Thinking Outside the Box: A Novel Interdisciplinary Research and Education Program in Environmental Engineering and Science

Maya Place,[1,5] Geoffrey J. Puzon,[2,5] Jennifer Shaltanis,[3,5] Candis Claiborn,[3,5] Markus Flury,[4,5] Brent M. Peyton,[1,5] and James N. Petersen[5]

[1]Chemical Engineering Department/ [2]School of Molecular Biosciences/ [3]Civil and Environmental Engineering Department/ [4]Department of Crop and Soil Sciences/ [5]Center for Multiphase Environmental Research, P.O. Box 642719, Washington State University, Pullman, WA 99164-2719

1. Abstract

Traditionally, graduate education is accomplished within established disciplinary boundaries. In addition, the complete education of the next generation of research professionals is often viewed merely as a byproduct of immersion in an intensive research experience. Although this approach is often successful, it has shortcomings and can be improved. A novel program has been developed within the Center for Multiphase Environmental Research at Washington State University, catalyzed by an IGERT grant from the National Science Foundation, which is designed to provide a more complete education for PhD environmental engineers and scientists. One of the most important outcomes of this program is the education of scientists and engineers who not only have depth in a single discipline, but also have a strong interdisciplinary background and a strong desire and ability to work with experts in other disciplines. The WSU program is thus highly interdisciplinary, with participants drawn from six academic programs in three colleges. In addition to the student's major disciplinary classes and intensive research work, the program includes interdisciplinary course work; laboratory rotations; internships; experience mentoring younger professionals in both classroom and laboratory settings; a seminar series; and discussions of professional ethics. Here the program is described in general, with detailed descriptions of the series of three interdisciplinary courses. In all these courses, active learning is emphasized, rather than relying on conventional lecture format. These courses achieve several objectives: 1) they introduce students to approaches to scientific problems that they may not have encountered in their own discipline; 2) they leave students with an awareness of how a multidisciplinary viewpoint can improve research; 3) they sharpen students' critical thinking skills; and 4) they expand the students' resource bases by exposing the trainees to a network of "experts" outside their own disciplines. As the students participate in these activities, they develop relationships with their peers from other disciplines, view alternative approaches to environmental problems, and develop collaborations with researchers from other areas.

2. Introduction

Traditionally, graduate education is accomplished within established disciplinary boundaries. As articulated by Golde and Gallagher,[1] three features of the doctoral educational system have led to this situation. First, the academic departments hold control of admission criteria, financial support, curriculum development, and graduation requirement. Second, PhD students work closely with a single faculty member, who directs their research, integrates them into a disciplinary research group, and determines when the students are ready to graduate. Finally, most research in the US is funded by grants to individual faculty members, thus reinforcing the tie between the student, faculty mentor and academic discipline, and which further encourages the view that graduate education should be a byproduct of immersion into an intensive research experience.

Students trained using traditional educational methods are at a disadvantage in a world where understanding of complex interrelationships, interdisciplinary thinking, and experience in collaborative problem solving are needed most.[2,3,4] Further, relevancy is often difficult for the student to grasp, in part because the unifying relationships are the fundamental laws of the natural sciences, but disciplinary isolation causes the student to not view these laws in the context of his/her work. In its brief on the 1995 report entitled *Reshaping the Graduate Education of Scientists and Engineers*, the Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academies[5] noted that:

> "Graduate education should prepare students for an increasingly interdisciplinary, collaborative, and global job market and should not be viewed only as a byproduct of immersion in an intensive research experience. The primary objective of graduate education should be the education of students."

In response to this articulated need, and to the call in the report for additional federal funding for training grants that facilitate the comprehensive education of students, the National Science Foundation implemented the Integrative Graduate Education and Research Training (IGERT) program. Catalyzed by an IGERT grant, a comprehensive graduate education and research training program has been developed within the Center for Multiphase Environmental Research at Washington State University. The program is designed to produce students who:[6]

- have a broad cross-disciplinary education and awareness
- readily integrate interdisciplinary knowledge
- work in a collaborative mode
- have a global perspective
- have effective communication skills, both oral and written
- benefit from professional conferences
- are flexible in resolving research problems by using other disciplines to help resolve problems
- have experience in interactions with industry

- pursue active involvement in team activities
- have an interdisciplinary perspective on responsibilities
- need less on-the-job training and are able to contribute to real work earlier in their employment than most other graduates
- have hands-on experience and are willing to apply hands-on skills
- are more sought after by industry, take responsibility and contribute earlier in their careers, and rise to positions of leadership more often than do other students.

