AC 2008-1967: IMPROVING THE PROFESSIONAL DEVELOPMENT COMPONENT OF AN REU SUMMER PROGRAM

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Improving the Professional Development Component 
of an REU Summer Program

Abstract

An NSF-funded Center, a three-university partnership with research focused on nanomanufacturing, has held a Summer Research Experiences for Undergraduates (REU) Program for undergraduate students over the past three years. Over 70 students have participated in the program, in which each student is guided in a project to learn more about research related to nanomanufacturing. In our laboratories, students with diverse technical backgrounds gain skills in electron and atomic force microscopy; chemical synthesis; MEMS and NEMS fabrication; dip pen nanolithography; template-guided assembly and transfer of polymers and nanoparticles; high rate polymer processing; assessing the impact of nanoparticles on the environment; and exploring economic and ethical issues associated with nanomanufacturing. A professional development component was also designed into the 10 week research program, which has morphed over the past three years, based on evaluation of students at the end of their summer experience.

REU Program

The NSF Nanoscale Science and Engineering Center for High-rate Nanomanufacturing (CHN) focuses on nanomanufacturing research is an equal partnership among three universities (Northeastern University, the University of Massachusetts Lowell (UML), and the University of New Hampshire) that are located about an hour’s drive apart. For the last three summers, the Center has held a Research Experiences for Undergraduates (REU) program. The participants spent 10 weeks in the Center’s laboratories (i.e., early June to mid August). Students, as individuals or in collaboration with other undergraduates, conducted research under the guidance of their faculty advisors, other faculty, graduate students, and post-doctoral researchers. In this program, students with diverse technical backgrounds gained skills in electron and atomic force microscopy; chemical synthesis; MEMS and NEMS fabrication; dip pen nanolithography; template-guided assembly and transfer of polymers and nanoparticles; high rate polymer processing; assessing the impact of nanoparticles on the environment; and exploring economic and ethical issues associated with nanomanufacturing. The participants presented the results of their research at the end of the program. Each year, a total of 16 to 30 undergraduate students have participated in the program, with the students split equally among the three Universities.

Table 1 presents the professional development associated with this REU program. The initial program included safety training, how to use the Universities’ libraries, attendance at the annual NSF Site Visit, and participation in a half-day poster session and a half-day ethics workshop. The students also had the opportunity to attend various non-specific professional development activities at each of the Center’s three campuses. Since evaluation of the Year 1 program recommended “additional collaboration and contact among the participating Universities and students engaged in the REUs,” a more structured program was designed to create the weekly professional development event (with lunch) in Year 2. Activities were expanded to include a writing component, more extensive training in presentation skills, attendance at a societal impact
session of a professional workshop, and a social activity. Evaluations for Year 2 showed that “many of the students … enjoyed meeting new people, including the weekly meetings which allowed participants to see the work others were doing and to learn from and interact with other students. The workshops were also noted by several students as a good opportunity to interact with others.” These components were refined again in Year 3.

### Table 1. Overview of Professional Development Program

<table>
<thead>
<tr>
<th></th>
<th>Year 1 2005</th>
<th>Year 2 2006</th>
<th>Year 3 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory safety</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Library skills</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Technical communication</td>
<td>○</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Ethics</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>NSF Site Visit</td>
<td>○</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Societal impact workshop</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Tour and social event(s)</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Unfilled circles indicate activities that were not required at all locations.

Evaluation of the REU program was performed using a web-based survey. Additional information was collected from focus groups consisting of the REU participants from one University. These focus groups were held at the end of the REU program. The evaluator reported that she had a difficult time extracting information the REU participants from Year 1, but that after the formal professional development program was introduced, the students had plenty to say.

### Laboratory Safety

Laboratory safety training has always been a formal 1 to 2 hour session presented by representatives from each University’s Environmental Health and Safety Office. Typically, the content includes identifying safety hazards, use of safety equipment, disposal of hazardous waste, and related issues. At one of the universities, the training is the same program that presented to all University researchers. This program concludes with a “standardized” test and the REU participants are awarded a safety certificate. At another university, students are given a lecture and then are asked to take a web based exam to “certify” their level of basic safety knowledge. All researchers must pass the exam before access to the clean rooms is permitted. This safety training is always scheduled during the first few days of the REU program.

