AC 2007-2958: DISCOVERING THE LINK BETWEEN UNIVERSITY AND INDUSTRIAL ENVIRONMENTAL RESEARCH

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Discovering the Link Between University and Industrial Environmental Research

Abstract

The University of Arizona has run a Research Experiences for Teachers Program funded by NSF for 10 years. This RET site teams together the University of Arizona (UA), City of Tucson Environmental Management Division, Raytheon Missile Systems, Tucson Electric and Power Company, Tucson Unified School District (TUSD), Marana Unified School District (MUSD), Nogales School District, and other districts in Pima County, Arizona. Annually, 6 UA faculty from the Department of Chemical and Environmental Engineering, 4 to 6 industrial mentors, 2 project evaluators, 12 to 14 teachers (ideally elementary + half math and half science secondary teachers), 8 pre-service teachers, 2 teacher leaders, and 8 undergraduate or graduate engineering students are part of the RET Site activities. These individuals impact around 2000 students annually. The individuals comprise 4 teams consisting of 4 teachers from the same school, 2 pre-service teachers, 2 engineering students, 1 faculty, and 1 industrial mentor. The overall objective is for teachers and pre-service teachers to work on environmental discovery-based research projects for 5 weeks during the summer, and transfer the knowledge learned directly to the K-12 classroom through core curriculum enrichment. The research plan provides a unique opportunity for participants to experience both laboratory projects and industrial scale applications. The projects focus on remediation of organics, metals removal, denitrification using alternative electron acceptors, and biofilm removal. In addition to research, the teams work together to improve classroom pedagogy. Teams attend workshops on current standards related to their discipline, inquiry based learning, stressing/encouraging problem solving as opposed to memorization, and minority and gender equity in the classroom. Teacher leaders from TUSD and MUSD lead some of these workshops. The pre-service teachers intern with the teachers during the following academic year to aid transfer of new knowledge gained from the RET experience into the classroom. In addition, project evaluators, faculty, industrial mentors, and engineering students visit the K-12 classroom during the academic year.

Introduction

There are two major opportunities for improvement of science and math teaching. One of these is to increase teachers' familiarity with the National Science and Math Education Standards [1-3] and to convince the teachers of the value of guiding instruction by the use of those Standards. The intent of the Standards is that science and math be taught with an emphasis on depth rather than on breadth of coverage, as has been the pattern in U. S. education. The developers of the Standards propose that fewer topics be taught to a deeper conceptual level, so that students develop an understanding of the big ideas, which can then be applied to other areas. One emphasis of the science Standards is on teaching science as a process of inquiry, honoring students' prior understanding of the natural world around them and building upon that by allowing students to investigate questions they themselves frame. When teachers and school districts develop their science and math core curriculum around the Standards, a more coherent program of instruction emerges; equity for all students and excellence of instruction are achievable.

The second great area of need for better preparation of teachers is to increase their content knowledge. For example in Arizona, many middle school science teachers do not have an undergraduate major in natural science. Under No Child Left Behind legislation, highly qualified teachers must demonstrate mastery of the subjects they teach through coursework or through a testing process. Professional development programs that provide teachers with high-level science content information and opportunities to practice science process skills in an authentic environment make them better able to guide students through inquiry investigations[4]. At the same time, these programs help teachers become designated as "highly qualified". The goal of this RET Site Project is to provide a quality research program that allows teachers to increase content knowledge while improving their Standards based teaching.

Specifically, this project improves K-12 education by exposing pre-service teachers, and K-12 teachers to environmental engineering and technological innovative research that is transferred to the classroom. This research is performed at the University of Arizona and at local industrial sites, thus the participants experience both bench-scale and field scale research. More specifically, the objectives of the project are to:

- Strengthen and foster long-term relationships between regional K-12 schools, the University of Arizona (UA) and industry.
- Provide a discovery-based research experience for K-12 teachers.
- Implement inquiry-based experiments and exercises in the K-12 classroom.
- Enhance the educational experience of students majoring in education by exposing them to state-of-the-art scientific research.
- Enhance the educational experience of engineering students by having them work more in teams and involving them directly in outreach activities.
- Increase awareness of multicultural and gender equity issues.