The 39 students that have been involved to date in the WSU IGERT program have come from a variety of disciplines in science and engineering. As shown on Table 1, more than 35 students are currently participating in the program, and four, who participated in the program, have received their PhD degrees.

Department	Participants	Graduates
Biological Systems Engineering	8	1
Chemical Engineering	5	
Chemistry	7	2
Civil and Environmental Engineering	11	
Microbiology	2	
Soil Science	3	1

Table 1. Number of students currently participating and having graduated from the WSU IGERT program.

Interdisciplinary research is at the core of the training program. Such interdisciplinary research forms the basis for meaningful side-by-side, day-to-day learning that comes from working closely with faculty and students in other disciplines. Students working in such an environment experience the conflicts and triumphs that come with interdisciplinary research. Such knowledge cannot be taught in a classroom, but must come from daily interactions that inevitably occur in close-knit groups working toward a common research goal. Hence, while the goal of this project is the training of professional scientists and engineers that have a strong desire to work with experts in other disciplines and are well-trained for either industrial, governmental or academic careers, it is essential that quality, focused research be performed.

In addition to the student's PhD research, other classes and activities have been developed to achieve students who have the characteristics articulated above. In addition to the student's major disciplinary classes and intensive research work, the program includes interdisciplinary course work; laboratory rotations, internships; experience mentoring younger professionals in both classroom and laboratory settings; a seminar series; and discussions of the professional ethics. Here the program is described in general, with detailed descriptions of the series of three interdisciplinary courses. Following these descriptions are reflections on the program from students having completed these courses.

3. An Overview of the Program

A graduate certificate program has been developed around the interdisciplinary training program described here. This interdisciplinary graduate certificate program is designed to help educate professional scientists and engineers who have a strong desire to work with experts in other disciplines, are well-trained for either industrial or academic careers, and are able to span cultural barriers, whether these barriers are imposed because of cultural, disciplinary, or national boundaries. These professionals are to be poised to lead the development of scientific and engineering solutions to global environmental problems.

The program complements existing Ph.D. degree programs, earned from associated academic departments. It does not necessitate a new degree; instead, each student enrolls in one of the participating departments and meets the degree requirements of that department. However, the interdisciplinary graduate certificate recognizes the additional effort and focus required of the participating students. The certificate program is designed to provide an integrated, interdisciplinary training that encompasses both modern science and engineering, while also providing these scientists and engineers with an understanding of the social, legal, and political issues that dictate our ability to implement the scientific and engineering solutions.

Each student completing this interdisciplinary certificate must satisfy the degree requirements of his/her home department and of the WSU graduate school. In addition, the following special requirements, designed to meet the certificate goals, must be completed.

3.1. Interdisciplinary Coursework

In addition to the departmental requirements, each student must complete three specific courses:

- Fundamentals of Multiphase Environmental Systems, a 3-credit course designed to provide the student with an understanding of the fundamental principles that underlie the physical, chemical, and biological processes that dictate chemical movement in the environment.

- Social, Economic and Public Policy Aspects of Environmental Science and Technology, a 3-credit course in which scientists and engineers are exposed to the ways in which social, economical and political considerations interact with science to lead to socially and culturally acceptable, politically sound, and legally defensible environmental solutions.

- Current Topics in Multiphase Environmental Systems, a 3-credit course in which faculty from a variety of disciplines use current refereed journal articles to form the basis for discussions about current scientific and engineering issues related to environmental transport and transformation of chemical species.

3.2. Interdisciplinary Laboratory Rotations

Students are to undertake laboratory rotations in two or three participating faculty members' laboratories, with each rotation lasting at least six weeks. Students are not expected to conduct advanced experiments in these laboratories, but rather to participate in group research meetings, to understand the facilities available in the laboratory, to learn about research capabilities, and to meet students, postdoctoral associates, and research technicians working in these laboratories. Essentially, these rotations are designed to foster cross-disciplinary interactions and information exchange. At least one of these rotations must be outside the student's home department. These laboratory rotations familiarize the students with a variety of laboratory and analysis techniques.