Additional laboratory safety training is provided in operator qualification tests for specific instrumentation. For example, operation of MEMS/NEMS fabrication and plastics processing equipment or of the scanning electron microscope requires written and practical examinations, both of which include safety requirements specific to that equipment. These operator qualification tests are administered after the REU student has been trained on the equipment.

The requirement for safety training was built on long-standing practice at all three institutions. Formal safety training is mandatory for all researchers at the graduate student level or higher. Student use of complex and hazardous equipment, particularly for MEMS/NEMS fabrication and
plastics processing, has created the system of additional safety training that was employed with the REU participants. In addition to strictly-enforced safety practices for the laboratories, there are written safety guidelines for all pieces of equipment.

Library Skills

As part of their research experience, REU participants were expected to research the state of the art associated with their research project. Previous work has shown that “students writing research reports (63% of students) generally ranked most highly sources that were easy to use and easy to find, whether those sources were library-based or Internet-based.” Therefore, each University’s librarians have provided training in the use of each library’s facilities. This training has included the use of computerized search engines, accessing of on-line journals, and programs for developing lists of references. Students are asked to identify a topic of interest in nanotechnology or assigned a topic related to their research project. A working session is committed where the research librarian and faculty help the student learn to use the search engines and to determine which citation databases are appropriate for the information sought. These sessions are effectively the same initial training given to the graduate students in using the libraries. Students are informed that librarians can assist when they perform literature searches. Library training is scheduled during the second week of the REU program.

Technical Communication

Since technical communications skills are essential in technical careers, one of the ABET criteria is the “ability to communicate effectively.” The teaching of technical communication, however, is a long-term process. Such training is often integrated into curricula. As a result, all three University’s provide workshops on aspects of technical communication and the University of Massachusetts Lowell’s College of Engineering requires the review (and revision) of at least one piece of student writing every semester during an undergraduate student’s university career. The challenge, therefore, was to provide some technical communication training in a 10-week-long research program.

During Year 1, training in technical communication consisted of a session on presentations, specifically PowerPoint presentations. These sessions were provided by various offices at each University. The faculty advisors and graduate students also provided assistance with the final presentations. The faculty assessment of the final presentations in Year 1 indicated that the students needed more assistance in developing their communication skills.

During Year 2, a professional technical writer associated with one University’s college of engineering conducted a session on writing an introduction or review for a technical paper. The REU participants then incorporated the results of their literature searches into a written document. After these documents were reviewed and marked up by the technical writer, the writer met individually with each student to review his corrections. The REU participants then corrected and resubmitted their written pieces.

This writing program provided effective communication, but had three problems. First, the writing assignment in Year 2 was focused on a topic that was not directly related to the students’ research projects, but rather for information to address nanotechnology development to create a
The students enjoyed learning about the extra topic, but felt that they lacked sufficient time for their lab based research project. The second issue was that the specific technical writer was not the right person for this program. Finally, the timing of the communications program needed modification. The introduction to technical writing was provided in the third or fourth week of the REU program with feedback on the writing skills in the seventh and eighth weeks of the program. As a result, the students were revising their written pieces at the same time that they were finishing their research projects and creating their final presentations. They felt stress.

For the Year 3 program, a lecturer was hired – an engineer with extensive professional experience and excellent writing skills – who provided an introduction to technical writing during the first week of the semester. The presentation was delivered to all the Universities via distance learning, thereby reducing the time commitment from the lecturer and the REU participants. The initial presentation included a discussion of how to conduct a literature review – not just how to use search engines – and how to incorporate the results of that literature search into the introduction to a technical paper. (The library workshop was moved to occur after this lecture.) The students conducted a literature search and wrote an introduction of their research topic. These written drafts were submitted to the lecturer at the end of the fourth week of the program. After the lecturer reviewed and marked up the introductions (over the July 4 break), she met with students individually during the fifth week of the program. While the revised introductions were not due until the end of the program, most were ready far earlier, and the revisions did not interfere with students’ preparation of the final oral presentations.

When delivered by the right person and targeted to the research project, this writing assignment was valuable. During the final oral presentations, the REU participants easily presented the state of the art for their research topic. Moreover, many of the introductions could be expanded for technical papers. The students still grumbled about writing (as they always do), but most submitted revised introductions. The overall program was so successful that a modified version of this writing an introduction program is under consideration for the Center’s graduate students.

