AC 2010-1101: RESEARCH EXPERIENCE FOR TEACHERS SITE: A PROFESSIONAL DEVELOPMENT PROJECT FOR TEACHERS

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Research Experience for Teachers Site: A Professional Development Project for Teachers

1. Introduction

In recent years, science and math educators, technology professionals, business leaders, and policymakers have pointed to an urgent need to develop a strong and technologically trained workforce to ensure American leadership in the 21st century "innovation economy." Unfortunately, the American K-12 education system is currently suffering from a crisis of inadequate teacher preparation in STEM[1] disciplines leading to poor student achievement in these areas. This is especially true for African American, Hispanic, and female students. Weak academic preparation of minorities and women closes these groups out of scientific careers at a very young age. In fact, on January 6, 2010, when President Obama launched his "Educate to Innovate" campaign, he said, "Teacher quality is the most important single factor influencing students' success or failure in STEM subjects." The Educate to Innovate initiative will train math and science teachers so that they can support their students to excel in these subjects.

For close to a decade, a team of engineering faculty, graduate researchers, and undergraduate students at the Polytechnic Institute of New York University (NYU-Poly) have collaborated to improve teacher preparation in STEM disciplines. With the support of various federal, state, and foundation grants, a variety of programs, from one-week to six-weeks in duration, have been conducted to introduce engineering disciplines and practices to over 150 teachers. This paper describes a pre-college teacher engagement project conducted under the Research Experience for Teachers (RET) Site program of National Science Foundation. The project is based within the mechanical engineering department at NYU-Poly. Ten teachers were selected to attend a six week summer research workshop in 2009.[2] The workshop consisted of two-weeks of "Guided Training" followed by a four-week "Collaborative Research" experience.

This paper provides an overview of the RET Site program's structure and activities. In addition, illustrative examples of teachers' research and its classroom integration are given. Highlights from external evaluator's report are also included.

2. Overview

Under the umbrella of an RET Site program, NYU-Poly offers a paid research opportunity to ten teachers each year to participate in an intensive professional development

[1] Science, technology, engineering, and mathematics

[2] Due to an unforeseen professional appointment, one teacher requested to withdraw from the project and was allowed to so.

opportunity in STEM disciplines. The project is led by an engineering faculty member and enjoys the enthusiastic participation of three additional engineering faculty and numerous undergraduate and graduate students. An external evaluator formulates and conducts project assessment. The main objectives of this RET Site project are as follows.

1. Introduce the multidisciplinary field of mechatronics to teachers using a structured and integrated learning environment, consisting of training, mentoring, and real-world engineering research.

2. Provide teachers with experience, skills, and resources in mechatronics-oriented, hands-on, engineering research so that they can improve their research skills and can integrate project-based learning in their classrooms.

3. Strengthen ties between NYU-Poly faculty and NYC school teachers.

Each spring, the project team invites STEM teachers from over 300 local high schools to apply for the RET Site project. The project is advertised through direct mailing of fliers to principals and science/math chairs of over 300 local high schools. Exceptional candidates who can integrate project activities at the middle school level are also encouraged to apply to the project. The project is also advertised at local events such as science fairs and FIRST Robotics competitions. An open house information session is conducted to allow teachers to visit the institute, meet project personnel, and learn about the project, e.g., requirements, research opportunities, summer time commitment, academic year follow-up, etc. A selection committee consisting of project faculty and experienced graduate students reviews all applications (over 30 each year) and selects ten finalists. The selection is based upon the evaluation of application material submitted by the candidates (e.g., cover letter, formal application approved by the school principal, scholastic record, vita, statement of interest, strength of letters of recommendation, commitment to develop and integrate hands-on engineering activities in the curriculum, etc.). The finalists are informed of their selection in the program and asked to provide a signed commitment to attend the program. A meeting of the project personnel and selected teachers is conducted to plan the summer program and facilitate teacher-mentor matching. Table I summarizes various recruitment and selection activities.

Table I: Summary of Recruitment and Selection Activities

January	Web announcement, project fliers mailed to schools and distributed at the borough-level FIRST robotics contests
March	Open house information session, project fliers distributed at the citywide FIRST robotics contests, application deadline
April	Application review, finalists informed
May	Teacher-mentor matching, finalists submit signed commitment

The first day of the summer workshop begins by providing the teachers an orientation to the university. For example, in summer 2009, at an RET Welcome Breakfast hosted by the Dean of Undergraduate Admissions, the Provost delivered remarks welcoming the teachers to the project. Next, the Dean of Undergraduate Academics provided an introduction to NYU-Poly. Moreover, the director of an outreach center discussed NYU-Poly's diverse array of educational and outreach activities geared towards the K-12 educators. Finally, an Associate Dean of Undergraduate Admissions discussed various opportunities for teachers to enhance their students' educational experiences through lab tours, college credits, etc.

