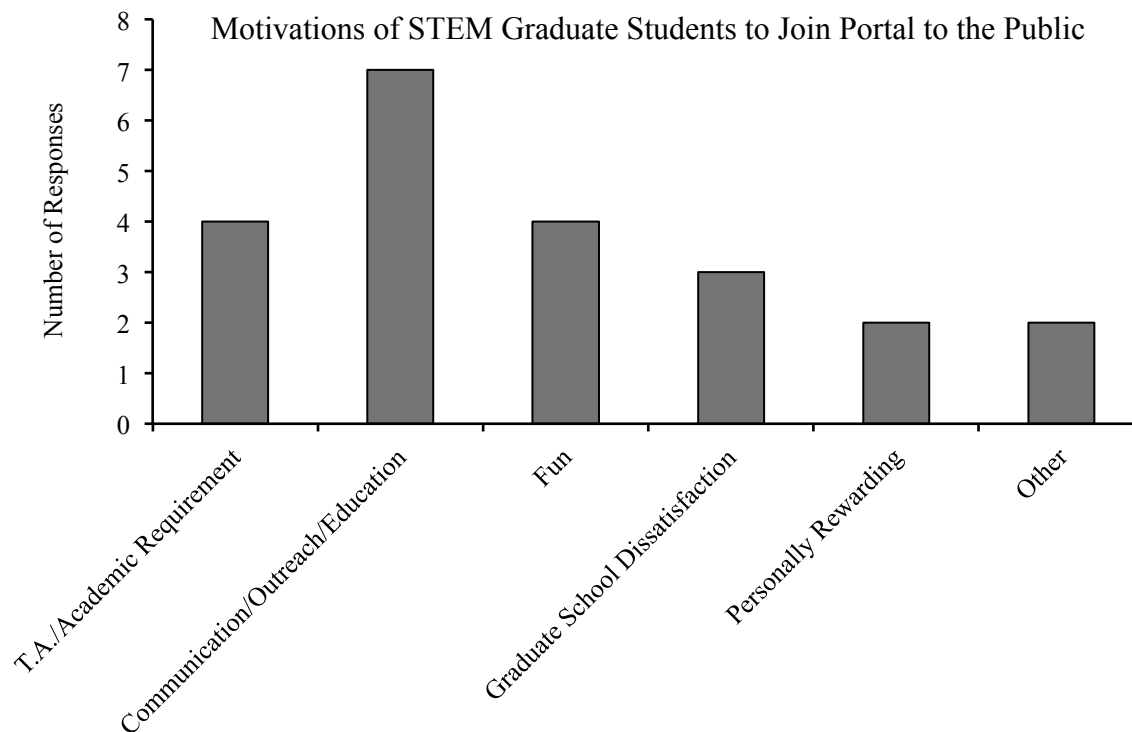


Figure 3. Most professional development workshops had a theme, or STEM concentration, which are here referred to as “cohorts.” MCB: Molecular and Cellular Biology Program Cohort. The students in the two MCB cohorts in 2008 and 2009 were almost exclusively from the molecular and cellular biology program at the University of Washington. Graduate students in the study spanned all six Portal to the Public professional development workshop cohorts supported by the first National Science Foundation grant cycle (2007-2010). The largest cohort, “Earth Revealed,” also had the majority of the individuals in the study.



T.A.: Teaching Assistantship

Figure 4. Individuals in the study had multiple motivations for participating with Portal to the Public. The “Other” category contains responses from two students, one of whom said their advisor recommended the program, and one student who said they joined the program because a friend wanted a partner for the program, but who was initially not interested in volunteering with the Pacific Science Center.

