AC 2009-1205: ENGAGING SCIENCE AND ENGINEERING GRADUATE STUDENTS WITH INFORMAL SCIENCE EDUCATION

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Having effective interactions with public audiences about science and engineering topics is challenging. Many training workshops, boot camps, and courses have tried to address this by training professional scientists and engineers using a variety of strategies; unfortunately, the literature on the effectiveness of these approaches is sparse. We present assessment and evaluation results from a course, “Informal Science Education for Scientists: A Practicum,” taught to graduate students in science and engineering-related disciplines in Spring 2008. This course provides a structured framework and experiential learning on informal science education for the graduate student participants during a semester-long experience. The iterative nature of designing an effective informal science education product and the importance of front-end, formative and summative evaluation are stressed throughout the course. The emphasis is placed on having students use a scientific approach in the evaluation of their product to determine if it was effective. Our results show positive outcomes related to changes in student perception of their communication skills, changes in student perceptions of audience, changes in student perception of their evaluation skills, and increased student understanding of the iterative nature of design processes.

Introduction

The past few years have seen calls to encourage and support scientists who leave the lab to explain science and their research to the public. Recent, growing research on the public understanding of science, science literacy, and science communication, are driving scientists and educators to articulate an increased need for people to be better informed about science[1,2]. At the core of this movement are nationwide surveys that tell us we are a scientifically illiterate public[2,3].

The goals that have been offered for promoting a scientifically literate society include benefits to both individuals and government[1,4]. As science and technology become the dominant engines for economic growth in the world, a better-educated citizen is able to increase his/her own status by being prepared for this new market; once a county’s citizens reach this point, of course, the country itself secures an enhanced place in the market. Especially in democracies, better-educated citizens can ethically decide on future scientific paths and technological uses[5]. In addition to the benefits to the public, scientists themselves benefit from having a better-informed population. Scientific funding depends on public understanding and support; indeed scientists have an obligation to report back to the taxpayers who fund their work[6,7]. Fundamental to all is the notion that science can help explain the beauty and grandeur in how our world works.

All this research and interest to counteract and fix the dearth of scientific knowledge in society has led to calls to make sure a more accurate picture of science reaches the public[2,8]. Efforts and initiatives to increase the public’s understanding of science, enhance science literacy, and/or improve public attitudes to science span the entire human lifespan, from elementary school to adult television viewing and informal education at zoos and museums. One avenue to improve the public understanding of science that has begun to blossom, again, is direct communication between scientists and the public. Who best to explain what they do, how their research matters, and the excitement of science than scientists and engineers? However, in general, scientists and engineers need training to learn how to talk to and engage non-specialists[9,10].

A few programs have been developed to provide science communication training to practicing scientists/engineers and scientists/engineers-in-training. However, it can be challenging to convince professional scientists and volunteers to embrace the idea that they need to develop a special skill set in order to be effective informal science educators. Evaluators associated with Try Science[11] reported that "scientists and engineers are somewhat resistant to the idea of traditional, formal volunteer training. Instead of developing a new expertise (i.e., informal science education pedagogy), they prefer to volunteer their strengths."[12] More success in finding openness to training has been found with scientists and engineers who are still in school at the undergraduate or graduate level. Several programs aimed at scientists and engineers-in-training have been successful in attracting both volunteer and paid participants.[13,14,15,16]

The Internships in Public Science Education (IPSE) Program run by the University of Wisconsin – Madison's Materials Research Science and Engineering Center (MRSEC) from 2002-2008 trained paid graduate and undergraduate student interns from diverse backgrounds, including science and engineering majors[17]. The interns designed hands-on, interactive activities, informal science education programs, and museum exhibits to explain cutting-edge nanotechnology concepts to K-12 and general audiences[14,15]. In addition to a substantial impact with the target audiences, interns in the program reported significant gains in their own professional development. "The interns also reported gains in skills related to public science education, including developing age-appropriate materials, creating a demonstration, communicating science topics to non-technical audiences, working effectively in teams, and interacting with K–12 students … Of these skills, the interns indicated that their greatest improvements were in the areas of communicating science topics to nontechnical audiences and interacting with K–12 students." [15] Several IPSE program participants also reported a shift in their career paths to science education or public understanding of science as a result of their experience with this training program[15].

