AC 2009-2496: INTERNATIONALIZING TOMORROW'S RESEARCHERS – STRATEGIES AND EXPERIENCES FROM THE PARTNERSHIP FOR EDUCATION AND RESEARCH IN MEMBRANE NANOTECHNOLOGIES

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Internationalizing Tomorrow's Researchers – Strategies and Experiences from the Partnership for Education and Research in Membrane Nanotechnologies

Abstract

The Partnership for Education and Research in Membrane Nanotechnologies (PERMEANT) is an NSF PIRE project involving Michigan State University (USA), Duke University (USA), Kyiv-Mohyla Academy (Ukraine), Université Paul Sabatier (France), Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement (France), Institut National Polytechnique de Toulouse (France), and Volgograd State University of Architecture & Civil Engineering (Russia). Our approach is to bring together engineers and scientists with complementary fields of expertise and facilities, as well as varying geographical and cultural perspectives, for collaborative research on issues related to public water-supply and treatment. Research projects address two principal themes: 1) development of nanomaterial-enabled membranes and 2) control of membrane fouling, and addresses fundamental nanomaterials chemistry and materials science as applied to water quality technologies. One key premise of our Partnership is that students are powerful catalysts for research collaboration. Our research is organized in international teams in which doctoral students supported by separate funding at a foreign institution are teamed with each student from a US institution supported by NSF funds. Students in these research teams work on related topics that naturally encourage international collaboration between graduate students and their faculty advisors. The team-based approach allows students to compare classroom experiences, share instructional materials, help one another with research methodologies, and forge long-term international contacts.

In this presentation, we describe some of the strategies that have been employed to develop an international perspective in our graduate students, and the skills necessary to effectively collaborate across geographic, political, cultural, and disciplinary boundaries. We report our experience, both positive and negative, and revisions we have made to the original model. Finally, we describe our plans for the future, which include a formal program assessment of the extent to which student in the program are better trained for international work in the future.

Introduction

Environmental science and engineering is becoming increasingly international in scope, in large part by the global nature of grand challenges facing the next generation of professionals. These challenges range from climate change and water supply to establishment of international standards on the materials we produce[1]. International collaboration in research and education is key to both resolving these problems and establishing an international community of environmental professionals that will address these issues. Although the number of U.S. college students studying abroad is at its all-time highest level, this number amounts to less than 1% of the nation's full or part-time students.[2] This problem is especially acute in engineering, which accounts for only 3% of all U.S. students who study abroad. Preparing internationally-competent scientists and engineers thus becomes a need that is crucial for successfully countering the emerging environmental challenges. With this in mind, the National Science Foundation (NSF) created the "Partnerships for International Research and Education (PIRE) program …to catalyze

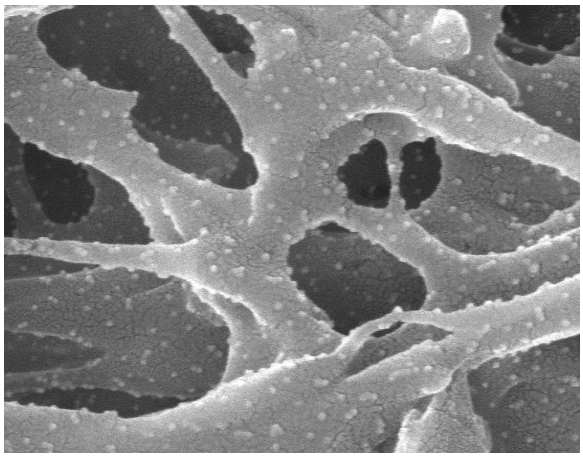
a cultural change in U.S. institutions by establishing innovative models for international collaborative research and education. [These] program[s]… enable U.S. institutions to establish collaborative relationships with international groups or institutions in order to engender new knowledge and discoveries at the frontier and to promote the development of a globally-engaged, U.S. scientific and engineering workforce."[3]

The stated objectives of the NSF program are

- Support research and education excellence.
- Deepen collaborative research and education between U.S. institutions and international counterparts.
- Provide international research experiences for U.S. students and faculty to prepare them to work effectively in the global research community.
- Engage resources within and across institutions to build strong international partnerships.
- Develop new replicable models for international collaborative research and education.
- Raise the profile and increase the importance of international collaborative research and education within the U.S. research and education community.

To respond to this opportunity we brought together a group of environmental engineers and scientists who are motivated by the vexing global problem of access to safe water supplies. We note that over 2 billion people live in regions with water shortages; that 50% of surface runoff is already appropriated and this may rise to 70% by 2025; that population growth and increases in population density have resulted in increasing potable water scarcity; and that water-related diseases are a leading cause of mortality and morbidity in many regions of the world, especially those that are under-developed.[4] We believe that the safety of the world's water supply is a global issue that requires coordinated international efforts ranging from establishing drinking water quality standards to developing and implementing the most appropriate water treatment strategies.