Following the Welcome Breakfast, the teachers were introduced to the participating engineering research labs and lab safety. In addition, experimental demonstrations of a variety of educational and research projects were given to stimulate teachers' interest in the RET summer workshop. Finally, teachers were given a kit of components and supplies for them to use throughout the summer workshop and eventually take back to their schools.

Next, for two weeks, 18 guided training sessions were conducted under the supervision of an engineering faculty, a graduate assistant, and two senior undergraduate assistants. The guided training sessions introduce teachers to the fundamentals of sensors, actuators, electronics, electro-mechanical components, microcontrollers, and robotics. Each morning and afternoon session of guided training includes a one-hour lecture, a two-hour structured project activity, and a one-hour discussion. The structured project activity for each session augments the corresponding lecture and consists of hands-on experiments with clearly-stated objectives, a sequence of steps to be followed, and a description of expected results. These activities illustrate real-world applications of material covered in the lectures, thus reinforcing and imparting a greater sense of understanding. The discussion hour of each session provides teachers with an opportunity to reflect on and further explore the session's work and to brainstorm ways of integrating these activities to illustrate pre-college science and math concepts. In summer 2009, during the guided training phase, 10 doctoral students interacted with teachers by serving as teaching assistants. Specifically, each doctoral student participated in two sessions. This opportunity allowed the research assistants to interact with teachers and learn about the K-12 environment. Table II summarizes various topics covered in the guided training sessions.

Table II: Guided Training Topics

Session	Topics	Session	Topics	Session	Topics
1	Resistor	7	ADC	13	Transistor
2	Mechatronics	8	Servomotor	14	Relay
3	LED	9	555 timer	15	H-Bridge
4	Button	10	Thermal sensors	16	DC motor
5	Capacitor	11	Robotics	17	RC filter
6	Optoelectronics	12	Infrared sensor	18	Op amp

In summer 2009, during the research experience phase of the program, three two-teacher teams and three individual teachers conducted research in a collaborative environment consisting of graduate researchers, undergraduate summer research assistants, and four engineering faculty. Furthermore, the teachers developed lesson plans to highlight salient aspects of their education and research experience for their future use and to share with colleagues. The project provided the teachers an opportunity to immerse themselves in a collaborative research environment with research assistants and faculty mentors to experience the process of conducting research. These experiences have allowed the teachers to practice and hone their research, communication, and teamwork skills. As delineated in Section 3, the participating teachers made significant contributions to six research projects. Table III summarizes various activities conducted during the summer workshop.

Table III: Summary of Summer Workshop Activities

Day 1	Welcome and orientation to NYU-Poly, tours of research labs, introduction to lab safety, distribution of and introduction to a mechatronics kit, administration of a pre-project survey
Days 2—10	Morning and afternoon guided training sessions, interaction with graduate assistants, planning meetings with research mentors
Days 11—29	Collaborative research projects, Friday review meetings with the lead faculty mentor to provide updates on progress of research and lesson plans, evaluator's visit (observations, focus groups, and lab visits)
Day 30	Administration of a post-project survey, research presentations

To foster on-going engagement with the teachers, several activities were conducted. For example, in fall 2009, a SMART Day event was held to showcase teachers' research to their colleagues. Moreover, all project teachers attended two Research Seminar Days at which university-based researchers presented progress reports on research projects that continued after the summer workshop. Individual mentors/research assistants visited their partner teachers' schools in spring 2010. Finally, some teachers have continued their participation in their research projects beyond the six week summer workshop.

3. Integrated Research and Education Activities

A Microcontroller-based Design and Realization of a Two Degree-of-Freedom Laser Doppler Velocimetry Traverse System: Laser Doppler Velocimetry (LDV) offers precise measurements of fluid flow regardless of its flow regime. The relatively low cost, ease of use, and expandability of LDV make it suitable for a wide array of fluid dynamic, vibration, and fluid structure interaction experiments. Interfacing the highly precise optical LDV equipment with physical phenomena necessitates creating a robust, simple, and precise control system. To create such a robust control architecture for the LDV measurement system, one can synergistically integrate the underlying mechanical, electrical, and computing components in the spirit of mechatronics. Mentored by a mechanical engineering faculty Professor Maurizio Porfiri, teachers Mirlene Leveille and Henry Penna collaborated with a Ph.D. student Karl Abdelnour to design, prototype, and evaluate a two degree-of-freedom electro-mechanical optical traverse stage for precisely controlling the motion of a laser probe. The teachers also developed a simple method for the calibration of the traverse stage. For classroom implementation, Ms. Leveille and Mr. Penna developed a lesson titled *How does an Electric Relay work?* This lesson considers the operation of electrical relays that are used in numerous electric devices. The relays allow low-power electronic control elements, e.g., microcontrollers, to actuate electrical devices requiring large current/voltage. Through this classroom activity, students learn about magnetism and electromagnetism, and use of these properties in creating electrically-controlled switches, i.e., relays.