Although a session on presentations, specifically PowerPoint presentations, was continued in Years 2 and 3, a day-long workshop on presenting technical material to non-technical audiences was added in Year 2. The session on PowerPoint presentations was scheduled during the third or fourth week of the program and the session on presenting to non-technical audiences during the ninth week. The latter session was delivered by science educators at the Museum of Science, Boston, which is partnered with the Center. To illustrate presenting technical material to non-technical audiences, the science educators started with a skit showing the poor delivery of the world’s worst PowerPoint presentation. The REU participants were then asked to pick out errors in the delivery and presentation of the material. After the science educators provided details on educating general audiences about a technical topic, teams of students developed and delivered presentations that explained their research to “their parents.” These student presentations were critiqued and improvements were suggested by the science educators and the other REU participants. Finally, the students visited the science museum exhibits and reported back on their observations.

The session at the Museum of Science was very popular with the students. In response to a Year 1 2006 survey by the Museum of Science, Boston, the students gave the program a “fun
ranking” (i.e., did you have fun today?) of 4.6 out of 6, and 100% of those who responded to the survey said that they would recommend the workshop to other students. From the 2006 Museum of Science survey, they considered the all aspects of program useful, particularly the presentation skills overview – i.e., ‘bad presentation’ skit and discussion (4.6 of 5), the tips for translating science and writing exercise (4.4 of 5), the discussion of props and demonstrations (4.4 of 5). “Students on average felt about 57% more knowledgeable about communicating scientific ideas to the public as a result of the workshop.” In evaluations of the 2006 and 2007 REU programs “students at each of the three universities reported the [Museum of Science] visit was exceptional and should occur every year.” These evaluations confirmed that the workshop “was really helpful,” and that “any time students go off site there ends up being more learning than what would occur in a classroom setting.” They also “enjoyed the opportunity to spend time talking with other students.”

In the 2006 and 2007 Museum of Science survey, 75-80% of the REU participants said that the “workshop would influence their future presentations.” These students did apply their newfound knowledge to their final presentations. Year 1 presentations were adequate technical presentations. With the Year 2 and 3 presentations, however, the REU participants spent more time providing context and explaining basic concepts for their research. For example, a biology major explained antibodies structure and function, a mechanical engineering major explained morphology in block copolymers, and a civil engineering student outlined the waste water treatment process before detailing their research. This factor made the presentation more understandable to the diverse audience – including parents and siblings.

Ethics

Another ABET criterion is the “ability to understand professional and ethical responsibility.” Most engineering programs have integrated professional ethics components. Ethics, however, is not always discussed in science programs, and if discussed, it is often in senior level courses. Therefore, with a diverse group of students, incorporating ethics during the REU program was a challenge.

During Year 1, REU participants, along with Center graduate and post-doctoral researchers, attended a half-day workshop, “AIR: Learning to Manage and Process Ethical Challenges in the Workplace.” The goal of this workshop was to introduce the AIR (awareness, investigation and response) model of ethical inquiry to students. This model provides students with the necessary tools to problem solve ethical dilemmas and challenges they incur during their work in the CHN. Students were placed in mixed university groups and each group was led by a trained faculty or staff facilitator. The workshop began with an interactive discussion of common issues and concerns that occur for students, including classroom, laboratory, place of business, and community settings. This segment was designed to explore initial assumptions and the knowledge base around the skills of ethical inquiry. This segment, however, also addressed the issues of power and authority that students face in difficult situations. A presentation of the AIR model\(^7\) introduced participants to the three elements of ethical inquiry: A – awareness, I – investigation and R – response. The workshop leaders explored the conditions necessary for ethical inquiry and helped students feel more comfortable in raising, inquiring, and processing these issues.
The workshop participants then discussed a series of application activities of the AIR Model designed specifically for the various environments in which the participants will work. Activities included applying AIR to an authentic situation via case study. The workshop leaders demonstrated a role-playing activity using AIR with students. Then participants were placed into triad situations where they practiced the model with feedback in a round robin format. Participants were then led through a debriefing exercise to refine their understanding of applying the model. Finally, student participants revisited their initial discussion and worked in small groups to use AIR to solve one of their ethical challenges.