These objectives result in the following outcomes:

- Teachers and pre-service teachers increase their content knowledge in math and science.
- Teachers and pre-service teachers build lasting relationships with university faculty and industry.
- Pre-service teachers are exposed to the K-12 classroom as interns prior to student teaching.
- Confidence and interest in science, math and technology is increased in middle and junior high school students.
- Teachers and pre-service teachers gain increased awareness of gender and cultural equity issues and strategies for engaging all children.
- Engineering students gain a greater appreciation for the K-12 classroom and give back to the community through outreach.

To accomplish these goals, an interdisciplinary, teamwork approach was formed that combines state-of-the-art research projects and standards-based instructional workshops. The research teams provide a unique and interdisciplinary environment, which allows the teachers to experience both bench scale and industrial scale research. There are five research teams annually. Each research team consists of 6-9 individuals - a faculty member from the Department of Chemical and Environmental Engineering involved in interdisciplinary NSF sponsored research; an industrial mentor (City of Tucson Environmental Management Division, Raytheon

Missile Systems, Tucson Electric and Power Company), whose primary responsibility is corporate environmental research and compliance; a graduate or undergraduate student; 1 to 2 pre-service teachers, and 2 to 4 teachers from the same school.

The targeted teachers are teams from the regional school districts, emphasizing those with high minority or disadvantaged student populations. The teacher teams from middle and high schools consist of a mixture of math and science teachers. Teachers from K-6 schools simply need to apply as a team dedicated to working together to implement change in their school.

RET Site Activities and Examples

Participant teams (K-12 teachers, pre-service teachers and faculty) focus on learning and applying scientific standards and the scientific method to multidisciplinary environmental problems that integrate math and science. The focus is on environmental issues related to industry. The knowledge gained then empowers the teachers to enrich nationally approved curricula, like *FOSS*, that focus on scientific inquiry not just reiteration of facts, and problem solving mathematics curricula, like *Contemporary Mathematics in Context*. The project strengthens a teacher's mastery of scientific and mathematic material through research, and their understanding of high quality curricula that is coordinated with the National Science and Math Education Standards.

The participant research projects are similar to projects given to undergraduates participating in the NSF Research Experiences for Undergraduates Program. The unique aspect of this RET Site project is the link between university bench scale research and industrial applications of the research. The faculty mentor provides the participants with a brief literature background, overall NSF project description (review of graduate and undergraduate research results to date), and defined project goals. The industrial mentor provides an introduction to the industrial based application. Student mentors are responsible for teaching day-to-day laboratory techniques. The participants learn how to plan experiments, how to obtain statistically significant data, how to analyze and graph data, and how to present research results and draw conclusions. Typically 2/3 of the time is spent on research either in the field or laboratory, and the rest of time is devoted to pedagogy and relating lessons learned to core curricula used by the district.

Every research experience begins with a laboratory safety class. Participants are introduced to laboratory safety through video and lecture and are given an exam at the end of the class. The focus is chemical safety and hazardous waste. After the general course, the teachers receive hands-on safety training in the individual laboratories. The PIs and graduate students provide the laboratory specific training as a team.

One specific example of a research project and how this was incorporated into the classroom is highlighted here. The teacher team from a middle school consisting of two science and one math teacher designed and built a water recycle system for a research-scale hydroponics green house used to grow tomatoes. The teachers designed a model of the system using a 3-D software and a rapid prototype machine, purchased the materials, installed and tested the system.

A block flow diagram of the system the team designed is shown in Figure 1. The water and excess nutrients not taken up by the tomatoes are collected in troughs that are drained to a sump. The water is run through a carbon filter with UV light to kill and remove bacteria and then stored in a tank. Additional nutrients and water are added to the tank and then the water is pumped to the tomatoes to complete the cycle.