Creep Test on HDPE and RFG using the Stepped Isothermal Method—Temperature Control Instrument: Temperature-induced stresses can be a major concern for reinforced concrete structures in regions of drastic temperature changes. Mentored by a civil engineering faculty Professor Magued Iskander, teachers Toufik Ayoub and Leila Cohen collaborated with a Ph.D. student Saumil Parikh to develop a mechatronics apparatus to control the temperature of a specimen subjected to a creep test. This apparatus facilitates experimental examination of the effect of combined temperature cycles and different loading rates on the durability of High Density Polyethylene (HDPE) and fiber-reinforced polymer (FRP) specimen bars. As test specimen were subjected to a series of cyclic temperature variation, the teachers collected experimental data and analyzed it from several aspects: ultimate strength under different loading rates, elastic modulus, fatigue strength, and failure mode analysis. For classroom implementation, Mr. Ayoub and Ms. Cohen developed a lesson titled *Specific Heat*. This lesson enables students to relate thermal energy to heat capacity by comparing the heat capacities of different materials and graphing the change in temperature over time for a specific material. Students explore the idea of insulators and conductors in an attempt to apply their knowledge in real world engineering applications.

Biomimetic Sound-Localization in the Plane Utilizing Head-Related Transfer Functions: Mentored by the author, teacher Jason Farina collaborated with an undergraduate researcher Renjun Liao to examine the feasibility of creating a biomimetic system to locate sounds in a plane. A sound measuring system consisting of two microphones with asymmetrical "pinnae" was constructed. To circumvent the need for knowing input sound wave, the ratio of Head-Related Transfer Functions (HRTFs) corresponding to the right and left ear was used for spatial mapping of sound field. Using a least squares matching method and a 72-position (5 degree increments) database, the proposed biomimetic system yields 100% localization accuracy when an actual sound source is located at any one of the 72 positions in the database. The present coarse database yields less than satisfactory results for adjacency-matching (when actual sound source is between two neighboring locations from database). The research team intends to improve the database with a finer discretization, which is expected to yield improved and accurate interpolation and adjacency-matching. In addition, advanced classification techniques are also being explored. As previously indicated, the proposed approach obviates the need to know the sound source signal. Furthermore, HRTFs have the benefit of potentially being distinct for all directions, eliminating the front-back ambiguity of strategies utilizing the inter-aural time delay or the inter-aural volume difference. For classroom implementation, Mr. Farina developed a lesson titled *Thinking Like a Researcher—Adding and Subtracting Integers*. Through this lesson, students are introduced to "Researcher Habits of Mind." A few habits are demonstrated to the students, who are then asked to utilize them to better understand the behavior of integers under addition and subtraction.

The research projects and lesson plans, respectively, developed by the remaining four teachers in summer 2009 are listed below.

Detection and Characterization of Damage in Beams using Chaotic Excitation and *Enhancing Students' Skills in Inverse Operation using Ohm's Law*—Seth Akomah

Evaluation of Fiber-Optic Loop Sensor Mounting on Laminated Glass Fiber Composites based on Power Modulation and *Simply Supported Beam Deflection*—Robert Gandolfo and John Schineller

iPhone/iPod Touch as a Mobile Data Acquisition and Control Device and *Making Sense of the iPhone Sensors*—Lindrick Outerbridge

4. Evaluation Results

An external evaluator performed following activities to assess project's impact: review of program literature and discussions with project faculty, data collection about implementation of different components of the program, interviews of selected research supervisors, site visit to interview teachers and conduct observations in their research labs, follow-up interviews with selected teachers, and analysis of data. Following are some of the highlights of project evaluation for 2009.

Teaching experience of the nine teachers ranged from three to 30 years with an average of ten years. During the previous school year, eight of the nine teachers taught math (3), robotics and programming (3), and physics and research (2). While four teachers had no prior research experience, four reported research experiences from undergraduate projects or careers as research engineers. Their teaching priorities include: ensure students learn accurate information (100% of teachers); teaching problem-solving (100% of teacher); finding interesting applications

(88% of teachers); getting students to work cooperatively (88% of teacher); and preparing students for standardized tests (77% of teacher). This illustrates that these teachers are conscientious and balanced in their approach to instruction and learning.

