An Integrated STEM Research and Professional Development Project for Teachers

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Abstract - **This paper presents the structure, execution, and evaluation process implemented to provide a research experience to 7th to 12th grade science and mathematics teachers and a professional development program in science, technology, engineering, and mathematics (STEM) education. Each year twelve teachers are selected to participate in the program. Each year four project topics are chosen to provide an overall view on the research related to performance evaluation, health monitoring, and rehabilitation of civil infrastructure systems. Three teachers work as a team on one project for six weeks during the summer under the mentorship of a Civil and Environmental Engineering faculty member and a graduate student. In the paper, first, the project administration process used and the research projects and professional development activities executed during the summer of 2006 are presented, second, the classroom activities planned by each RET team as an outcome of their research activities are presented, third, the assessment process used as part of the evaluation plan is described, and fourth, the summative outcomes of the evaluation plan are presented. Hopefully, this documentation will help others in planning similar experiences for K-12 teachers.**

Index Terms - Civil Engineering, Research experience, Secondary school teachers, Professional development.

OVERVIEW

The Department of Civil and Environmental Engineering (CEE) at the University of Cincinnati (UC) has established the means for sustained research on various aspects of performance evaluation, health monitoring, and rehabilitation of civil infrastructure systems. With this base, and with support of the U.S. National Science Foundation (NSF) in the form of a Research Experiences for Teachers (RET) Site, twelve promising 7th to 12th grade teachers were immersed in authentic research in civil infrastructure engineering. This program hoped to motivate teachers to become critical thinkers, apply science to daily living, use civil infrastructure examples as a context to convey math and science concepts, and encourage their students to consider engineering careers. The teachers were divided into four teams of three teachers in each, and they worked on a research project under the supervision of a CEE faculty member and guidance of a graduate student. Following four projects were pursued by the teachers: 1) Modern Aseismic Design Strategies for Buildings; 2) Elimination of Persistent Odorous Compounds from Drinking Water; 3) Air Quality Sampling and Analysis; and 4) Impact Analysis of Traffic Control Infrastructure.

As part of the RET experience, the teachers took four one-credit hour professional development seminars taught by education and engineering faculty members and practicing engineers. They also worked with a team of five engineering graduate fellows working for a NSF Graduate K-12 Fellows Project STEP (Science and Technology Enhancement Project) on developing lesson plans before they finished the RET summer experience. These results are to be disseminated to other K-12 teachers through a dedicated Website (http://www.eng.uc.edu/dept_cee/research/ret/). The project evaluation plan includes assessment of both the impact of the research experience on the teacher and on student learning after the teacher classroom implementation.

The work done by the teachers is notable since today's civil engineers face the grand challenge of updating the nation's infrastructure, which is vital to its economy, security, and international competitiveness, and to provide for expanding populations while maintaining a balance between cost and adverse environmental effects. Globally, there are not enough civil engineers to face these challenges. Students need to be motivated to enter science, technology, engineering, and mathematics (STEM) fields. Nationally, students are not interested in math and science and failing to enter fields in the numbers needed. The RET program seeks to raise student interest by developing highly qualified and motivated teachers who teach math and science skills that results in solid learning and who can motivate and inspire students to enter careers in science, math or engineering.

PROJECT ADMINISTRATION

Teacher selection was based on the following process: an online application, an online review and rating, an interview, and final rating and selection. Upon obtaining the award from NSF, a flier announcing the "RET Opportunities" was sent to the principals of the secondary schools in 18 school