In 2007, the US House of Representatives introduced a bill (HR1453 or The Scientific Communications Act of 2007) requesting the National Science Foundation to offer grants specifically for science graduate training programs to "develop communications skills that will enable them to effectively explain technical topics to nonscientific audiences," specifically policymakers and business leaders[18]. Warren, Weiss, Wolfe, Friedlander, and Lewenstein sum the message up by writing: "[a] cultural shift is under way, reflecting the higher stakes of research, and an increased recognition by scientists, stakeholders, and policymakers that (i) scientists need to get their message out, (ii) scientists need training to learn how to do so, and (iii) training should begin at the graduate level"[19] . In a recent editorial in *Science*, Alan Leshner, the chief executive officer of the American Association for the Advancement of Science (AAAS), has echoed this call[20]. By offering training at the graduate level, one could conceivably reach all future scientists, and that effect would trickle up as more and more communications-trained individuals filled the field.

Course Description

The results reported below are based on a 15-week graduate level course created in 2003 entitled "Informal Science Education for Scientists: A Practicum"[21] taught at the University of Wisconsin-Madison in affiliation with the Delta program in Teaching, Research and Learning, a part of the Center for the Integration of Research, Teaching, and Learning [22]. Initially developed through a joint effort by an atmospheric scientist and a journalism professor, the course seeks to familiarize science graduate students with the concepts and processes needed to communicate science successfully with a variety of audiences. Beyond providing these basic tools, the course "encourages participants to see these tools as grounded in an ongoing process of inquiry that can be constructed much like the research they conduct in their own disciplines"[23]. In this class, students develop more than a passing familiarity with informal education processes by designing and carrying to fruition a specific outreach project.

This course is part of the Delta program in Teaching, Research and Learning[24]. The three foundational concepts of Delta are "teaching-as-research," "learning community," and "learning-through-diversity." These three pillars are incorporated into each Delta course and program. This paper focuses on the incorporation of the Teaching-as-Research philosophy into this course on Informal Science Education. Teaching-as-Research involves the deliberate, systematic, and reflective use of research methods to develop and implement practices that advance the learning experiences and outcomes of the target audience. One way this was incorporated into the course was to have students use an iterative design approach to develop and implement an outreach activity.

Although the course has evolved over the past six years, it has always been co-taught by a social scientist/humanist and a scientist/engineer, and the basic goal of applying research skills to understanding communication challenges has been maintained throughout. A main focus of the course in the spring of 2008, co-taught by faculty members from journalism and engineering, involved an emphasis on three aspects: the evaluation of instruction and experiences; the iterative nature of the design process; and understanding the audience and the diversity of backgrounds that it brings.

Designing an informal science education opportunity requires an understanding of audience. And determining the effectiveness of a message once it is shared requires an understanding of audience impact. In both cases, evaluation research is a critical part of an informal educator's tool kit. The course introduces participants to evaluation research techniques and encourages their use of these strategies through an iterative design process built into the course itself. Among the specific learning tools employed in service to this skill are formative and summative evaluation components of an informal education product. Through working in groups, students design and implement an informal science education project, an interactive tabletop exhibit. This interactive exhibit is implemented in an annual campus wide public science day, Science Expeditions.

For the interactive culminating project, the 2008 students focused on formative and summative evaluation of the idea and design of their interactive table-top exhibit, or informal education product. Students had two separate opportunities to redesign and improve their informal education product based on their own data collection, so the iterative link between evaluation and redesign was embedded in the structure of the course. The opportunities for product redesign were built into the course so that students could experience first-hand the challenge of trying to explain a topic to nonscientists and then collecting data to understand what their audience did indeed learn. For most students, this was the first time they had to interact with a large group of lay persons, or "the public." In order to scaffold the students, a dry-run experience was developed so the students could explain their topic to other classmates. It was thought this first experience, in a safe environment, would allow the students to see their most glaring omissions or difficult hurdles in explanations, as well as what explanatory techniques were successful. Following this experience, the students displayed their informal education products at a campus-wide science day event, Science Expeditions. Following that experience, the students packed up their informal education product s and transported them to the Museum of Science & Industry (MSI) in Chicago for a chance to interact with a more diverse crowd than the one offered at UW-Madison. This was the first time the course asked students to display their informal education product s in two venues.