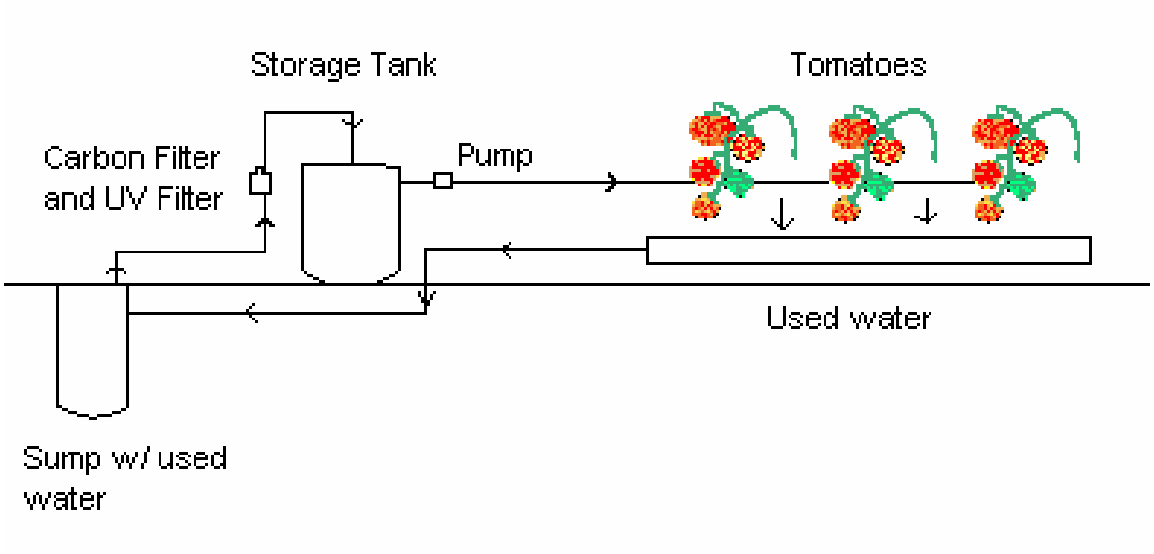

Figure 1: Schematic of water recycle system designed, ordered, and installed by a team of middle school science and math teachers.

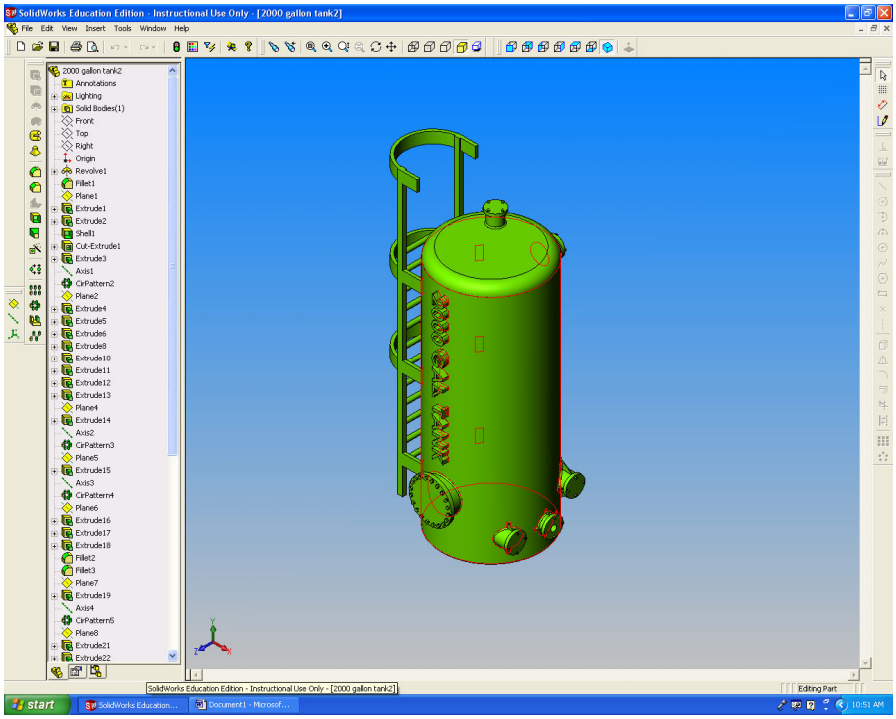

Figure 2: Example of a Solidworks drawing. This is the recycle water storage tank.

After the team designed the system on paper, they learned how to use Solidworks to construct a 3D model of the system. The Solidworks drawings were then converted to a model using a rapid prototyping machine. An example of one of the pieces of equipment drawn in Solidworks is shown in Figure 2. Finally, the team installed the water recycle system and tested the system for bacteria (Figure 3).

Figure 3a) Installation of the water recycle system in the hydroponics green house; b)Testing for bacteria within the system during operation.