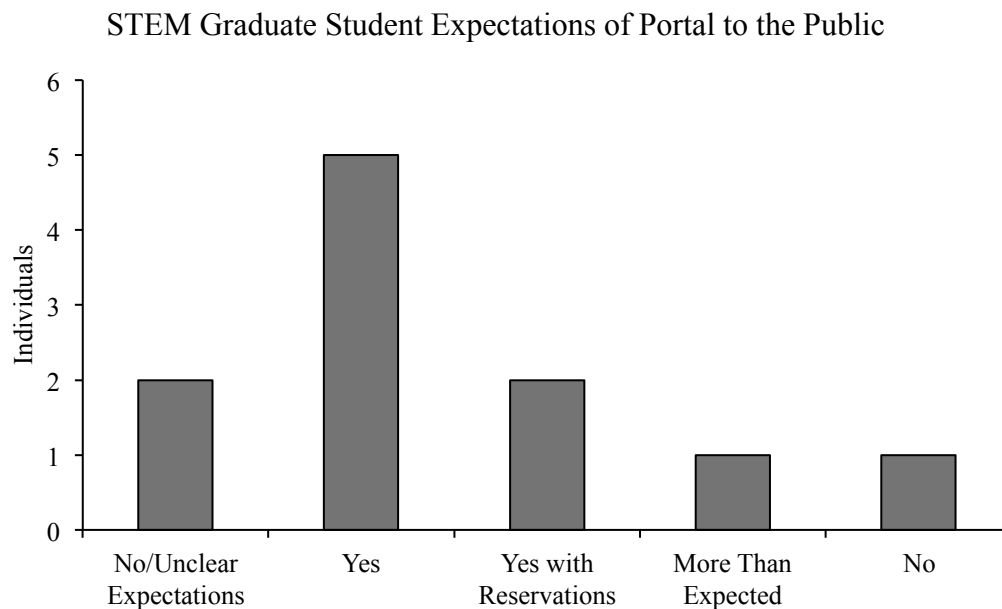


Figure 5. Graduate students were asked to self-evaluate whether or not the program fulfilled their expectations. A small number of individuals had unclear or no expectations of the program prior to starting the professional development workshops. Though individuals with no expectations may have responded having received more than expected (see results section), they were not counted as part of the “More Than Expected” category because of the incapability of the researcher to accurately assess their pre-workshop thoughts versus post-workshop thoughts. During the interviews individuals expressed multiple expectations, but their responses were coded as to have each individual counted once for the purposes of graphical analysis.

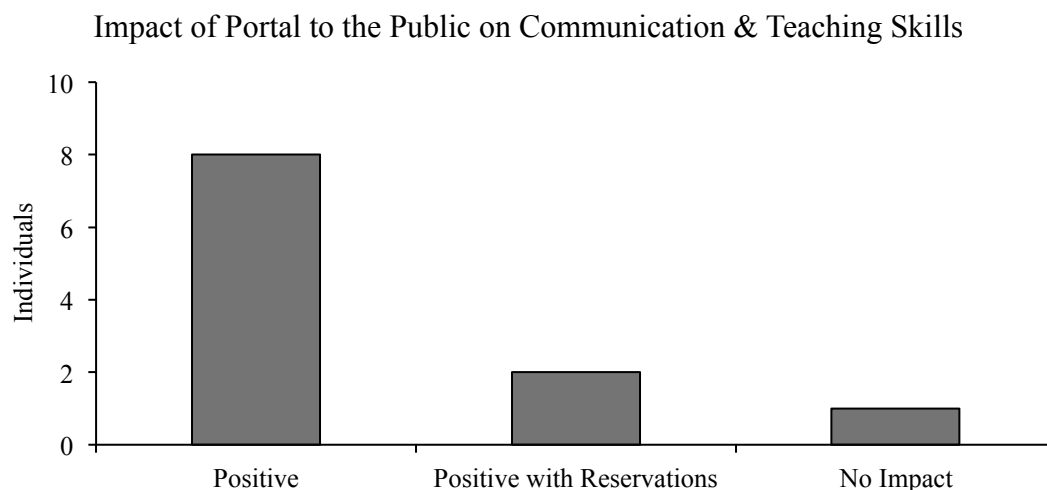
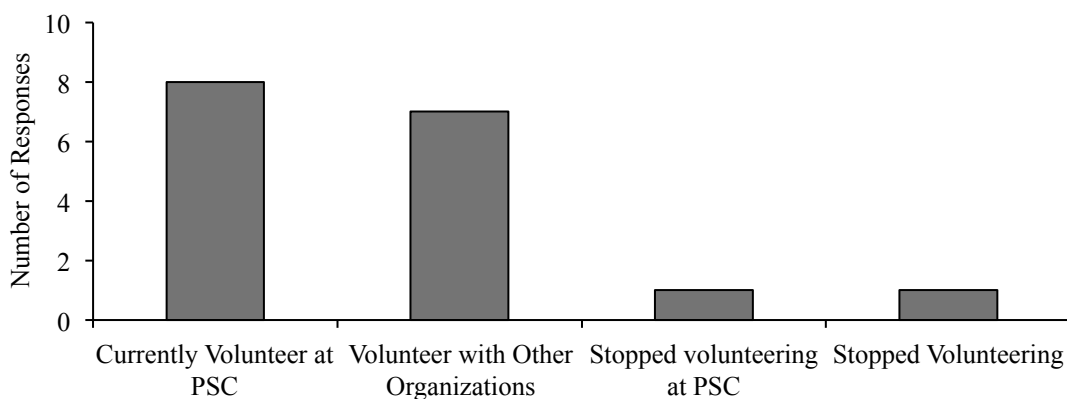


Figure 6. A total of ten individuals responded that Portal to the Public positively impacted their science communication and teaching skills, of which two added the skills learned were limited to the museum setting. Only one person responded that the program had no impact.