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districts. RET Site visits by Faculty Mentors to selected secondary schools was also made. Applicants completed an online application which included: 1) an application form with demographics; 2) a resume with educational background, occupational history, and description of special skills; 3) a short paragraph explaining the reasons for participation and goals for Post-RET implementation; 4) ranked choice of the research projects; 5) a letter from principal supporting the post-RET implementation; and 6) a recommendation letter from another administrator or teacher "leader." These online applications were rated by each Project Team Member (PTM). Each PTM was also asked to write a brief comment on each candidate on the following items, and then rate each item on a five-point numerical scale: 1) Experiences with position duties, skills, and performance? 2) How long and extensive is the track record? 3) Specific preparation, training, courses for this position? 4) Any unique strengths and likely contributions? 5) How good are the references? 6) Questions or gaps in the resume? Also, each member was asked to frame a unique question to ask the candidates if interviewed. After compiling the ratings, the PTM met to determine which applicants to interview for a 30 minute conference-call telephone interview. For 12 positions, 24 applicants were selected for interviewing. Each interview call was attended by at least four PTM and all calls were organized based on time convenient to the teachers interviewed and PTM. Each applicant interviewed was ranked on a Likert scale on overall quality and suitability for the four projects. In addition, the PTM were asked to briefly comment on: 1) How well did this person answer interview questions? 2) What stands out about this person? 3) Did you detect gaps, issues, problems? 4) What first impressions did you consider, then set aside? 5) What special follow-up action with this candidate should be done, if any needed? The final selection was based on a combination of merit and women or minority status, and suitability for the four projects. Scores were tallied, PMT members deliberated, and selected the 12 teachers which included 10 secondary and 2 middle school teachers. Upon selection and prior to the official start date, classroom visits were made. The visit entailed an observation of the teacher teaching multiple classes and a post-observation interview. This visit documented teacher's pre-RET skills.

The teachers conducted their *research* in the morning from 8:00 a.m. to 12:00 noon, and participated in *professional development (PD) seminar series* from 1:00 to 5:00 p.m. given by UC engineering and education faculty members and local professional engineers. The PD also included working with five engineering Graduate Fellows participating in an ongoing NSF GK-12 Fellows Track 2 Project and the four RET Graduate Research Assistants for developments of their lessons and posters. The teachers gave *biweekly PowerPoint presentations* and written progress reports on their research and development of lesson plans from it. The biweekly presentations were followed by a social hour during which food was served. They also participated in four *field trips*, one pertaining to each research project area. Some time was set aside for the teachers to prepare their biweekly presentation, lesson plans, and project report. Each participant maintained a daily log of research and PD activities in an electronic *"Journal Entry Book"* reflecting on the work done. These entries were sent daily to evaluation team, and the Faculty Mentor for the teachers' research projects. When goals of a project were nearing completion, teachers were assisted in writing their work as a *Technical Research Report*, *Lesson Plans* from research pursued, and a *Display Poster* documenting Post-RET activities planned. The presentations, technical research report, lesson plans, and poster, were evaluated by an invited panel of three external judges, who were professional engineers. Research report and lesson plans were hand delivered to the judges one day before the presentation. As teachers implemented their lessons and teacher-researcher skills during the following school year, a second classroom visit was done to observe the teacher. This was compared to the pre-RET observation. Contact was maintained with the teachers upon returned to classrooms and support was provided as they implemented new skills to improve student learning. Thus, the RET Site provided a "total" experience--learning, research, report writing, presentation, and translation into classroom activities.

DESCRIPTION OF THE RESEARCH PROJECTS

Modern Aseismic Design Strategies for Buildings

The objective of this RET Project was to test, evaluate, and compare results from small-scale models (1/24) of steel frames fitted with various types of damping and base isolation devices and subjected to base motions simulating an earthquake. Base isolation systems are a means of allowing the ground to move horizontally underneath a building due to an earthquake while the building remains relatively steady. These systems are gaining popularity as more economical and effective isolators have been developed. The teachers first conducted six experiments on one- and two-story small-scale building models to explore their use: to experimentally determine their lateral stiffness, frequencies, mode shapes, and damping characteristics. The models used consisted of four spring steel columns for each floor, which have fixed connections at the base, and a large steel block mass for each floor. The effectiveness of following three types of dampers was explored: viscous, friction and beam yielding. The experiments were then extended to test, evaluate, and compare results from small-scale models of steel frames fitted with base isolators, mounted below each column to decouple the frame from the shake table, and subjected to base motions. The shake table is forced to move horizontally simulating the ground motion caused during an earthquake. This RET project evaluated the use of the two types of base isolators, the commercially available rubber mounts used for machines, and the in-house fabricated elastomeric base isolators laminated with steel plates and with and without lead plugs. The lead plug yields when the isolator is displaced in shear and thus provides additional damping. To evaluate the use of such base isolator for aseismic design, experiments were conducted with three different size diameter rubber mounts, and three different types of elastomeric base isolators. Each of the rubber mounts selected was of the same height, but different diameter, thus varying in vertical and horizontal (shear) stiffness. The elastomeric base isolators included following types: 1) 3 layers and 2) 5 layers of very thin steel plates, and 3) optimum of 1) and 2) with a central lead plug. In this part of the project the teachers worked along with two undergraduate students who were participating in a Research Experiences for Undergraduates Site. Figure 1 shows the setup for a typical forced vibration test in which a model is mounted on a shake table. The educational extensions from the research project planned by the teachers includes: 1) The Effect of Earthquakes on Structures and 2) Wave Motion. The teachers prepared full lesson plans for these activities.