As stated earlier, one of the goals is to transfer the knowledge the teachers gained to the K-12 classroom. Thus, approximately 1/.3 of the time the teachers participate in workshops, industrial tours, and curricular work session. Workshops and tours include:

- Inquiry and Notebooks
- Mathematics Pedagogy
- Standards
- Integration of Science in the Elementary Classroom
- Equity in the Classroom
- Career Pathways in STEM fields
- Power Plant Tour
- Bioremediation Site Tour

The curricular work session provide time for the teams of teachers to refine their lesson plans and ensure that their lessons are inquiry based and tied to the Standards. The lessons developed based on the water recycle research experience include:

Lesson 1) Water Dilemma Simulation

Objective**:** Given a water dilemma scenario, the student will analyze the problem and determine a solution based on his/her given role by creating a t-chart with at least three advantages and disadvantages to the proposed solution.

Lesson 2) The Dissolving Power of Water

Objective: After conducting a simple experiment, the student will gain an understanding of water's ability to dissolve more chemicals than any other substance on Earth by attempting to dissolve a variety of solids in water and then in oil.

Lesson 3) Water Filtration

Objective: Given the materials, the student will be able to accurately demonstrate the four of the five procedures that municipal water plants use to purify water for drinking.

Assessment and Academic Year Follow-up

At the beginning of the experience the teachers complete a pre-Institute survey. They are asked:

- How they heard about the program and their expectations?
- How much experience they have with inquiry based learning?
- How successful are they at promoting gender and minority equity in the classroom?
- What is their previous experience in developing lesson plans, activities, laboratory experiments, etc?
- What products do they want to produce during the program and what are their priorites?
- What is their experience as a career mentor?

Answers to the above questions vary considerably. Most have some experience with developing lesson plans and inquiry based learning. Most want to develop were labs, mini-lessons, cross-curriculum learning related to math, and exercises on data collection. Most have given some career advice but are uncomfortable doing so. Here is an example of the pre-survey information that indicates the background of the Institute teachers:

- **How teachers heard about the institute and their expectations**

Of the 15 respondents, 5 teachers learned about the Institute from a mailing that was sent either to them or their school, 3 were told about the Institute by a colleague, 2 saw a flyer sent to TUSD, 2 were sent an e-mail, and 1 each saw information about the Institute in the UA/SAMEC newsletter, saw a memo at school, or attended a previous ERC Teacher Conference. When asked what they expect to gain from the experience, 7 wanted to develop lesson plans, 4 would like to gain skills on inquiry-based learning, 4 wanted more knowledge and connections with industry, 2 asked for a better understanding of the state science standards, and 2 desired information on the environment/pollution.

- **Success in promoting gender and cultural equity in their classrooms**

There were several different ways teachers promoted gender and cultural equity in their classrooms. The most popular way was to put students in diverse groups, with 3 teachers indicating this was successful. Two teachers each said they treated the students the same, gave them equal opportunity to succeed, or gave them equal wait time. Other successful methods that were mentioned included teaching students about how people in other cultures have overcome inequality, making students feel comfortable and important, using GESA practices, and considering all cultural celebrations/events of the students in the class.

- **Experiences with inquiry-based learning**

Almost all the teachers reported using inquiry-based learning. A total of 11 teachers indicated they used inquiry-based learning in their science classes, while 2 used this type of learning in their math classes, and 1 used it in the library.

- **Products teachers want to develop**

The most popular products teachers wanted to develop were labs, mini-lessons, cross-curriculum learning related to math, and exercises on data collection. Two teachers wanted material they could incorporate into the new state standards.

- **Prior experience developing lesson plans, labs and exercises**

Most of the teachers have developed lessons, labs or exercises. 10 teachers developed Science materials, and 3 teachers developed math materials. While 3 teachers have specifically developed labs for science classes, others developed lessons for the math and science curriculum.

- **Prior experience seeking funding**

More teachers have not written proposals to outside organizations to fund classroom activities, with 9 indicating they had not and 5 indicating they had. Grants that had been awarded included those for multicultural celebrations, ABLE literacy plan, Multiple Intelligence, Balanced Literature, Hands on Science for Primary, Literacy/Multicultural Study, upgrades to computer lab, professional development, and field trips. Generally, the teachers do not consider themselves to be familiar with the sources of grant money, with 4 not familiar at all, 6 not very familiar, 4 somewhat familiar, and only 1 who is very familiar.

- **Teachers as career advisors**

Although 10 teachers said they did advise students on career paths, 5 indicated they did only sometimes; 3 teachers said they did not advise students. When asked how knowledgeable they are about technical career opportunities, 2 indicated they have a fair knowledge, 11 said they are somewhat knowledgeable, and 1 is not knowledgeable at all.