In the first two weeks, guided training sessions provided morning and afternoon lectures, each followed by structured projects in which the learned concepts were applied to practical engineering situations. In interviews, several teachers indicated that they had familiarity with topics such as electric circuits but found the review to be helpful. At the start and at the conclusion of the project, teachers were administered a 35-item inventory on familiarity with skills, concepts, and devices introduced during guided training. While at the start of the project, teachers' reported low levels of familiarity with project topics (average 2.02 out of 4), by project's conclusion, teachers reported high levels of familiarity with project topics (average 3.24 out of 4). The very substantial increase in familiarity with the 35-item inventory is not surprising since most material was new to teachers. However, it is gratifying to note that teachers' familiarity was enhanced throughout an extensive list of skills, concepts, and devices. In interviews, the teachers reported that the structured portion of the program was very practical, saying that they learned it and then went out and did the exact same thing. These evaluation results illustrate that Objective 1 of this RET Site is successfully met.

Research projects and teams were assigned based on teachers' background knowledge and training, current responsibilities, and match with the participating labs at the university. All projects included a strong teamwork component and the teachers reported different ways in which the members of the teams complemented one another. Different team members were skilled and experienced in programming; designing and building experimental apparatus, or analyzing data. Thus, the team-members sorted out the division of work themselves. Those working alone as well as in teams were pleased with their undergraduate or graduate research partners and faculty research mentors.

The teachers recounted a number of ways in which the experience provided new and deeper understandings of the research process. From their perspective, research projects were found to take longer than expected; often materials, devices, or procedures did not work as expected; and in general it was more difficult than anticipated to achieve desired results. Several teachers reported that they made the mistake of thinking they would be able to accomplish more than they could in the allotted time. Yet, some teachers commented that the research experience, with its frustrations, would be useful in working with research students in their schools. They now had first-hand experience of what it means to "do" as well as to learn science. They reported that they would be able to tell their students what to expect, to help them budget time, to tailor research objectives to the available resources, and to supervise students with greater understanding. Finally, teachers identified a number of satisfying experiences and benefits from their research experience, e.g., working on compelling projects and making significant progress, working with innovative technology and understanding how it can be used in classroom, using material learned during guided training in research projects; etc. The aforementioned summary of teachers' assessment of their research experience reveals that Objective 2 of this RET Site is being satisfied.

The faculty research mentors were pleased with the quantity and quality of teachers' research. One mentor said that he had hoped that the teachers' work would yield some useful data and it actually did. He added that he had advised his teachers to use imagination and devise common sense schemes to solve the research problem. He concluded by saying that the participating teachers had developed methods that would contribute to the overall goals of his research. Other faculty mentors also discussed various research projects in which the teachers participated. These discussions revealed that in all cases, teachers encountered problems, obtained direction from their mentors, and worked productively with undergraduate or graduate students. The issue of time was always present and research mentors said that the teachers had to learn that there were clear limits on what could be done in four weeks. Some teachers continued with their projects after the allotted time of the program. This is allowing NYU-Poly faculty participants in the project to continue their collaboration with project teachers, fulfilling Objective 3 of this RET Site.

It is natural to expect that after successfully completing the RET Site project, teachers will be better equipped to address STEM learning and training needs of their students. Thus, in a post-program survey, teacher's response to a question concerning challenges in teaching science revealed a breadth of vision in discussing long-term knowledge, connections, and the motivation of their students. They listed challenges including: student interest and motivation, teaching/learning strategies suited to different student levels; adequate coverage of different subjects, incorporating research methods and technology, etc. However, a common thread of their response was the desire to engage all students. Engagement is understood to mean becoming involved in science that is applied and relevant in today's world. Since the research topics of this RET Site answer this need, the teacher were generally pleased with the program, reporting that it would serve them well in their schools.

5. Conclusion

Under National Science Foundation's RET Site program, NYU-Poly is offering paid research opportunities to ten teachers a year. The project engages teachers in numerous hands-on engineering learning and training activities to hone their skills and enable them to conduct inquiry-based, engineering research. Participation in the project reinforces teachers' science and mathematics skills; enriches their STEM experience through exposure to real-world engineering applications; and develops their research, communication, and presentation skills. Through successful completion of the project activities, teachers develop capabilities to: integrate real-world, hands-on, learning activities in their classrooms; assist students to conduct research and participate in science competitions; and become science and technology ambassadors in their schools.

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