Evaluation of the workshop was conducted using a pre-assessment survey, a post test and session evaluation, and a follow up survey was that was sent to the participants four months after the session to determine the value and usage of the model to students. The post-test and session evaluation results (Table 2) reflected the attendees’ initial perceptions of the workshop and the AIR model. The usefulness of the workshop was directly related to the perceived relevance of ethical thinking in the student work. Not only are the statistics for Questions 1 (usefulness) and 2 (relevance) exactly the same, but looking at individual responses, the majority of ratings for Questions 1 and 2 were usually the same. While the results are positive, it still indicates that some students do not see any relevance in having a concrete ethical problem solving schema for their work in nanotechnology. The students also appreciated the opportunity to come together to discuss these issues and noted only that some facilitators were faculty (who were not permitted to attend by workshop organizers). A surprising finding was the strong rating (3.8) that a single workshop improved their thinking about how to address potential ethical challenges. Although this is only perception, the positive response may suggest that previously students did not have any way and that even one workshop with concrete applications was helpful.

<table>
<thead>
<tr>
<th>Question</th>
<th>Rating (1 to 5)</th>
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<tbody>
<tr>
<td>Overall value of the workshop</td>
<td>3.6</td>
</tr>
<tr>
<td>Concept and issues were relevant to my work on the grant</td>
<td>3.6</td>
</tr>
<tr>
<td>Workshop facilitators were effective</td>
<td>4.0</td>
</tr>
<tr>
<td>Small group discussions were useful</td>
<td>4.1</td>
</tr>
<tr>
<td>Workshop improved my thinking about how to address potential ethical challenges</td>
<td>3.8</td>
</tr>
</tbody>
</table>

The return rates from the follow up survey four months after the workshop were too small to make conclusions, but some thoughts about the data reinforce the idea that a single short intervention works only with those who have either a pressing need to solve an ethical dilemma or have an interest in ethical issues in research. Without on-going reinforcement, students probably are still unaware of issues unless obvious and may still not understand how to respond. Suggestions for improving the workshop and follow up include:

- Having professors (who have frequent student contact) reinforce the importance of the ethical and societal implications of their work.
- Allowing students to informally talk more about ethical concerns and problem solving.

These results, however, were influenced by the presence of graduate students and post-doctoral researchers. Informal discussions with the REU participants indicated that the AIR model was too abstract for them. They were more interested in practical suggestions for evaluating ethical
problems that would arise in work (industrial) settings. As a result, the focus of the ethics component of the professional development program was changed.

In Year 2, a civil engineer instructor with significant industrial experience offered a lecture titled “Incorporating Ethics into Professional Decisions.” He discussed issues of professional engineering ethics, and how the use of specialized knowledge should be governed when providing a service to the public. Some case studies were discussed, for example the Challenger Disaster. The lecture morphed into more of a discussion about issues and what should be considered when making professional decisions. He discussed the engineering codes of practice that must be followed to prevent exploitation of the client and preserve the integrity of the profession. In the evaluation of the Year 2 2006 REU program, the REU participants reported that the new format “was a good experience and what the presenter did was effective” given diversity of the group that attended the session. Since the students felt that this presentation was more relevant to them than the AIR workshop, the lecture format was continued in Year 3.

In Year 3, to further the discussion on the ethical issues and responsibilities of engineers and scientists working on the development of nanotechnology, another lecture was added to the agenda. Societal dimensions include a diverse range of subjects, such as access to benefits arising from nanotechnology, effects on the labor pool, changes in the way medicine is practiced, concerns regarding possible health or environmental effects, privacy concerns arising from distributed nanotechnology-based sensors, and issues of environmental justice. A lecture was presented by a faculty member and researcher in the CHN from the Department of Philosophy and Religion, who works in the areas of environmental ethics, and ethics and technology, in particular nanotechnology. He imparted new ideas and new ways of thinking to the engineering undergraduates, creating opportunities for a dialogue with the students and helping them to think outside the box. This lecture was presented live at one university location, and was transmitted to the other two locations. Students at the remote locations were engrossed enough in the topic to actually join the discussion at length.

Societal Impact Workshops

The REU students also attended the environmental impact sessions of 4th and 5th New England International Nanomanufacturing Workshop. These morning session of the workshop was well-attended by local and international industry members who were interested in the environmental health and safety issues associated with nanomanufacturing. A list of speakers and seminar titles for the 5th Workshop is shown in Table 3. Again, this portion of the professional development curriculum offered the undergraduate students broader perspectives on the risks of some aspects of this emerging technology. Both industry and government - in the U.S. and abroad - are concerned about safety and are working together to advance the understanding of nanomaterials properties and risks. This session provided all with an outlook on how much research is still required to determine the risks of specific nanoparticles, yet offered insights on best practices that could be adopted to prevent worker exposures. Legal issues and regulation were also discussed in light of all the companies that are already using and producing nanomaterials.