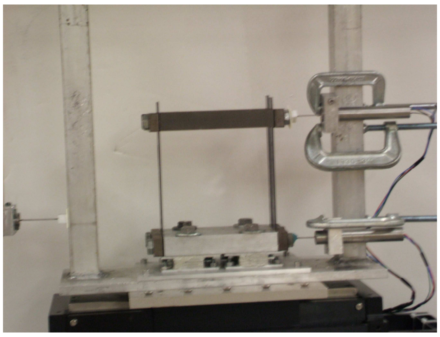

FIGURE 1
BASE-MOTION TEST SETUP

Elimination of Persistent Odorous Compounds from Drinking Water

Taste and odor have long been associated with the suitability and safety of our drinking water. Geosmin (trans-1, 10-dimethyl-trans-9 decalol-C2H22O) and 2-methyl isoborneol–C11H20O (MIB) are the major taste-and-odor-causing compounds in drinking water obtained from surface water. Adsorption by granular activated carbon (GAC) is considered as one of the best available technologies for removal of organic contaminants from water. However, natural organic matter (NOM) levels of 3–10 mg/L competitively reduce activated carbon adsorption capacity for MIB or Geosmin. Compared with GAC, activated carbon fibers (ACFs) have attracted increasing attention due to their excellent surface properties, high adsorption capacity and are an ideal adsorbent for targeting the impact of pore size. The purpose of this study was to integrate environmental technology with nanotechnology and surface chemistry to examine the selective adsorption of odorous compounds commonly found in water. The teachers evaluated the adsorption of Geosmin by activated carbon fibers in the presence and absence of humic acids. Four activated carbon fibers with varying degree of critical pore diameter were evaluated. These ACFs were ACC-10, ACC-15, ACC-20 and ACC-25.

In this study, the teachers were trained in the use of Gas Chromatography (GC) in analyzing for Geosmin. The method utilized was the latest method developed for analysis of odorous compounds, known as solid phase microextraction (SPME). The SPME is a solvent-less extraction technique that involves the exposure of a chemically coated fiber to a gaseous or headspace above the sample. 30 mL of the sample containing 5 g NaCl was placed in a 40 mL vial. The fiber coatings consist of a variety of polymers and solid adsorbents. Under controlled conditions (65 ^{o}C and mixing for 30 minutes), chemical compounds present in the sample adsorb onto the fiber coating. The next step was to desorb the fiber in the heated injection port of the GC for analysis. This procedure is used for establishing the calibration curve for the experimental samples. The calibration curve was determined by using linear regression analysis of the peak area of the compound determined in the GC and the theoretical concentration of the compound of interest (Geosmin). Once a good calibration curve has been determined ($R^2 > 0.95$ and coefficient of variation, CV < 10%), the experimental samples obtained from the isotherm bottles were then analyzed. 30 mL of the experimental sample containing 5 g NaCl was placed in a 40 mL vial and the procedure of the SPME outlined above for the calibration was repeated again. The concentrations determined by using the calibration curve was then used to determine the amount adsorbed. The data collected was then analyzed against two well known isotherm equations, Langmuir and Fruendlich. The analyses against these equations were run by using regression analysis in Sigmaplot Software. The results obtained revealed that ACF with the lowest critical pore diameter (ACC-10) did not adsorb any Geosmin. Adsorption by ACC-15 was significantly impacted by the presence of humic acid. ACC-20 adsorption with and without humic acid was similar to the adsorption of Geosmin by ACC-25 with humic acid. This clearly indicated that ACC-20 could be the adsorbent of interest that would not be impacted by the presence of humic acids. Figure 2 shows the test setup used by the teachers.