The course instructors demonstrate the teaching-as-research approach to instruction by collecting and analyzing student feedback throughout the course. Through this analysis, we are able to show that by emphasizing an understanding of the audience, the iterative nature of design and the need for evaluation, we see a change in student outcomes. We also see gains in self perceptions of students' communication and evaluation skills and an increased understanding of both the audience and the iterative nature of designing an informal education product.

Results

In the spring of 2008, 14 STEM graduate students (5 males, 9 females) from the University of Wisconsin-Madison were enrolled in the Informal Science Education course. The various STEM disciplines represented in the course included six life science students, two physical science students, two engineering students, two atmospheric science students, one social science student, and one astronomy student. Although students received credit for their participation in the course, the data used in this paper are based on both course assignments and additional research-related activities. All participation in the research portion was voluntary and conducted with Institutional Review Board approval.

One of the most important skills students need to develop during their graduate career is the ability to communicate their work to a wide array of audiences. That ability enables them to speak effectively about their research with scientific peers, as well as to tell an audience in an informal education setting about the same, exciting research. As part of assessing learning gains, three main types of data were collected in this study: self perception of explanatory skills, gathered at different time points throughout the course; pre-post course attitudes about the importance of informal communication and one's skills in that arena; and open-ended questions about the nature of evaluation research.

Our results show positive outcomes related to changes in student perception of their communication skills, changes in student perceptions of audience, and changes in student perception of their evaluation skills. Students were asked at four different points in time to self report their confidence levels in terms of their ability to explain the topic and in the ability of their informal education product's design to effectively communicate the topic. Responses were coded on a Likert scale of 1-5 ranging from "No Confidence" to "Very High Confidence." Students completed surveys four times throughout the course: at the beginning of the class, right after the dry run, and following both Science Expeditions and their museum experience at MSI.

The largest gain in students' self perceptions of skills, not surprisingly, occurred between the start of the course and after demonstrating their exhibit at the MSI. The experience of employing an iterative design approach to practicing and refining their messages moved the students one full scale point, from Medium/Good Confidence to Good/High Confidence, in perceptions of their own ability and their informal education product 's ability to communicate to informal education audiences; this was a statistically significant gain in student confidence. They also moved almost a full point to a higher level of confidence in their ability to use the knowledge and skills they gained from the class (See Table 1.). Almost as large a gain, and still statistically significant, were increases in confidence between entering the course and the intermediate time point after participation in Science Expeditions. It appears there was little need to practice a third time for significant gains in student confidence in their own ability and their informal education product's design to communicate to informal education audiences. There was no gain in confidence in students' ability to communicate their topic to audiences between the time they entered the course and the first dry run of their informal education project.

We see meaningful and significant jumps in student's self-reported skills through the Likert questions given before and after the course (Table 2). Substantial gains were also seen in students using and understanding evaluation techniques to determine effectiveness of communication. Students moved, on average over two points, from feeling Slightly Informed/Skillful to feeling Fairly and Very Informed/Skillful in using evaluation strategies to determine the effectiveness of science outreach. There was a one point gain in students' perception that they are better informed in explaining a topic to a lay audience.

Table 1 The pre- and post-test means, the difference and significance for three questions on a course survey administered in the Spring 2008. The informal education product was referred to as the "booth" in the survey. The Likert scale indicated confidence level was: 1=No; 2=Low; 3=Medium; 4=Good; 5=High

	Mean course beginning	**Mean final exhibition**	**Difference**	**Sig (paired samples t-test)**
How confident do you feel in your ability to communicate your booth topic to the Science Expeditions/MSI audience?	3.54	4.62	1.08	.000 *
How confident do you feel that your booth's design will effectively communicate the topic to the Science Expeditions/MSI audience?	3.46	4.46	1.0	.000 *
How confident do you feel that you are using the knowledge/skills you have gained in this class?	3.62	4.38	0.76	.012 *

* sig. <.002 paired samples t-test

Table 2 The pre- and post-test means for items on the course survey administered in the Spring 2008. The Likert scale was 1=Not at all informed/skillful; 2=Slightly informed/skillful; 3=Somewhat informed/skillful; 4=Fairly informed/skillful; 5=Very informed/skillful. Significant changes have an asterisk.