3.3. Internships

Students supported by NSF IGERT funds are required to complete an internship, with a duration of two to six months, at a national laboratory, industrial environmental department, the environmental or natural resources department of a regional Indian nation, a government regulatory agency such as the US EPA or the Washington State Department of Ecology, or an international educational or research institution. Students supported on other funds are encouraged to complete such an internship if it will complement his/her graduate studies. Students may complete internships at any time during the first three years of graduate study. Such internships will have a variety of educational benefits, including exposure to the cultures of each of the sites.

Each student who intends to participate in an internship must provide a document that outlines his/her goals for the internship. These goals should be scientific and cultural (i.e., make use of specialized equipment, interact with experts at the laboratory, learn about how science is conducted at the organization, meet and interact with managers to learn of their perspective on science, learn how projects are funded and time managed, etc.). The student's on-site internship mentor must also provide a document that outlines how they will help the student accomplish these goals. Then, following the internship, each student must: 1) submit a report that describes how the stated goals were accomplished and what was learned, 2) make a presentation that describes the experience, and 3) request that his/her internship mentor provide an assessment of the experience.

3.4. Seminars and Symposia

Students participate in an invited seminar series by helping select and host seminar speakers. The students then spend time with the seminar speaker during an informal meeting time and, in relatively small groups of 3-5 students and the speaker, eat lunch and/or dinner with the speaker. Each student is required to attend at least five seminars outside his/her home discipline in each of six semesters, and to complete a brief evaluation of the seminar. In this way, the students are encouraged to think through the components of a quality seminar.

3.5. Interdisciplinary Thesis Research

Students perform Ph.D. dissertation research under the direction of faculty from the participating departments. To complete this certificate program, co-advisors or thesis committee members from an academic department outside the student's major, or from industry, a government agency, or a national laboratory must serve on the student's dissertation committee. Research that is performed, in part or wholly, at a collaborating institution is encouraged.

3.6. Mentoring

Regardless of the career path chosen, Ph.D. scientists and engineers will be responsible for mentoring others. Such mentoring will occur either in formal settings, such as classrooms, or informal settings as the PhD holder participates in the training of a younger researcher. Thus, programs were established to facilitate both of these components.

3.6.1. Research Mentoring

Because every PhD holder is often called upon to mentor younger researchers, each student participating in our program must be responsible for mentoring at least two undergraduate students during either the academic year or the summer months of the first three years of graduate study, for a total of 20 weeks (full-time equivalent) spent mentoring a younger researcher. The participant will be responsible, in consultation with his/her major research advisor, for devising a research plan for the undergraduate student and to monitor that student's progress. Moreover, the graduate student must be responsible to help the undergraduate prepare a presentation at an undergraduate research competition and a publication of his/her work.

3.6.2. Instructional Mentoring

Under the direction of the major research advisor, the graduate student prepares course materials and delivers lectures for a significant portion of one of the courses for which the research advisor has instructional responsibility. Thus, responsibility for the course still resides with the faculty member, but the graduate student prepares all pedagogical aspects of a block of the course, including lectures, exams, course outline, etc. In this way, the graduate student is exposed to the manner in which such materials are prepared and the thought processes involved in their development, while still having access to someone who has the time and inclination to ensure that course quality is maintained. Because of the objectives of this portion of the program, serving as a regular teaching assistant (TA) for a laboratory generally does not meet this requirement.

This activity has benefits to the graduate student that extend well beyond learning to be an effective class-room instruction. Such benefits include learning to think on his/her feet, to answer unexpected questions, to organize material in a logical fashion, to discern the important from the merely interesting, etc. Sherwood, et al.[7] provided a description of this approach and its benefits to the graduate student, the undergraduate student in the class room, and the faculty mentor.

4. Course Details

Regardless of the formal name of the academic department in which the trainee is working, and regardless of the particular focus of a student's research, a solid grounding in both technical and non-technical aspects of environmental technology is crucial. Hence, all trainees are required to complete a common course sequence designed to help the students better understand the societal context of their work, and to help them become more effective researchers. Details of these programs are provided below. In section 3.1 above, we provide a brief overview of each of the courses described in this program. Here, we provide additional descriptions of the courses, including the philosophy and the course objectives. In all these courses, active learning is emphasized, rather than relying on conventional lecture format.

4.1. Fundamentals of Multiphase Environmental Systems

In this first integrating course that the students take, which is taught by Drs. Petersen and Claiborn, we use the text entitled *Process Dynamics in Environmental Systems* by Weber and DiGiano[8]. In this course, the students are first introduced to the fundamental processes that constitute each of the steps in the interactions between various phases. As they begin to understand this, the students are then taught that they need to first write energy and mass balance equations. Then, they are taught the constituent components of these balance equations: reaction kinetics and transport processes in homogeneous systems. Finally, the students will be taught how these components are integrated to describe multiphase contaminant transport processes.