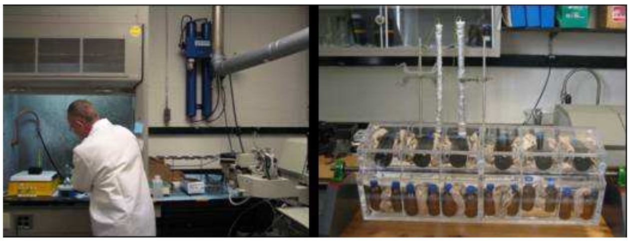

FIGURE 2
ENVIRONMENTAL CHEMISTRY LAB USED FOR THE PROJECT

The teachers along with the Faculty and Graduate Student Mentors wrote an editorial that appeared in the January 2007 ASCE *Journal of Environmental Engineering* [1] outlining the lessons gained from the research project. The educational extensions from the research project planned by the teachers were the following: 1) Removal of foul odors by using water with garlic smell to pass through an activated carbon adsorber; 2) Use of chromatography in separation by using filter paper (a pencil line drawn along the paper and a dot placed by an eraser pen at the bottom of the line) dipped in water; and 3) Studying the conditions that affect algae growth, which is a major cause of odor in drinking water.

Air Quality Sampling and Analysis

The goal of this project was to measure air pollutant emissions from biodiesel usage in a diesel generator, and compare the results with those of petroleum diesel. To train the teachers for the project handouts were given prior to their arrival, which included a general introduction, information on biodiesel, examples of biodiesel's use in the tri-state area, other energy conservation practices, useful websites, the description of EPA Method 5 for "Determination of

Particulate Matter Emissions from Stationary Sources," and a virtual PowerPoint tour of the Center Hill Research Facility, where the biodiesel tests were planned to be performed. The teachers also received on-site training in the first week to operate the various equipments. They used the gas analyzer to measure CO, CO_2 and NO_x. They learnt EPA sampling techniques, setting up generator loads, filter preparation, conducting gravimetric measurements, and procedure to calculate concentrations of the diesel particulate matter (DPM). They used volumetric devices to measure the volume of diesel and biodiesel and mix them at 1:1 and other different ratios. The teachers used laptop computers for data analysis and computations.

Teachers took samples from a diesel generator at UC Center Hill Research Facility, and collected DPM samples at various engine loads (idle, low, medium, and full load). Figure 3 shows a picture of the teachers working on this project. The graduate student assisted them in analyzing the organic compositions of the DPM samples. Based on their findings the teachers made following broad conclusion: 1) There is higher fuel consumption for B50 (50% organic material - plant oil and animal fat) when compared to B0 (pure petroleum diesel); and 2) Exhaust components such as CO_2, NO_x, and PM (particulate matter) increase in concentration as the load increases.

FIGURE 3
BIODIESEL LAB USED FOR THE PROJECT

Each of the three teachers developed lesson plans to bring the RET experience to their classrooms. This included the following: 1) Teacher 1 (Math teacher, 7th grade) developed a lesson plan entitled "Air Quality: Air Pollution Data Analysis," to be offered over 10 class periods of 45 minutes each; 2) Teacher 2 (Physical Science teacher, 9th grade) developed a lesson plan entitled "Air Quality: Air as a Solution, Colloid, and Suspension," to be offered over 2 class periods of 50 minutes each; and 3) Teacher 3 (Physical Science teacher, 9th grade) developed a lesson plan entitled "Air Quality: Alternative Fuel Sources," to be offered over 3 class periods of 90 minutes each.