In evaluations of the REU program, there has been disagreement in ratings for the Nanomanufacturing Workshop session. Some participants have felt that the content is “too
advanced for most to understand or be interested in.” Others have disagreed, “saying the [Workshop] helped to put the big picture in perspective.” This viewpoint seems to be divided along disciplinary lines, with the engineering students tending to enjoy the big picture.

Table 3: Agenda for Environmental Health and Safety Session of the 5th New England International Nanomanufacturing Workshop

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Presenter</th>
</tr>
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<tbody>
<tr>
<td>Nanotechnology and Nanomaterials: Are the Workers Safe?</td>
<td>Senior Manager, Environ, Inc.</td>
</tr>
<tr>
<td>Evaluation of Exposure to Nanomaterials</td>
<td>Director, Toxics Use Reduction Institute, UML</td>
</tr>
<tr>
<td>Department of Energy Nanoscience Research Centers Approach to Nanomaterial ESH</td>
<td>Environment, Safety and Health Manager for the Center for Functional Nanomaterials, Brookhaven National Laboratory, DOE</td>
</tr>
<tr>
<td>Local Oversight of Emerging Technologies, The Cambridge Experiment</td>
<td>Director of Environmental Health, Cambridge Biosafety Committee, Cambridge Public Health Department</td>
</tr>
<tr>
<td>Risk Mitigation Strategies For Companies Manufacturing Engineered Nanomaterials: A Legal Perspective</td>
<td>Reed Smith</td>
</tr>
<tr>
<td>Panel Discussion</td>
<td>All Speakers</td>
</tr>
</tbody>
</table>

Tours and Social Events

REU participants have always expressed the desire “to have more contact with students in the REU program at the other CHN sites.” The tours, social events, NSF Site Visit, and Nanomanufacturing Workshop were also designed as social opportunities for REU participants at the three Universities.

During Year 2, some REU students checked out the water slides at a water park, while other REU participants took the locks and canal tour at the Lowell National Historical Park. The latter event was a great hit as one student was permitted to drive the trolley. For Year 3, the students toured a local company which manufactures nanotubes. Most of the students, however, rushed back to their laboratories rather than heading to the beach.

In general, students provided mixed reports related to field trips and social activities. Some students felt these events were very important and wanted more of them, whereas others felt that they took too much time away from the research and should be optional events.

Conclusions

The initial program included safety training, how to use the Universities’ libraries, attendance at the annual NSF Site Visit, and participation in a half-day poster session and a half-day ethics workshop. The students also had the opportunity to attend various non-specific professional development activities at each of the Center’s three campuses. In Year 2, a more structured program created the weekly professional development event (with lunch). Activities were expanded to include a writing component that was based on short topics related to student interest. The students were required to do a literature review and find citations on science and engineering discoveries. After assessment of this activity, the writing component was focused on the student’s research – i.e., they researched and wrote a background for their research - and the timing of the assignment was changed to facilitate the students’ overall research activities.

Although the REU participants were trained in presenting technical information in all three years, the program was formalized in Year 2 with all students receiving a primer on professional presentations. In addition, the science educators at the Museum of Science Boston gave the REU...
participants pointers on presenting technical information to the general public. This informal science education-based training was very successful. The students enjoyed their interaction with the science educators and the program assisted the students in presenting final presentations that could be understood by all REU students as well as visiting relatives.

The Year 1 ethics workshop “AIR: Learning to Manage and Process Ethical Challenges in the Workplace” was considered too abstract by the REU students. Therefore, in Years 2 and 3, the REU participants attended two lectures on ethics: professional engineering ethics and ethics particular to development of nanotechnology. In addition, students were exposed to issues of environmental health and safety (EHS) through attendance at the EHS session of the New England International Nanomanufacturing Workshop. REU participants have considered all events to be very useful.

Overall, the weekly professional development sessions have brought the REU students together to create a research community for the students during their summer experience. The students also participated in industry tours and other more social professional development events. When we suggest going to the beach, however, all head back to their research. If only they were so dedicated during the academic year…

Acknowledgements

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References