Outreach Activities After Initial Participation in Professional Development Workshops



PSC: Pacific Science Center

Figure 7. Individuals were asked to describe their outreach activities after finishing the professional development workshops series and outreach event associated with their cohort. Eight students continued to volunteer with Pacific Science Center. Many individuals elected to join other organizations and participate in more outreach activities. Because of work and school-related obligations, two individuals stopped volunteering in science outreach. The individual in the “Stopped Volunteering at PSC” column volunteered once for an event at another museum in Seattle, WA, but then ceased to volunteer thereafter.

Time STEM Graduate Students Volunteered at Pacific Science Center

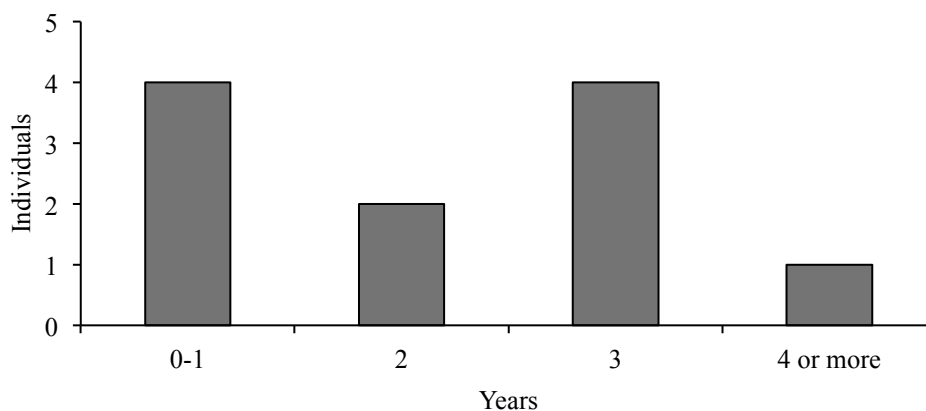


Figure 8. Seven of the eleven study subjects have volunteered with Pacific Science Center (PSC) for two or more years. Embedded in the illustration is that seven out of the eleven study subject have continued to volunteer after finishing the professional development workshops series and outreach event associated with their cohort, these individuals share some overlap with those that have volunteered for two or more years.

Awareness of Employment Opportunities
In Science Outreach & Communication

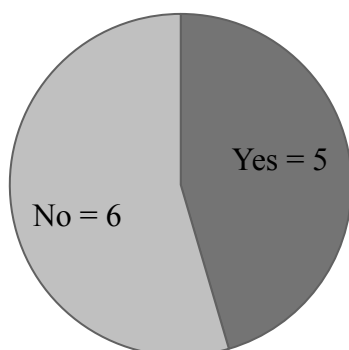


Figure 9. Five of the eleven individuals became aware of possible employment opportunities or careers in science outreach and communication because of their exposure to Portal to the Public and museum staff.

Awareness of Volunteer Opportunities
In Science Outreach & Communication

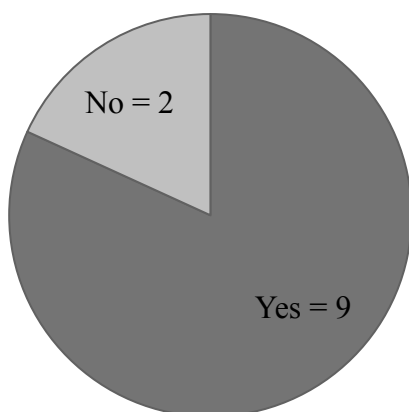


Figure 10. Nine of eleven individuals expressed learning more about volunteer opportunities in science outreach and communication because of their experiences with Portal to the Public. Four of nine learned of more opportunities only at Pacific Science Center and not with other organizations.