Impact Analysis of Traffic Control Infrastructure

The specific goals of this project were to provide opportunities to the teachers to: 1) Explore the traffic engineering method of inquiry and the critical research skills that engineers use to solve traffic operation problems at a signalized intersection.; and 2) Apply their research experiences to inspire students to learn math and science by showing its context in the world they live and to also make them aware of the different engineering career pathways. To achieve the above goals, the following objectives were fulfilled: 1) The teachers learnt traffic engineering techniques for data collection in field using traffic movement counters and videotaping methods, and the skills of analyzing the observed data to demonstrate abstract concepts in algebra and statistics. 2) The teachers learnt the use of traffic analysis and simulation software to show how to identify traffic problems and evaluate proposed alternatives for intersection improvements. The teachers understood that computer simulation enables decision-making process risk free, because one could try any possible scenario. 3) The teachers also learnt how to use simulation feedback output files to visualize and understand the nature of traffic problems and think of improvement alternatives.

Following training was first provided to the teachers in order to proceed with the project: 1) Lectures on Basics of Traffic Engineering Theory (One Week); 2) Field Data Collection Training with Use of Traffic Movement Counter and Videotaping Techniques (One Day); 3) Highway Capacity Software (HCS) and Synchro Software Training (One Week) to further understand the fundamentals of traffic analysis; 4) Microscopic Simulation Software VISSIM Training (Two Weeks) to learn VISSIM, including how to build network and travel features, set up output files, and demonstrate animations in 3D mode; 5) Training for Integrated Traffic Analysis Methods (One Week) to analyze results obtained from Highway Capacity Software (HCS2000), Synchro, and microscopic simulation software VISSIM4.1, as well as their perceptions through field videotaping observations; and 6) Field Trip to Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) (Half Day) to see how traffic flow data in collected and analyzed in real time using advanced information technologies (IT) and how the information generated is used to regulate traffic and respond to accidents in a major metropolitan like Cincinnati.

The trained teachers applied their knowledge to collect data for an actual intersection in the city (see Figure 4), analyze it, and design traffic control strategies to improve the traffic flow and decrease chances of accidents. Traffic movement counters, stop watches, and videotaping equipment were used to collect data on traffic volume and signal phasing at the intersection. They used traffic simulation software to design the network with the existing road conditions and signal configurations to test the current Level of Service (LOS). Then, they used the traffic simulation software Synchro and VISSIM to redesign the network to test possible solutions that improved the existing LOS. Finally, the teachers developed lesson plans and activities for a Geometry course which included practical field work, classroom data analysis, and application of traffic engineering and simulation concepts for engineering design.

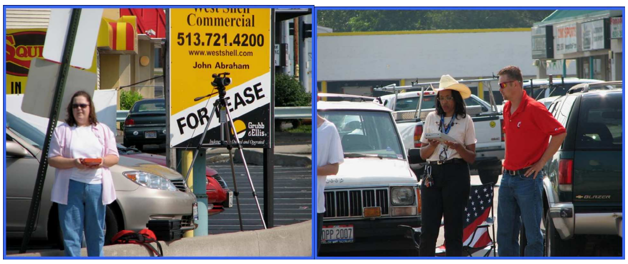

FIGURE 4
TEACHERS COLLECTING TRAFFIC FLOW DATA

PROFESSIONAL DEVELOPMENT AND TRAINING

Learning By Inquiry. The learning by inquiry seminar was designed to parallel the inquiry the teachers were experiencing in the laboratories. The three sessions were: Structure of Knowledge, Nature of Knowledge Production, Nature of Learning, and Nature of Inquiry. The fourth session then was adapted to reflect on the nature of learning and the nature of inquiry in the classroom. It appeared that most of the teachers began to wonder about the preconceptions they held on learning and discovery learning. The teachers at this time were fairly along in their own research and were able to make connections between engineering research and the structure of the instruction in their own classrooms.

Evaluating Authentic Teaching and Assessment. RET participants took part in 14 seminars on evaluating authentic teaching and assessment. The seminars were designed to reinforce and expand teacher knowledge in this area through teacher-lead discussion, hands-on activities, and the infusion of technology. Teachers were encouraged to bring in their current assessments for comparison and rework.