This process then leads them to understand how to attack, from a research standpoint, multiphase environmental research problems. They gain an appreciation of each of the components in this process, and they begin to understand why researchers in each discipline view similar problems in different ways.

During this course, the students are also required to write a literature review of a particular aspect of multiphase environmental research. In preparing this document, the students are required to work in multi-disciplinary teams. These teams are required to address the interdisciplinary aspects of various problems.

Table 2: Initial subject plan for the first required course, Fundamentals of Multiphase Environmental Research

No. of weeks	Subject
1	Introduction to the Center for Multiphase Environmental Research at WSU
3	Conservation principles - Conservation of mass and the control volume - Conservation of energy; the first law of thermodynamics - The second law of thermodynamics
3	Chemical transformation - Reaction equilibria - Reaction kinetics
3	Transport processes in homogeneous systems - Diffusion processes - Advection processes - Turbulent processes - Example - Application in the atmosphere - Example - Mass transfer principles
3	Transport processes in heterogeneous systems - Introduction to multiple phases - Gas-liquid Interactions - Gas-solid interactions - Liquid-solid interactions - Darcy's Law - Example - Contaminant interactions with soil in groundwater systems
2	Other transfer/loss processes including biologically catalyzed chemical transformations

When our program was first developed, this course was taught in a traditional way, following the schedule shown on Table 2. However, student feedback led us to understand that this was not allowing us to meet many of the course objectives. As a result, the course format was changed to facilitate significant interactions between the students from the various disciplines. This was accomplished by having the instructor provide fewer lectures on the material, and by having the students then solve problems that were posed as either the initial assumptions presented in manuscripts published by the participating faculty, or by having the students examine results presented in manuscripts published by the participating faculty. In this way, the students from the various disciplines interact extensively with each other, and all students see that, regardless of disciplinary background, they add a unique perspective to understanding the issues involved in the problems.

4.2. Social, Economical, and Public Policy Aspects of Environmental Science and Technology

Environmental engineers and scientist often have limited knowledge of the social and economical implications of environmental science and technology, yet social and economical aspects are important constraints for any science and technology. Scientifically and technically sound solutions to environmental problems may not be feasible from a social science view point. It is therefore necessary for scientists and engineers to understand the social, cultural, economical, legal, political, and public policy aspects of science and technology. Unfortunately, regular courses in liberal arts and economics colleges are often not suitable for scientist and engineers because the courses offered are often too specialized, too theoretical, or too advanced.

We have therefore designed a special course for the certificate program to expose the students to approaches and thought processes in social sciences and economics. This course is specifically designed for science and engineering students, and places science and engineering into a social science and economics perspective, including a cultural perspective, which is particularly relevant for environmental problem solving. The idea of the course is not to make the students social scientists or economists, but rather to teach them the way social scientists and economists work and think and reveal the ramifications of environmental problem solving.

The course is coordinated by one faculty member (Markus Flury), and co-taught by four supporting faculty members from different disciplines, including: (1) Comparative American Culture, (2) Sociology, (3) Resource Economics, and (4) Public Policy. The course is taught using theoretical concepts tied to case studies that show the role of the different disciplines in environmental problem solving. The individual disciplines are taught in blocks of four weeks each, in the order indicated. The fourth block on public policy integrates the previous topics and the students are engaged in a role playing exercise at the end of the semester that requires synthesis of the entire course. A field trip in the second half of the semester helps the student to experience the material learned in the lectures. We are visiting the US Department of Energy's Hanford Reservation in south-central Washington State, a site that embraces the interplay between scientific, technological, cultural, social, political, and economical challenges in an exemplary fashion.

The objective of the course is to provide an understanding and appreciation of the social, cultural, economical, and public policy implications of environmental science and technology. Science and engineering students learn how to communicate effectively with social science and economics partners. The students are exposed to a different kind of thinking than that from their disciplinary courses, and they are required to read social science and economical texts, which are written very differently from the texts to which the students are used to reading. These aspects make the course challenging, for both the students and the instructors. The course is taught by drawing heavily on case studies, which helps to make the often abstract concepts better comprehendible. Students like the case studies, and particularly the field trip to the Hanford Reservation, which integrates the course material and brings the students into contact with professionals. The Hanford Reservation is a prime example illustrating that environmental problem solving must consider not only science and engineering aspects, but also the social and economical implications, in order to be acceptable to stake holders, regulators, and the general public. At the end of the semester, students have to play the role of a specific stakeholder of the Hanford Reservation and defend their views and ideas of the problem solving of the site. Students really engage in and enjoy this role play exercise.