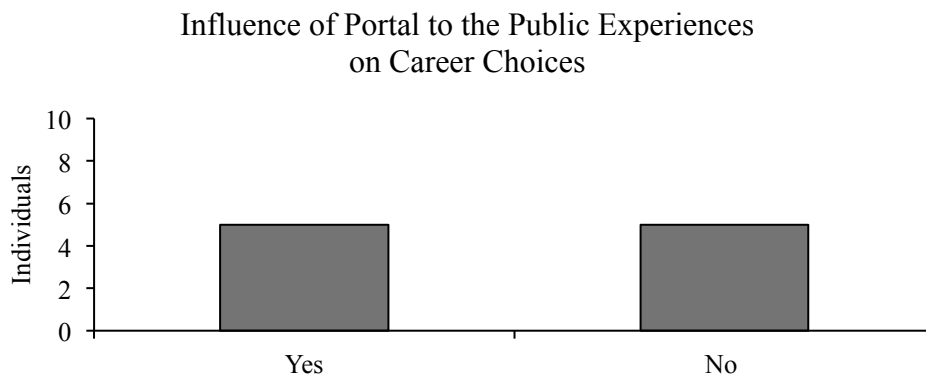


Figure 11. Participation with Portal to the Public had an equal effect on influencing and not influencing thoughts on future careers in science.

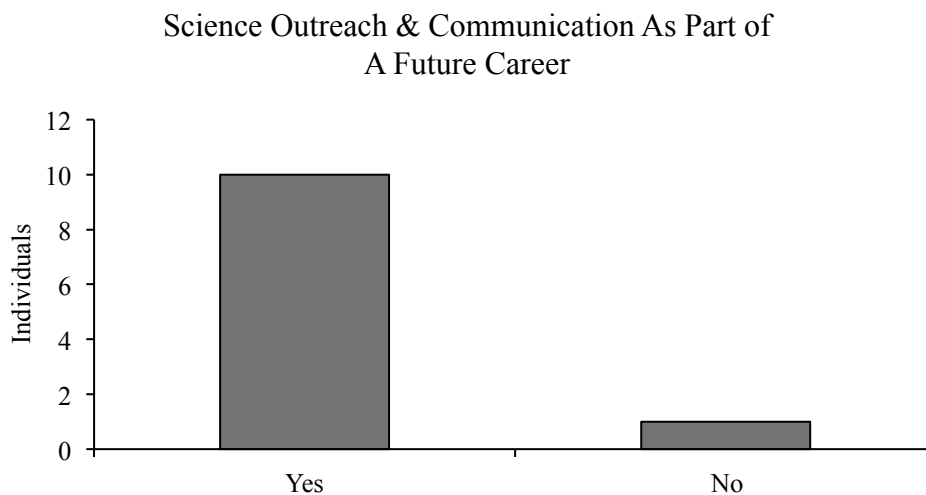


Figure 12. Ten graduate students wished to incorporate science outreach and science communication as part of a future job in science. Graduate students desired to become faculty members at a college or university, conduct research outside of academia, or pursue a career in science communication.

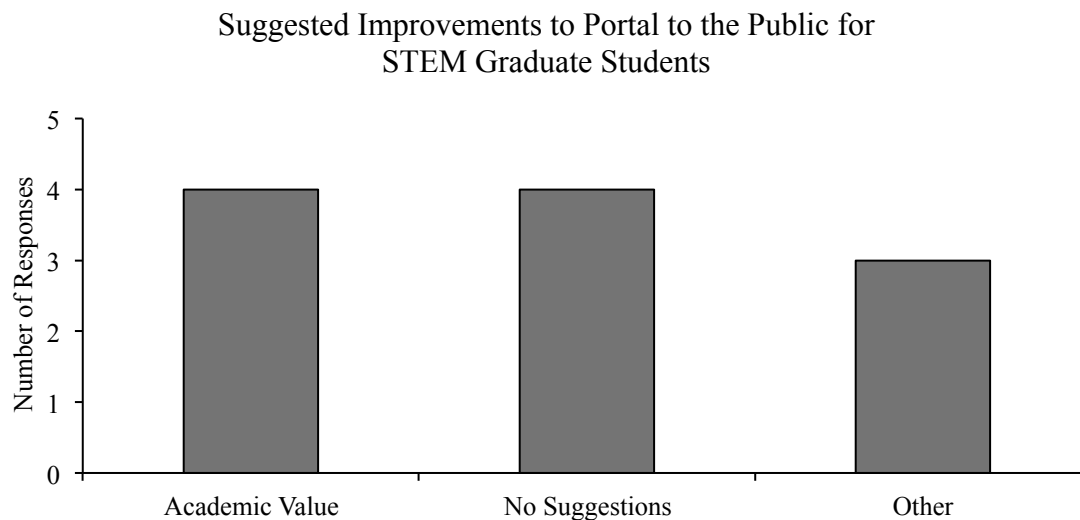


Figure 13. Four graduate students suggested an academic value (teaching assistantship, research assistantship, or course credit) be applied towards participation with Portal to the Public. Four had no suggestions. Three students suggested other types of improvements such as: more constructive criticism on the hands-on activities, a workshop informing students of careers in science outreach, and opportunities to volunteer with different outreach events the muse