How INFORMED do you consider yourself about:	**Mean Pre**	**Mean Post**	**Change**
Evaluation as a tool to determine the effectiveness of science outreach activities	2.21	4.64 *	+2.43
How SKILLFUL do you consider yourself about:	**Mean Pre**	**Mean Post**	**Change**
Clearly explaining your research verbally to a public audience that has little or no knowledge about your field	2.71	3.93 *	+1.21
Using evaluation strategies to determine the effectiveness of your science outreach activities	1.79	3.93 *	+2.14
To what extent do you AGREE or DISAGREE with the following statements:	**Mean Pre**	**Mean Post**	**Change**
I am qualified to educate the public about science through informal education strategies.	3.29	4.21 *	+0.93

* sig. <.002 paired samples t-test

Students enrolled in this class represent a self selected population who already recognize the importance of science communication to non-scientists. As such, between the start and end of the course there was very little change in students' commitment to educating the public about science. This commitment is important to improving the public understanding of science and scientific thinking; however, achieving this objective also requires training. This course was designed to contribute to achieving this objective by training graduate students to communicate and interact with the public. There was a significant gain in students' perceptions of their qualifications to educate the public about science through informal education strategies (Table 2).

A final piece of data comes from an open-ended question posed to the students at the end of the course: What process would they use to design an informal education product in the future. Based on the course goals and content, we felt students should discuss both using evaluation methods to fine tune their product's goals and message as well as demonstrate an understanding of the iterative nature of this type of design (i.e. trying something, collecting data, revising based on that data, and then repeating this). All 14 students included a discussion of evaluation in their responses, and 13 students discussed the importance of the iterative nature of evaluation.

Discussion

Effective science communication to the public requires messages with clear objectives. This requires careful thinking about personal objectives, about target audiences, and about defining the message one wants to transmit. An appropriate assessment strategy is needed to determine if one has accomplished one's goals. A group at the University of Wisconsin-Madison has developed a course to train graduate students in explaining their research to the public, with an emphasis on the need for developing effective evaluation strategies. The course challenges students to create and implement an interactive science activity appropriate for a general public audience. Throughout the semester, groups generate documents reflecting various design and implementation stages. They select the focus of their informal education product and then move through design and production stages, culminating in an interactive, table-top activity. Students test their prototype as an exploration station at the UW-Madison Science Expeditions, which attracts thousands of area residents. In the spring 2008 version of the course discussed here, evaluation conducted at Science Expedition led to yet another iteration of the informal education product, which was then exhibited at the Museum of Science and Industry in Chicago.

Applying research skills to understanding communication challenges is an important component of the course. Evaluations throughout the course demonstrated the success of using an iterative design approach to develop a hands-on exhibit or informal education product. Graduate students leave the course feeling more skilled and confident at communicating science to the public. They also appreciate the importance of continued assessment and adjustment of their outreach activities.

Our most immediate future plan is to compare these Spring 2008 data with data from previous incarnations of the course to determine if the added emphasis on evaluation and on the iterative nature of design made a significant enough impact to warrant a permanent place in the course structure. In other future work, we will continue to evaluate the outcomes of annual offerings of the course; the addition of data from future student participants over time will permit more nuanced tests of the link between course structure and learning.

Conclusion

We have described a semester-long course for science and engineering graduate students on informal science education which stressed the iterative nature of designing an effective informal science education product and the importance of front-end, formative and summative evaluation. Three types of data were collected in this study: self perception of explanatory skills, gathered at different time points throughout the course; pre-post course attitudes about the importance of informal communication and one's skills in that arena; and open-ended questions about the nature of evaluation research. The students' experience of employing an iterative design approach to practicing and refining their messages produced substantial increases in how informed and skillful they felt about using evaluation strategies to determine the effectiveness of their informal science education project. We also believe that our results show that the students internalized the need for iteration and evaluation in the design of an effective informal education product. Positive outcomes related to changes in student perception of their communication skills and changes in student perceptions of audience were also demonstrated.

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