4.3. <u>Current Topics in Multiphase Environmental Systems</u>

The "Current Topics" course helps meet our need for students trained in a cross-disciplinary fashion to address the complex physical, chemical, and biological phenomena that dictate environmental chemical transport between various phases of material (e.g. soil/groundwater interactions). Dr. Brent Peyton coordinates the course and serves as the "primary" instructor. However, faculty from various disciplines lead critical discussions on aspects of multiphase environmental systems.

As such, this 3-credit course is divided into four sections, with one professor taking lead responsibility for each section. Dr. Peyton works with the participating faculty to ensure that the course content is effective and builds toward a better comprehensive understanding of the scientific underpinnings of the physical, chemical and biological phenomena that underlie chemical transport and transformation in the environment. CMER-associated faculty from two colleges and three departments participate in the instruction of this class. In addition to introducing the graduate students to current topics in multiphase environmental research, course goals are to emphasize scientific communications through discussion and proposal writing, critical thinking, and synthesis learning.

To achieve the above goals, faculty use current refereed journal articles, with a specific emphasis on topics related to their particular research areas. During each 4-week period, the "lead professor" provides copies of key papers in a single aspect of multiphase environmental research. These current, carefully selected articles are reviewed by the students and form the basis for discussions about current scientific and engineering issues related to the environmental transport and transformation of chemical species. The participating lead professor, in coordination with Dr. Peyton (the primary instructor), then guides the students through a critical discussion of the manuscripts and how the concepts used in the manuscript form the disciplinary basis for the interdisciplinary work being undertaken by graduate students. This facilitated discussion enables each student to expand his/her understanding of a particular aspect of the scientific underpinnings of the research being performed and of the interdisciplinary nature of the coordinated work being undertaken within the IGERT program. Topics that have been covered in this course include:

- The microbiology and biochemistry of contaminant degradation processes;
- Soil chemistry and its impact on contaminant transport and bioavailability;
- Hydrogeologic controls on subsurface contaminant transport in the vadose zone;
- Atmospheric contaminant transport mediated by multiphase interactions.

These topics are representative of the current scientific application of the underpinning fundamental concepts of chemical reaction kinetics and mass transport. However, rather than being taught from a textbook, the concepts are introduced through recent peer-reviewed journal articles.

In addition to article reviews and discussion, students are taught how to communicate their research ideas in a proposal format. Practical proposal development skills are taught using training materials from a variety of sources. The critical discussions that were held earlier in the course help prepare the students for this assignment by helping them to understand what comprises quality interdisciplinary research. Their proposal must be written such that it builds on the student's capabilities for research at WSU. Students and the faculty work through and discuss materials designed to improve proposal quality and writing styles. These materials were developed by Westinghouse Electric Company as means to improve proposal-writing skills. In addition, contrary to the format of many proposal writing workshops, these materials put the student in the "reviewer's seat" to show how proposals are reviewed and demonstrate that there can be many interpretations of even simple sentences. Students then develop an "NSF" style proposal based on their own research or desired research area. Guidance is given on the format and examples from course instructors are also given to assist in this assignment. For many students, this is their first exposure to learning this important aspect of research. At this point, a second package, a proposal 'self-assessment" tool is introduced. This tool was also developed by Westinghouse Electric Company and is distributed by the Carlsbad office of the U.S. Department of Energy. The handout material is an extensive checklist that students can use to improve the readability and overall chance of proposal success. A unique aspect of this assignment is the student-based peer reviews of the proposals. Peer review panels are assigned, and the panels receive copies of the proposals from the other students. Three student reviewers read each proposal and prepare written evaluations. Review panel discussions are held, during which the readers will summarize the proposed work and offer their comments both on the strengths and weaknesses of the proposal.

