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Internships in Public Science Education: A model for informal science education

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Abstract

The NSF-funded Internships in Public Science Education (IPSE) program at the University of Wisconsin-Madison (UW) provides a unique opportunity for undergraduate and graduate students with diverse academic backgrounds to experience learning and teaching science - specifically in the field of nanotechnology - to the general public and middle-school students. The program is a collaboration with Discovery World Museum of Milwaukee, Wisconsin, which provides expertise in public science education, access to local science teachers, and opportunities to test materials with a live audience. Since the program began nearly three years ago, UW IPSE interns have created a number of classroom activities ranging from understanding the scale of a nanometer, to experimenting with liquid crystal sensors, to critically examining the societal implications of nanotechnology. The program focuses on both the development of activity modules and the professional development of the interns. During activity development, intern teams learn about nanotechnology, gather background information, brainstorm ideas, present and receive feedback on their ideas, conduct experiments, build hands-on models, and create instructional materials to explain nanotechnology and related science concepts. During professional development, interns learn about creating classroom activities, techniques for presenting to non-technical audiences, and strategies for assessing their materials; and work on their skills in teamwork, project design, leadership, and science communication. In addition to visiting middle-school classrooms, interns participate in on- and off-campus informal science education events where they present to wider audiences ranging from science teachers, to members of the adult lay public, to groups of middle-school-age children. In this paper, we discuss the development, implementation, and assessment of the UW-Madison IPSE program.

Introduction

In the fall of 2001, the University of Wisconsin-Madison (UW) Internships in Public Science Education (IPSE) program began as a way to connect audiences of all ages to world-class science expertise and cutting-edge research. Graduate and undergraduate interns design hands-

on, interactive activities that use basic science concepts to explain cutting-edge nanotechnology. The UW IPSE program is a National Science Foundation (NSF)-funded collaboration between the UW Materials Research Science and Engineering Center (MRSEC) on Nanostructured Materials and Interfaces and The James Lovell Museum of Science, Technology, and Economics in Milwaukee, also known as Discovery World (DW), the largest science center in Wisconsin.

UW IPSE's collaboration between a research university and a science center is an innovative program that draws on the strengths of each partner to bring cutting-edge science to the public. In the process, the UW IPSE interns receive technical training and engage in an iterative project development process as they gain experience in communicating science, and students and the general public gain a better understanding of and appreciation for nanoscale science, technology, and engineering.

The UW MRSEC on Nanostructured Materials and Interfaces comprises three interdisciplinary research groups (IRGs) in the areas of materials integration on silicon, high temperature superconductor applications, and biological applications of nanostructured materials. UW MRSEC has made a major commitment to nanoscience and nanotechnology education and outreach and has developed a number of tabletop demonstrations relating to nanotechnology and advanced materials in addition to numerous educational products. UW MRSEC provides a fertile technical and educational training ground for the UW IPSE program.

While UW MRSEC offers the UW IPSE interns technical training and educational materials, DW helps the interns gain access to the public, including students and teachers. While at the museum, DW patrons can participate in various labs and activities, tour the exhibit floors, and see live theatrical science shows. Through its regular interaction with teachers and school districts, DW has developed a network of teacher contacts that became an important resource for UW IPSE outreach efforts. DW contributes other resources to the UW IPSE program as well, including expertise in graphics design and formal and informal public science education.

Program Structure and Intern Training

The UW IPSE program was structured around two primary goals—1) to provide both technical and professional training for the interns; and 2) to develop hand-on activities and instructional materials related to nanotechnology for middle-school students and the general public. We learned from the experiences of the program's first year and from intern feedback that critical components of the program include clearly defined goals and expectations, structure, coordination, and communication.

Graduate and undergraduate interns were recruited from a variety of disciplines at Madison and Milwaukee-area colleges, although most participants have been UW students. The UW IPSE interns have come from a wide range of academic backgrounds, including chemical, mechanical, and biomedical engineering, biochemistry, chemistry, biology, food science, toxicology, experimental neurobiology, secondary education, computer science, math, history of science, psychology, journalism, and life sciences communication. The diversity of academic and science education training of the interns proved to be a strength for finding novel ways to

demonstrate science and engineering concepts and for encouraging the interns to learn from each other.

Each intern was hired for an academic year and expected to commit an average of 10 hours per week to the program. At the beginning of the first semester, interns were divided into teams that were devoted to creating activities and materials to help the public learn more about various aspects of nanotechnology. The composition of each two-member team was determined by the interns' preferences for offered projects and by the interns' backgrounds. Since interns possessed a gamut of science experiences, we did not try to match specific projects with pre-existing intern skill sets, but rather encouraged the interns to be open to a nanotechnology topic outside their area of specialization. Each team was assigned a mentor and an expert content consultant. These expert resources ranged from campus faculty, to graduate students, to industry contacts. For example, one of the recent team projects involved a close collaboration with a paper manufacturing company.