Membrane-based separation is increasingly recognized by the international community of researchers and practitioners as an emerging water treatment and quality control technology of great promise.[5] This promise is rooted in membranes' capability to remove a wide range of contaminants from water and the small environmental footprint of membrane-based treatment systems. Recent advances in nanotechnology offer new possibilities for membrane manufacture and the development of a spectrum of new generation membranes. Such membranes should allow new strategies for alleviating fouling, degrading pollutants, and performing high flux separations. An example of such an advance is shown in the scanning electron micrograph to the right. The oxidative catalyst nanoparticles that can be seen on the membrane surface result in a membrane that functions not only as a separation device, but also provide a capability for chemical degradation of the pollutants in the water contacting these surfaces.[6]

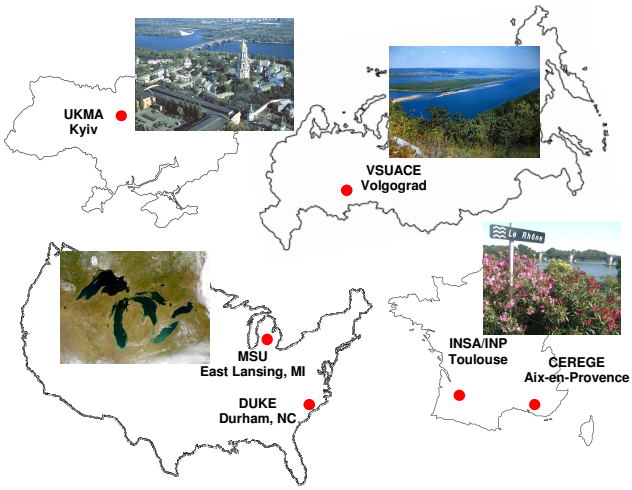


The PERMEANT Project

The project awarded to a group of researchers in late 2005 at Michigan State University and Duke University under the NSF PIRE Program is identified as the Partnership for Education and Research in Membrane Nanotechnologies – PERMEANT.[7] The project integrates research on membrane nanotechnologies with education at the high school, undergraduate, and graduate levels and with international collaboration involving students and faculty participants. In addition to the NSF Program Objectives, we have developed several additional objectives specific to our project.

- Enable international opportunities for career growth and collaborative research
- Evaluate water treatment alternatives across a range of economic, geographic, climate and water composition contexts
- Advance applications of nanotechology to membrane science and water treatment
- Investigate potential for membrane applications in developing economies

A group of international partners were invited to participate in the project by identifying internationally prominent groups who brought specific expertise complimentary to the capabilities of the U.S. team. For example, a group in Toulouse, France was well known for their ability to produce custom hollow-fiber membranes that offered a unique opportunity to extend our work with modification of membrane surfaces that had previously been limited to less efficient planar materials. Partners also agreed to embrace the educational objectives of the project and actively participate by hosting research visits by U.S. students and serving on students guidance committees. The core international partners in PERMEANT are



- Kyiv Mohyla Academy, Kiev, Ukraine (UKMA)
- Université Paul Sabatier, Toulouse, France (UPS)
- Le Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement, Aix-en-Provence, France (CEREGE)
- Volgograd State University of Architecture and Civil Engineering, Volgograd, Russia (VSUACE)

We also work with other institutions in these countries as the research projects progress, and new, potentially beneficial collaborations are identified.

Research activities are organized under two thrust areas. In the first, we are developing new nanomaterial-enabled membranes with improved performance or with new capabilities over existing membrane materials. These include projects to incorporate oxidative catalyst nanoparticles into membranes designed for wet-air oxidation of pollutants, to use polyelectrolyte multilayer surface modification to modify separation characteristics, and to develop silver-

polysulfone nanocomposites for biofouling mitigation. The second thrust area is focused on a factor that is often responsible for limiting the applications for which membrane technologies can be cost-effectively used, membrane fouling. We are exploring the use of silver nanoparticles in polyelectrolyte films to inhibit biological growth, use of cleanable membrane materials for use in membrane distillation systems, and facile control of colloidal fouling in polyelectrolyte multilayer-based nanofiltration systems. In addition to these two primary thrusts, complimentary research is also conducted when appropriate and productive. Typically, these involve opportunities to advance membrane applications for important classes of practical problems, and to understand related environmental implications of membranes.

The heart of the PERMEANT project involves individual student projects designed with collaborative links between projects and with foreign institutions. Students conduct much of their research as they would with any other laboratory-based project. A key difference is that their projects are designed around teams involving US and international co-advisors, students from both countries, and a study design based some activities being carried out in the laboratory of the international co-advisor. These student exchange visits are flexible, and driven by the research needs of the project. For example, a student may spend a period in the foreign lab to learn a technique necessary to produce a new membrane material, and then return to the U.S. to use these new skills. Alternatively, the student may visit a lab because they have specialized equipment, for example, to characterize new materials. The key concept we have employed is that student exchanges are driven by the needs of the research – students spend time abroad in order to make progress in their research. In other words, students learn to work across national and cultural barriers not because of some abstract notion that their research will benefit, but because it is necessary to cross these barriers to get access to new and exciting expertise and facilities.