In summary, from an instructor's perspective, this course fills a need in our graduate curriculum for development of skills necessary for critical evaluation and discussion of interdisciplinary research. The course also fills a dire need for the development of practical proposal writing skills and provides students with tools for self-evaluation of proposals. The course is taught by instructors from various disciplines, colleges, and departments to provide a breadth of instruction rarely found in a single course. This facilitates interdisciplinary interactions among students and instructors, and helps demonstrate with current peer-reviewed literature that basic fundamental concepts underlie both science and engineering, regardless of academic discipline.

4.4. Summary of Course Details

These courses achieve several objectives: 1) they introduce students to approaches to scientific problems that they may not have encountered in their own discipline; 2) they leave students with an awareness of how a multidisciplinary viewpoint can improve research; 3) they sharpen students' critical thinking skills; and 4) they expand the students' resource bases by exposing the students to a network of "experts" outside their own disciplines. As the students participate in these activities, they develop relationships with their peers from other disciplines, view alternative approaches to environmental problems, and develop collaborations with researchers from other areas. The common course sequence also builds trust and colleagueship among the participating students.

5. Student Perspectives of the Program

The overall structure of the IGERT program leads to the knowledge of essential soft skills needed for effective scientists and engineers in the global job market, mainly interaction and collaboration. Its vision is to produce a more enlightened, adaptable student, prepared for many of the unexpected situations the professional world experiences. The IGERT program employs several methods to accomplish its goals for the students in the training. Interaction between students of different backgrounds and disciplines results from coursework, office space networking, and outside activities. It broadens the students' knowledge base in areas outside their primary research focus, which often extends research emphases and experimental possibilities. This expanded outlook that the student acquires ultimately channels research to a wider range of disciplines, yielding better subsequent results and more application abilities.

The program centers itself around three multidisciplinary courses. The mission of the classes in the IGERT program is twofold: the first focus is on the content and the second on communication and teamwork. While these courses aim to provide knowledge supplementary to core education, they also offer networking opportunities that the students' departmental courses may not supply. Teamwork and discussions are emphasized, rather than hard-core science, engineering, and mathematics that would be dictated, for example, by a strictly chemical engineering course. Rather than lecturing with material dated in excess of several decades, the changes and improvements are made immediately. This quick turn-around mandates student interaction, which then leads to the increase of the individual students' width of knowledge base. This process cannot be achieved in the individual departments alone, as they are designed to promote the students' knowledge of their respective core area.

5.1. <u>Interdisciplinary Coursework</u>

Classes specific to this program introduce a broad range of issues normally not addressed in discipline classes. In a sense, the IGERT classes try to bring real-life situations into the classroom experience. These areas include technical considerations as well as societal forces. The use of current topics and research issues introduce students to professionals and existing situations. The aim is to complement core classes' technical content with problem solving techniques and consideration of decision-governing influences.

Accomplishing a significant part of the mission of the IGERT program, the classes lay a foundation for greater understanding of the implications of students' work and help them consider issues beyond the narrow scope of their research. This education guides graduates to make more complete, informed research goals.

The classes have evolved over a short time, and have matured since the program's inaugural semester. Subsequent semesters' curricula have improved based on student and professor feedback, so much so that student learning and professor goals are optimized. The interactive teaching style used in these courses helps maximize learning by putting the learning process into the students' hands. Students form mutually beneficial relationships with each other with respect to one another's technical strengths. Thus, students are adequately prepared for information outside of their fields. These abilities to adapt and interact are the keys to the courses being successful.

As mentioned earlier, the first class uses underlying environmental engineering principles to connect the various research fields and lays the foundation on which graduates can initiate the multi-disciplinary process. Fundamental engineering principles are presented such that the class can appreciate how the ideas apply in all fields in practice. Such a style eases the barrier between areas of research, making it easier for someone to work in a cross-disciplinary approach. Students are broken into groups consisting of a mix of backgrounds, and given real-world environmental problems to solve. Problems are often current environmental concerns and require the knowledge of several disciplines to develop deeper understanding as well as a solution. Students can appreciate how other fields relate to their own, and acknowledge the significance of incorporating them for more complete solutions to environmental concerns. The individuals of the group, with a broad diversity of backgrounds and educational experiences contribute their knowledge to the group and to the solution, while learning from each other in this teamwork environment.