The first half of the year focused on "research and development," where interns learned background information about their topic, brainstormed ideas for instructional and interactive demonstrations, received technical and communication training, and developed activities and demonstrations. Examples of professional training activities include learning about classroom and audience management; practicing presentation and communication skills; performing nanoscale experiments from the MRSEC web-based laboratory manual;[1] learning how to give previously developed MRSEC demonstrations; and receiving feedback on intern-developed activities from other interns, educators, museum staff, and UW MRSEC personnel.

The second semester focused on "implementation," where interns were expected to lead their team activity with public or pre-college audiences several times throughout the semester. Weekly meetings focused on discussing intern outreach experiences and preparing for upcoming events. Interns were also given a leadership task – a major event that they were responsible for organizing. Finally, interns wrote a short, informative article for a general audience about their nanotechnology topic area.

Intern training and professional development centered on goals related to four major skill areas: working effectively in teams, mastering technical content in an area of nanoscale science and engineering, communicating science effectively, and assuming leadership roles. During their internship, the UW IPSE participants cultivated this range of valuable skills while learning new science concepts, developing and presenting their instructional activities, and assessing the effectiveness of their materials and delivery methods and styles.

Efforts to improve teamwork skills included regular team meetings, feedback exchanges about their activities, a group project, and a team-building adventure workshop. The goal was to impress upon the interns that they could rely on each other and the staff for assistance and guidance, and that the success of their project relied heavily on working closely and well with their teammate. All the presentations connected to the in-classroom instructional activity – including initial brainstorming, development, and the final activity – were done in teams.

The UW IPSE interns, program leader, and program coordinator held weekly meetings throughout the year. The main goal of the team meetings was to increase communication among interns and staff by sharing concerns, ideas, and news; brainstorming; and participating in training activities, such as evaluating the interactive and educational strengths and weaknesses of each team activity.

As part of their technical training, the interns gained valuable experience in cutting-edge science and technology through using MRSEC educational materials and interacting with MRSEC personnel. Many of the professional development meetings included a technical portion, during which interns learned about advanced and nanoscale materials and conducted basic lab experiments. In addition, when learning about their chosen nanotechnology topic, developing their instructional activities, and writing an article on their team topic for a lay audience, interns researched related secondary and primary scientific literature.

The interns also gained valuable experience and training in cutting-edge science and technology by working in interdisciplinary teams and interacting with their expert content consultants. Interacting with students from other disciplines allowed interns to learn from each another, and visiting labs and/or companies related to their project exposed the interns to current research in nanotechnology. For example, one of the teams learned to make a temperature-responsive liquid crystal from a MRSEC scientist doing cutting-edge research on liquid crystal sensors.

Learning to communicate scientific knowledge to a lay audience was an important part of intern professional development. By presenting MRSEC-created materials at DW and on the UW campus, interns learned the importance of assessing their audience's level of knowledge and experience and adjusting their presentation accordingly. This gave interns ample opportunity to work on their communication skills and interact with different audiences. Teacher training opportunities, such as a teacher workshop at the Wisconsin Society of Science Teachers (WSST) annual conference, provided interns with additional venues to hone their science communication skills. Finally, writing a general science article challenged the interns to summarize aspects of what they had learned about their team topic in an accessible, interesting written document.

The interns also learned about classroom management skills through a workshop held in conjunction with DW. They were introduced to effective methods of classroom management and essential skills for successful in-classroom presentations.

The fourth goal of building leadership and organizational skills was achieved in part by requiring each team of interns to organize a significant outreach or teacher training event during the second semester. Interns also made contacts with companies and other consultants to secure information and materials for their team activities, and developed networks with various groups of individuals, including teachers at Educators Night Out and the WSST conference. Finally, each team member was assigned a role of being in charge of either "communications" or "materials/supplies" for their project.

Assessment of the Program

The UW IPSE program included several assessment components that evaluated the performance of the interns, the materials they created, and the program as whole.[2] Some of this was done in paper survey form (initial, mid-year, and year-end surveys) or on the web (monthly intern feedback). In addition, one-on-one meetings between the program leader and each intern were conducted once a semester to assess the overall progress of each intern. Interns also received continual support and assessment from their project mentor and from their peers, the latter in the form of written or verbal feedback during group presentations. Overall, there was a strong coordinated effort within the program leadership both at UW and DW to support and guide each intern.