The team-based approach allows students to compare classroom experiences, share instructional materials, help one another with research methodologies, and forge long-term international contacts. Student exchange visits are coordinated with a variety of complimentary activities designed to provide additional benefits to the student beyond the specific research objectives. We identify other opportunities for professional interactions such as visits to governmental organizations involved in environmental activities, to funding organizations and to organizations involved in water treatment such as consulting firms, equipment manufactures and water plants. For example, a group students working in two different labs in France visited the Méry-sur-Oise water treatment plant, shown to the right, that uses membrane technology to provide 140,000 m^3/day of water for 4 million Parisians.[8]

Students often take advantage of other educational opportunities including language and culture classes, short courses, conferences, and workshops. We have also experimented with involving undergraduate students in these international visits by bringing several students involved in a

study-abroad program to a collaborating lab for a short research experience under the guidance of one or more graduate students already working in the lab.[9]

Another aspect of our PIRE project is that we attempt to create a framework of international collaboration throughout all of the U.S. labs involved in the project in a way that engages the students not formally a part of PERMEANT. We do this by including the extended group of students in regular research meeting, regularly inviting international collaborators for seminars and setting aside time for the extended group to discuss research, and holding video seminars, conference calls and occasional joint meeting in which students participate.

Faculty members participating in the project also take on additional responsibilities as a part of the international dimensions of the project. Investigators typically travel with their students on their first visits to a collaborating laboratory. Their initial role is to help the students simply learn how to operate in the new environment. This includes the details of travel and living arrangements, establishing connections in the host organization, and finalizing the research work plan. In most cases, the faculty member also devotes a considerable amount of time to strengthening existing collaborative activities and identifying new opportunities. Students are included in some of these activities so that as they become more experienced, they will be able to do this on their own. The overarching goal is to build sustainable partnerships, which requires careful attention to issues such as institutional support, cultural sensitivity, interpersonal relationships, equity, and funding. We take the approach that we can best teach students how these issues relate to internationally collaborative research by including them in the process to the extent possible.

Lessons Learned

The PERMEANT Project was designed to produce graduate students who would not only conduct outstanding research, but would also gain the experience and expertise necessary to compete and collaborate in an international research environment. We proposed an approach based on our own international research experience. It was recognized that this was an experiment, as the pedagogical literature provides a little guidance on how to train students to be "internationalists." Our approach has been to develop our best ideas through discussion amongst the investigators, try them out, learn from the experience, and iterate. Three years into this project, we offer the following observations.

- While students can be trained to work internationally, not all students are well suited to this type of work. Identifying those students who can really excel at it remains challenging.
- Careful attention must be given to mentoring students in the international aspects of such research for it to be successful.
- Students who find that they really like this type of work and are give the opportunity to pursue it, rapidly develop a perspective that not only benefits their research, but can fundamentally change their approach to research. We have had one student venture out to a new foreign institution and develop a new collaboration on his own initiative.
- Undergraduates can participate in and benefit from international research experiences, but selection is perhaps even more critical than with graduate students.

- Issues of equity are extremely important in maintaining internationally collaborative relationships. It is not essential for all things to be equal, but the collaboration must be mutually and equitably beneficial.
- International work is inherently inefficient. There may be clear advantages in terms of the quality of science, but the work slower and costs more.
- There are numerous personal institutional challenges to involving students in international projects that include family obligations, course and exam requirements, insurance and safety issues, and in some countries, language barriers.

Future Plans

During the last two years of the project we will attempt to refine our approach in two respects. First, we will explore methods to better cultivate a strong commitment to international research in students that do not naturally gravitate to this position. We believe that this can be accomplished by increasing their engagement with the international dimensions of the project and with the foreign collaborators prior to international travel. The goal is to produce a greater percentage of "committed internationalists." Second, we will attempt to extend the depth of commitment in those students who become highly motivated by this type of work. We will attempt cultivate an approach where these students become comfortable seeking out the expertise they need to accomplish their research objectives, regardless of the national and cultural differences. We will do this by working with our students to identify key groups in other countries and letting these students take a leadership role in developing a collaborative partnership.

We are also in the process of formulating a more formal assessment mechanism to evaluate the extent to which we are meeting our educational objectives. This will involve an evaluation of individual research visits, and an overall evaluation that attempts to understand the impact of the PERMEANT experience on the student's graduate training.

Conclusions

We conclude that it is not only possible to train students to be "internationalists," it is an essential element of modern graduate education. We have found that with proper mentoring, international activities will result in both educational and research benefits to students who are carefully selected to participate in such collaborative projects. Our current model of graduate education poses many challenges to this type of approach, but none of these are fundamental. In balance, we believe that the benefits significantly outweigh the costs. The research world is flat and top quality work must involve competition and collaboration with the best researchers regardless of their location. Students have always been catalysts for change, and by empowering them to work globally, they are capable of taking us into territory that is scientifically exciting and productive.

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