The second class addresses those issues not found in classical engineering and science courses, attending to the societal impacts on environmental research, including political and economic motivators, legal considerations, and social influences. In this class students learn how culture and ethics can affect design and implementation of environmental programs. Since this aspect of the research is not discussed nor addressed in most major programs, these topics provide valuable insights into the total environmental picture. Students are given a chance to step back from the rigorous science and engineering to which they are accustomed, and view the environmental science and policy from the public's perspective. What issues are most important to the average person? How is the scientific work going to impact the region? The act of role-playing of different cultural, economic, and political communities, as well as government agencies, brings to light the complexities and importance of considering all possible impacts of science. The topics and role-playing exercises are related to the remediation activities at the nearby Department of Energy's Hanford Site, in Richland, Washington. Integrated into the classroom is a field trip to the Site, providing first-hand experience of how the Site is situated, as well as the history behind each location and the site-specific problems presently researched and managed.

The third class in the series concentrates on current topics in environmental research. A key of this course is the exposure to all disciplines in the program, which enables students to contemplate new research questions or locate faculty who have the background necessary to aid in addressing the question of how to approach a solution. Recent journal articles serve as the basis to engage discussion. These environmental journal articles may involve research in only one discipline, but the aspects of the other disciplines represented by the students are brought forth and integrated into the dialogue. In addition to including relevant issues related to the topics from other disciplines, this course also educates the students about new information in other disciplines that may even help them with a problem in their own research. Since all the components of the IGERT program are presented here, the format gives both the instructor and the students who have an appropriate disciplinary background a chance to lead discussions and inform other students of the methodology behind research in that discipline.

5.2. ***Seminars and Symposia***

In addition to the three courses that form the core of the program, students are also required to attend five seminars sponsored by departments outside their own academic discipline. These seminars are dually valuable. They are opportunities for graduates to gain awareness of current research outside their fields. Students become acquainted with WSU research as well as work from other institutions. Seminars also offer chances for students to sharpen their presentation skills. Graduates evaluate the strengths and weaknesses of the speaker, using a standard form. In this manner, students recognize and subsequently correct their own presentation skills, based on what they observe.

5.3. ***Additional Opportunities***

The training classes are supplemented by other group and individual assemblies. These exist in the form of structured office assignments, informal forums, mentoring, and professional and student advisory boards. All of these features incorporate themselves into different parts of a student's academic life, creating a holistic approach to the professional preparation of the student. Each of these reinforces and encourages student relationships and communication. Students gain a broader knowledge perspective, in addition to the depth of individual disciplines.

5.3.1. Technical Advisory Board Interactions

Not only are the classroom and forum settings the object of knowledge advancement and networking. In addition the professional setting and networking can be established in the program. Seminar speakers visiting campus interact with IGERT participants at meals and other informal settings. Yearly advisory board meetings provide an opportunity for students to interact with outside professionals, and set the stage for networking in the professional world. This gives the opportunity for students to gain the advantage of making early outside contact, which can lead to committee memberships, internship opportunities, or even future jobs. In addition to this experience, the students also gain the opportunity to establish more effective presentation skills, through a poster presentation session. The students are advised on effective poster preparation and presentation and are provided an opportunity to present their research to advisory board members. This gives the student not only the opportunity to establish their presentation skills to professionals (especially outside the classroom setting), but it also gives the student the opportunity to meet with the experts in his or her field or research area, and to gain invaluable insight into their research and methods from an outside expert opinion. This can lead to more effective research, broader scope, and more applicable results.

5.3.2. Student Advisory Board

The Student Advisory Board (SAB) consists of a panel of students that represent the departments in the IGERT program, whose terms are for one year. These students create an important communication link between the students in the program and the professors and directors that run it. While the board welcomes ideas and concerns from the students, its main function is to voice concerns, ideas, and questions for the students who are not yet comfortable with those leading the program. New graduate students and those of varying cultural backgrounds are not always aware that such informal, yet professional, communication can exist. The SAB exists to generate dialogue, raise the awareness that student input is crucial for the shaping of the IGERT program, and to discuss methods of improving all aspects of the program.

5.3.3. Brown Bag Series

The IGERT program at WSU further promotes relationships among the students with regular meetings in the form of a weekly Brown Bag lunch. Brown bag lunches are an informal forum where IGERT students and professors can meet and discuss relevant issues that do not fit into conventional courses or even the IGERT classes. Such topics include research ethics and professional decision-making advice. The Brown Bag creates a relaxed environment in which the students can be with their peers and see their advisors as colleagues. It is within this forum that students voice their needs. The purpose here is to satisfy what students and advisors believe are any remaining holes in the guidance the student body may need.