The formal evaluation of the UW IPSE program comprises two key components: assessment of the interns' expectations and experiences and assessment of the pre-college students', educators', and museum visitors' experiences with the interns and the materials they presented. While in the program, interns had opportunities to increase their technical knowledge of nanotechnology and to practice their science communication, teamwork, and leadership skills. Specifically at issue was how their communication skills, their knowledge of science and technology, and their comfort level in speaking to the public changed as a result of their internship. The impact of the program on the interns was formally evaluated through pre-, mid- and post-year attitudinal surveys, monthly progress surveys, one-on-one meetings, and videotape performance assessments.

Among other things, the attitudinal surveys investigated perceived gains in knowledge about nanotechnology, science communication skills, and comfort levels with speaking to the public about science and technology. For example, interns were asked to rate their knowledge of the following topics before and after participating in UW IPSE: general science and technology, advanced materials, nanotechnology, their team activity topic, the mission and methodology of science museums, and public science education. Intern surveys show a significant knowledge increase in all of these areas upon completion of the program. The attitudinal surveys also provided feedback regarding the structure and management of the program.

In addition to the pre-, mid-, and post-surveys, interns also participated in formative assessment by completing monthly web-based progress surveys. UW IPSE staff used the surveys to monitor intern satisfaction and progress and to gauge the need for adjustments throughout the program. Interns reported on the month's activities, their goals for the upcoming month, their satisfaction with their team and with the UW IPSE staff, and their perceived progress in various skills, such as creating a demonstration and their ability to work effectively in a team.

In order to understand how the interns and their materials program impacted their audience, feedback was solicited from educators and youth organization leaders (such as the Girl Scouts). The survey assessed their satisfaction with the presentation and interest in future visits from UW IPSE interns. Based on the reactions of educator and public audiences, it became clear that there is interest in nanoscale research and its applications in both museum and classroom settings. Some challenges were identified and addressed as a result of this feedback. For example, audiences wanted a decrease in the volume of information presented, a clearer rationale for the need to understand nanoscale science and technology in terms of applications in everyday life, and more effective means for understanding the concept of nanoscale. This need propelled the

group activity "What is nano?" which took place during the second year of the program and explored a number of ideas for conveying the scale of nanometer to a range of audiences.

Sample Instructional Materials created by UW IPSE Interns

The activities created by the UW IPSE interns can be categorized into three general areas: "What is nano?" nanoscale activities, societal implications of nanotechnology, and nanotechnology applications. Below are examples of activities from each category. These and other activities are available on the IPSE website.[3]

Nanoscale: How small is a carbon nanotube?
One "nano" activity compares the diameter of a human hair to the diameter of a carbon nanotube. The activity helps a middle-school audience develop an appreciation for the scale of the nanometer, specifically as it relates to a carbon nanotube. After discussing the definition of "nano" and other metric prefixes and measuring various objects in the room, participants construct a circle of rope 4 meters in diameter. The circle represents the scale of a single hair (~40 μm) if magnified 100,000 times. Students then choose the object that they think would represent the relative size of a nanotube if it were also magnified 100,000 times. Through the activity, students learn about the scale of nanotechnology while reviewing the metric system, ratios, and conversions.

Nanotechnology and Society: NanoCommunities
The goals for this activity included introducing the basic concepts of nanotechnology to middle-school students and encouraging them to think critically about the integration of nanotechnology, and technology more broadly, into society. The interns created a classroom activity that illustrates the connections between technology and communities within society. In the activity, students explore how different communities use technologies differently. After a brief introduction to nanotechnology and to community usages of current and past technology, students design an application of a nanotechnology for a specific community. The students are divided into small teams, each of which represents a different community, such as a retirement community, a prison, a deserted island, a small fishing village, or an industrial city. Each team invents possible applications for their community of nano rope, an extremely strong, but lightweight thread made out of nanofibers that is modeled after spider silk. The teams create a poster about their application and present it to the class. A short discussion about how different communities use technology in different ways concludes the activity.

Nanotechnology Applications: Liquid Crystal Sensors
This activity introduces students to liquid crystals (LCs) and to their potential use as sensors (Figure 1). The atoms in a solid are compact and maintain a fixed orientation, whereas those of a liquid move around and assume the shape of the container. Liquid crystal is another phase of matter that has the fluidity of liquids and the ordering of solids. The partial ordering or coordination of LCs allows one atom in the LC phase to impact the orientation of its neighboring atoms. These subtle changes in molecular structure affect the wavelengths of light that are absorbed or reflected by LCs, resulting in an apparent change in color of the material. Many scientists and engineers work on utilizing the sensitivity of LCs and nanotechnology to create sensors that can detect extremely small numbers of molecules like pathogens, toxins, and

chemical agents. Through this activity, students learn about the different phases of matter, especially liquid crystals. Students begin by learning about the important light reflecting properties of some LCs by experimenting with two such examples: soap bubbles and temperature sensitive LCs in sealed vials. Students then receive a plastic bag containing a hidden message, and several thermally sensitive LC sheets, which they use to decode the hidden message after it has been heated or cooled. The activity concludes with students brainstorming possible uses of LC sensors. Through this activity, students learn that molecules can be manipulated at the atomic scale to create extremely sensitive sensors and that there are many different ways to "sense" the world around us.