Engineering Seminar Series. Each seminar included following three elements: 1) skills sets and educational training needed; 2) practice of engineering with examples of actual real-world projects; and 3) examples and resources available that can be used in the K-12 classrooms. All seminars were held typically from 1:00 to 3:30 p.m. with a break in between. All seminars allowed time for direct two-way interaction between the professional engineers and teachers to address teacher specific needs. A brief description of the contents of the seven engineering seminars follows. 1) *Engineers and What They Do*. A faculty member from the Department of Civil and Environmental Engineering presented an overview of the primary duties and definitions of the different engineering disciplines and different sub-disciplines of civil engineering in particular. A typical undergraduate engineering curriculum and the math and science preparation needed by High School students was presented. 2) *Structural Engineering Professions* A Structural Engineer from THP Limited, Inc., Cincinnati, Ohio briefly described some of the general aspects of structural engineering, including design methodology as well as properties of commonly used construction materials. How subjects such as trigonometry, calculus, algebra, physics, and chemistry are utilized to solve structural design problems were presented. 3) *Geotechnical Engineering Professions.* Geotechnical Engineer from Richard Goettle, Inc., Cincinnati, Ohio introduced the field of geotechnical engineering by presenting different types of geotechnical projects in Cincinnati and surrounding States which their company has designed and constructed. Applications of algebra and trigonometry with regards to behavior analysis and design of earth retention structures were presented. 4) *Water Resources Engineering*. An Administrator from ORSENCO (Ohio Valley Water Sanitation Commission), Cincinnati, Ohio described the pollution and water quality monitoring program along the Ohio River Basin and its impact, and described the K-12 outreach programs offered by ORSENCO. 5) *Air Pollution: Toxic Air Contaminants in Hamilton County.* An Administrative Coordinator for Hamilton County Environmental Services, Cincinnati, Ohio gave an overview of the types and levels of contaminants in the local region, how they are measured, the risks they pose, and possible outcomes. 6) *Environmental Engineering and the Capacity Assurance Program Plan for Metropolitan Sewer District of Greater Cincinnati.* An Environmental Engineer from CH2M HILL, Cincinnati, Ohio described how storm water collection systems are planned, designed, and constructed. Actual storm water data was presented to show the mathematics of the process used to evaluate alternative pipe-network systems as part of a water treatment facility. 7) *Transportation Engineering Professions.* A Transportation Planner from URS Corporation, Cincinnati, Ohio discussed about the geometric aspects of highway design and practical applications that can be used in high school algebra, geometry, pre-calculus, and calculus classes.

PROJECT EVALUATION

The project evaluation plan includes assessment of both the impact of the research experience on the teacher and on student learning after the teacher classroom implementation. The RET projects are to provide an opportunity to the teachers to learn how they can engage the interests and abilities of their students by allowing them to see how STEM concepts are used to discover the world and solve society's pressing needs. This RET Site provided the teachers with experience in using state-of-the-art testing, data recording equipment, and simulation tools and a "total" experience of learning through research, report writing, presentation, and translation into classroom activities. All constituencies identified in the project were involved in the assessment: teachers, university instructors, faculty mentors, Graduate Research Assistants, and the students of teachers. Baseline data on attitudes and instruction practice, as well as general demographics of each constituency, was collected at the beginning of the project and periodically throughout the project, and at conclusion. The quantitative and qualitative instruments used to conduct the evaluation for the RET project and the timeline for their implementation are presented in Table I. Teachers indicated their prior experiences in engineering research and education before entering RET. After participating in the RET Site the teachers rated a variety of teaching skills and techniques and their levels of confidence in using these. These reflect a range of traditional to more authentic techniques. This inventory was done pre and post to measure changes as a result of participation in RET. Teachers rated the training environment of the research project and instruction they received during RET. Teachers completed pre and post surveys to determine changes in their confidence about and attitudes towards teaching and learning in science and math. In addition to the above data, teacher participants submitted Daily Journals, Course Assessment Surveys, Faculty Mentor Ratings, Graduate Research Assistant Ratings, and Teacher Feedback/Satisfaction Surveys. Judge Evaluation Scoring Form for Participant Technical Research Report, Participant Presentation, and Participant Poster Presentations were completed by a team of three professional engineers who