- **Teacher priorities for Institute**

The most popular Institute goal was developing classroom materials, followed by integrating math and science, promoting inquiry-based learning, providing teachers with a research/industry experience, and promoting gender and cultural equity.

At the end of the experience the teachers complete an evaluation. All of the workshops and tours are evaluated as well as the program as a whole. Numerically the teachers rated the Institute 4.3 out of 5. They particularly valued the research and internship experiences, and networking with other teachers. The teachers reported that greatest benefits of attending the Institute were developing curriculum and lessons, learning real world applications, having a research experience, working with other teachers, and gaining knowledge on inquiry-based instruction. Some teachers reported learning about industry as a benefit. Other benefits mentioned were dealing with classroom management, learning how to write a grant, developing a thematic unit, reviewing the new science/math standards, incorporating gender equity into their lessons, and learning what engineers do. Exit survey responses indicated the majority (66%) of the teachers were appreciative of the workshops, and felt they helped provide information about inquiry science, as well as useful ideas for the classroom.

Below are some quotes from the teacher's post evaluation forms:

- I gained a chance to combine real-world experience and creativity to create new classroom experiences. I gained adult collaboration dealing with classroom management and inquiry-based lessons.
- I gained an opportunity to work with other teachers in developing new real-world curricula. Also, through the workshops, I have refocused on how to incorporate inquiry and gender equity into my lessons.
- Gained knowledge on inquiry-based instruction. Opportunity for collaboration with other teachers and UA students. Biggest benefit was lab work. Real-life applications.
- I gained experience working in a lab setting (opening my eyes to real math/science applications).
- The research experience was the best part for me. I got a chance to see how I can use what I teach.

The final component for the program is academic year follow up. The pre-service teachers intern in the classrooms of the teacher participants during the fall semester. These students typically help prep for new laboratory experiments and provide additional help during implementation of the laboratory exercises. All of the teachers are observed during the fall as well. The point of the observation is to ensure that the new lessons are being implemented and to provide feedback to the teachers in terms of how they are doing in terms of gender and minority equity in the classroom and inquiry based teaching.

More specifically, each teacher participant designed and developed an inquiry-based lesson to be taught during the following fall semester. Then, Tim Wernette and Lisa McDonnell conducted observation and evaluation of most of the participants' lessons. The observation and evaluation of the lessons focused on the four traits of inquiry-based science instruction (connecting, designing, investigating and constructing meaning) and the GESA teacher-student interaction patterns. Following each observation/evaluation a report was provided to the teacher as feedback.

Although it is difficult to generalize from all of the different inquiry-based lessons that were taught, overall the instructors and their lessons were of high quality, with lots of active participation on the part of their students. Teachers generally interacted relatively equally with both females and males and the various ethnic/racial groups of students in their classrooms. Most of the classrooms had positive representations of both genders and various ethnic/racial groups on the classroom walls.

The main problem and shortcoming of many/most of the lessons was the inability to include all four elements of the inquiry-based model into one classroom lesson. Because the lessons were conducted during one class period, most of them focused on the investigating element, and many did not include much or any of the connecting and designing elements. If the entire inquiry-based model is implemented, it requires multiple class sessions (or an extended class session: more than a 50-60 minute period). If this were implemented, it would make observation and evaluation of the lessons difficult due to the need for repeat visits to each teacher's classroom/school.

A summary of the information provided to a middle school teacher involved in the water recycle is provided here. The observer saw the water filtration laboratory exercise in action. He

commented that the teacher equally acknowledged and called on both girls and boys in the classroom, that the students seemed involved and all of the major traits of an inquiry based lesson were implemented. Furthermore, the students learned how the lesson relates to the "real world" of hydroponics green house design, water recycle, and bacterial removal.

Summary

Summer internships for teams of teachers and pre-service teachers, with opportunities for ongoing collaboration and support throughout the year, provide participants with both content and pedagogical knowledge. This improves the quality of instruction and student achievement. Overall, this program is highly successful. The enthusiasm the teachers bring to the laboratory makes the summer more enjoyable. The program routinely receives excellent feedback. The program should continue into the future and most of the recruitment is now via word of mouth. Of course, the program can always be improved and updated. One suggestion is arranging more field trips for teachers with their students during the academic year.

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