5.3.4. Research Mentoring

Another significant and often overlooked aspect of graduate education is the competence to teach those less informed about environmental research. The WSU IGERT program attempts to remedy this through mentoring opportunities. Again here the goal is to minimize the experience spin-up time of a new professional. Each IGERT student has to mentor undergraduate students in a research project. The goal is for the graduate to guide the student in research methods, technical practices, and writing skills. The only defined project requirements are the development of a written manuscript and presentation of the work in a poster presentation, both of which are completed at the end of the session. The graduate mentor otherwise designs the whole program for the student. In this program not only do graduates employ their technical skills; they also become more experienced in leadership and authority. The mentoring proves to be good practice for graduates in teaching and supervising others in research.

5.4. Concluding Student Remarks

Students gain vicarious understanding from a widespread group of peers. In harmony with conventional class work and research structures, students can learn a great deal from each other about environmental scenarios. Students share offices with other IGERT students in similar but not identical fields. They grow to rely on one another as friends to help one another in areas in which one has little background and they gain perspective on the related research concerns. This structure makes efficient use of time as most students may not seek out such knowledge, given their limited free time. Social discourse can be a productive way to increase topical knowledge not provided in class settings, seminars, or research. This is unique in that the various disciplines are in close, individual contact. In conferences, departmental settings, and most other media, graduates and professionals have limited possibilities for cross-topic interaction; here, the constraints of a student's educational regime (i.e., "the box") are widened while being substantiated with instruction and research.

The core features of the program (i.e., the classes, mentoring, and seminars) are required. The degree to which the students take advantage of the remaining structured opportunities is up to each person. Here, how much each student benefits from the program is directly related to how much effort and time he/she puts into the activities. The structure is in place to nurture the students' self-confidence and polish presentation skills.

6. Conclusions

A novel, interdisciplinary, graduate education and research and training program (IGERT) has recently been established at WSU, which is designed to provide a comprehensive education of PhD environmental engineers and scientists. The students trained in this program not only have depth in a single discipline, but also have strong interdisciplinary skills and a strong desire and ability to work with experts in other disciplines. This program includes several components that enhance the students' education. In so doing, the goals articulated in the 1995 National Academies report entitled "*Reshaping the Graduate Education of Scientists and Engineers,*" including preparation of students who have an interdisciplinary, collaborative, global perspective, are being accomplished. Nearly 40 students from engineering and sciences, many of whom would not have come to WSU were it not for the WSU IGERT program, have graduated, or are currently participating. Students' reactions have generally been positive and have indicated an appreciation and understanding of the program goals.

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9. Biographical Information

MAYA PLACE is a second-year IGERT fellow and a graduate student in the Department of Chemical Engineering at Washington State University. Her research focuses on ^{137}Cs accumulation, kinetics, and transport by microbes in contaminated soils.

GEOFFREY J. PUZON is an IGERT Fellow and a fourth year microbiology graduate student in the School of Molecular Biosciences at WSU. His thesis research is focused on the biochemistry of chromate reduction by microorganisms.

JENNIFER SHALTANIS is an IGERT Fellow and a first year student in the Laboratory for Atmospheric Research in the Department of Civil and Environmental Engineering. Her research focuses on atmospheric aerosols and receptor modeling.

CANDIS CLAIBORN is an Associate Professor in the Laboratory for Atmospheric Research and Department of Civil and Environmental Engineering, and an Associate Director of the Center for Multiphase Environmental Research at WSU. Her research focuses on the measurement, phase distributions, and chemical characterization of atmospheric aerosols for determining the sources, transport and fate, and health impacts associated with exposure.

MARKUS FLURY is an Associate Professor of Soil Physics in the Department of Crop and Soil Sciences at Washington State University. His research focuses on flow and transport processes in the vadose zone, including the movement of contaminants facilitated by colloidal particles. He is also Associate Editor of the *Vadose Zone Journal*.

BRENT M. PEYTON is an Assistant Professor of Chemical Engineering and an Associate Director of the Center for Multiphase Environmental Research at Washington State University. His interdisciplinary research is focused on characterizing microbial reactions for in situ bioremediation and for industrial applications using bacteria from extreme environments.

JAMES N. PETERSEN is a Professor of Chemical Engineering, the Associate Dean for Research and Graduate Programs, and the Director of the Center for Multiphase Environmental Research at Washington State University. His research has concentrated on the kinetics of biologically mediated reactions and especially on those that describe the reactions involved in the destruction of environmental contaminants.