TABLE I
EVALUATION IMPLEMENTATION TIMELINE

Description of Data Source	Description of Timeline					
	1*	2*	3*	4*	5*	6*
Classroom Observations	X				X	
Course Assessments			X			
Curriculum/Instruction Inventory	X				X	
Faculty Mentor Rating Scale			X			
Focus Group Interviews	X		X			X
Graduate Research Assistant Rating Scale			X			
Judge Evaluation Scoring Form for Participant Poster Presentation			X			
Judge Evaluation Scoring Form for Participant Presentation			X			
Judge Evaluation Scoring Form for Participant Technical Report			X			
Prior Exposure to Engrg. Res. Questionnaire	X					
Research Training Environment Survey			X			
RET Tracking Form						X
Student Learning Activity Feedback					X	
Student Math Attitude Questionnaire				X	X	
Student Science Attitude Questionnaire				X	X	
Student Subject Preference Inventory				X	X	
Teacher Feedback/Satisfaction Survey			X			
Teacher Journals		X	X			X
Teacher Self Efficacy and Attitude	X		X			
Teacher Skills/Confidence Inventory			X			
Website Material				X		
Papers/Presentations				X		
OGT results				X		
Student Learning Portfolios				X		
Classroom Observations	X				X	

* 1= Pre Project Term; 2 = During Project; 3 = Post Project; 4 = Pre-Year 1; 5 = Post-Year 1; 6 = Long Term

TABLE II
MAPPING OF THE TEACHER GAINS WITH PROJECT GOALS

Goal	Key Question	Teacher Gains
I	To what extent did the RET program empower teachers to use inquiry and critical research skills to solve real world science and math problems in their classroom?	• Gained knowledge of technical information and writing. • Gained knowledge of research and scientific method process • Learned to take data for what it is. • Learned variety of fields and careers of engineering • Learned science is a discipline • Learned development of rubrics and assessments • Learned how engineers work • Compiled list of contacts for resources • Improved, more effective lessons • Team approach and collaboration valued
II	To what extent do the teachers share skills learned in RET with students and colleagues?	• Teams • Staff Meetings • Presentations • Showing • Modeling • Sharing flyers, booklets • Ambassador for program • Share with other buildings in district
III	How does the RET program impact learning in the science and math classrooms?	• Will utilize community resources to enhance authentic experiences • Fieldtrips • Knowledge of engineering fields and careers • Guest speakers • Effective Lessons • Integration of technology • Reduces classroom management problems by engaging students • Renewed support for use of teams and collaboration

evaluated the products created by the teachers as a results of their involvement in the project - the technical reports projects based on their research projects; the presentations based on their research projects and lesson plans; and the posters created by each teacher based on their lesson plan. These evaluations demonstrated the teachers' acquisition of learning and critical thinking skills as a result of project participation. Due to page limitations not all the above evaluation results can be presented in this paper. The overall project effectiveness will involve both formative and summative evaluation. Annual summative evaluations will serve as the basis of the formative evaluation for the subsequent year. The gains for each of the project goals are summarized in Table II based upon teacher focus groups and Teacher Feedback/Satisfaction Surveys.

CONCLUDING REMARKS

In summary the teachers experienced research and developed authentic learning activities and have become familiar with the importance of the scientific method of inquiry and the critical research skills that engineers use to solve open-ended real-world problems. They learned practical considerations of research, technical writing, lesson planning, and presentation. They have shown an increased understanding of skills required and their own confidence in using skills. They have also shown an increase in skill and understanding on how to directly link their education to events and issues occurring within their community. Teacher comments are highlighted from the Teacher Feedback/Satisfaction Surveys are presented below:

"I have seen the math and science in so many aspects of my life now. I can't drive home without thinking about the geometry and the science behind how I can drive home. I feel like real-life application is easier for me now".

"I forgot how much fun research could be!"

"I enjoyed the seminars. I found them educational in that I learned something new. My favorites were the ones that geared it back to how we could use it in the classroom. I don't know which was the best. I don't know that any were outstandingly better than others. I just really liked the portions when they would say "in your classroom you could…" Great ideas. I wish they were a little more geared that way. I now have a better knowledge of how I can use examples".

ACKNOWLEDGMENT

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