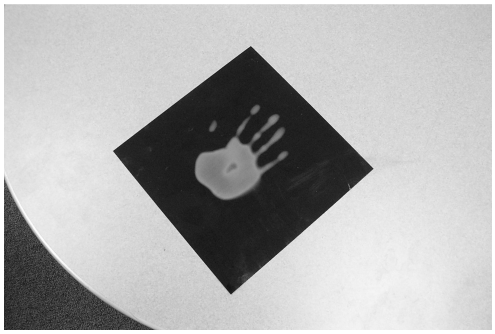

Figure 1. Use of thermally sensitive liquid crystal sheets that detect the presence of heat (here a hand) after the source has been removed, seeing the "unseen."

Outreach Activities

The outreach activities of UW IPSE are loosely divided into two categories— 1) in-classroom activities that use emerging nascent applications in nanotechnology and advanced materials to address Wisconsin science education standards (similar to the *National Science Education Standards*[4]), and 2) tabletop demonstrations based on nanoscale science and engineering concepts at various informal settings.

Classroom educational activities like Liquid Crystal Sensors and NanoCommunities were presented at middle and high school classrooms in Milwaukee Public Schools during the second semester. Interns were responsible for organizing their activity presentation and for communicating with the teachers about relevant concepts and education standards. Occasionally, teachers introduced their students to additional information prior to the intern visit to optimize the educational value and maximize the impact of the activity. The performance of the interns and the impact of their activities were assessed by the educators and by the interns themselves via surveys. Throughout the semester interns used these events and feedback results to optimize their educational activities and improve on integrating the activity with the overall science education curriculum of Madison and Milwaukee-area middle schools.

Interns also participated in ongoing outreach events such as *Secret Saturday Labs* at DW where they experienced first-hand the challenge and satisfaction of informal science education in a museum setting. The interns presented and explained UW MRSEC-created nanotechnology tabletop demonstrations to museum visitors, comprised of a wide spectrum of age and interest in science. Interns also participated in science education outreach events on the UW-Madison campus. For example, female interns led activities at *Expanding Your Horizons*, where a large number of middle-school girls from the state visited women scientists and engineers on the UW-Madison campus. After each outreach event in which they participated, both on and off campus, interns assessed their performance and what they learned from the experience. It became clear, although not measured, that through the participation in such events all interns showed

significant improvement in presentation skills, poise, control, clarity, and other qualities necessary for effective informal science education.

UW IPSE interns also participated in two large-scale science and technology expositions in order to reach a wider audience. At the biannual UW *Engineering Expo*, UW IPSE staff and interns led tabletop demonstrations. The UW IPSE interns also participated in *Nano All Around Us*, a conference on nanotechnology for both academic and public audiences. The conference organizers drew upon UW IPSE contacts to publicize the public exposition and asked UW IPSE interns to organize activities and demonstrations for the event. During the exposition, a group of interns led tabletop demonstrations, while others led the more extensive team activities.

Figure 2. Science Saturday series on UW-Madison campus that involve parental participation. Here students are doing the "Black Box" activity where they use measured sticks to map the topology of mystery objects in a shoebox. The activity introduces tools of nanotechnology and the concept of seeing the "unseen."

In addition to informal science outreach activities targeting the general public, interns also participated in events and workshops for science teachers. They presented to Milwaukee-area middle- and high-school science teachers at the annual Educators Night Out held at DW and at the Wisconsin Society of Science Teachers annual conference. These events were effective venues for publicizing UW IPSE online educational materials and for building future collaborations. These interactions helped educators learn about nanotechnology and its applications, offered educators opportunities to work directly with interns, provided educators with resources for additional information about nanotechnology, and increased educator awareness of the UW IPSE program.

Conclusion

The University of Wisconsin-Madison IPSE program is a model informal science education program for undergraduate and graduate students from diverse academic backgrounds. The program has created exciting new educational materials on different aspects of nanotechnology for middle-school students and the general public, while simultaneously providing technical and professional training for participants. The UW IPSE interns have benefited from structured professional development activities and have gained the ability to translate complex scientific jargon and concepts into language accessible for the non-expert. UW IPSE has strived to help student and public audiences realize that research at the forefront of science and engineering can be both exciting and accessible. Through these efforts, UW IPSE has heightened public appreciation for nanotechnology and inspired the imagination, interest, and enthusiasm of children and adults alike. More information about this program and the activities created by the interns can be found at http://www.mrsec.wisc.edu/ipse.

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