# 2006-23: IMPROVING K-12 TEACHING THROUGH THE RESEARCH EXPERIENCES FOR TEACHERS PROGRAM AT THE UNIVERSITY OF HOUSTON

**Julie Trenor, University of Houston**

JULIE MARTIN TRENOR is the Director of Undergraduate Student Recruitment and Retention for the Cullen College of Engineering at the University of Houston in Houston, Texas. She teaches freshman engineering courses, and serves as the director the women-in-engineering program as well as the NSF-sponsored Research Experiences for Undergraduates and Research Experiences for Teachers programs.

**Jennifer Ruchhoeft, University of Houston**

JENNIFER L. RUCHHOEFT is the director of Girls Reaching and Demonstrating Excellence (GRADE) Camp Director and Educational Grants Manager in the Cullen College of Engineering at the University of Houston in Houston, Texas.

**Frank Claydon, Unviersity of Houston**

FRANK J. CLAYDON is a Professor in the Department of Electrical and Computer Engineering at the University of Houston, in Houston, Texas and is the Associate Dean of Undergraduate Programs and Computer Facilities in the Cullen College of Engineering.

**Stuart Long, University of Houston**

STUART A. LONG is a Professor in the Department of Electrical and Computer Engineering at the University of Houston, in Houston, Texas, and is the Associate Dean for Educational Activities in the Cullen College of Engineering.

## Improving K-12 Teaching Through the Research Experiences for Teachers Program at the University of Houston

### Background and Program Description

The National Science Foundation (NSF) initiated the Research Experiences for Teachers program as part of the Directorate for Engineering in fiscal year 2001 with the goal of engaging in-service or pre-service teachers in university engineering research so that the teachers can introduce engineering content in their pre-college classrooms. The University of Houston's Cullen College of Engineering is an NSF-sponsored RET site now entering its third year. The program is designed to give Houston area mathematics and science teachers meaningful engineering-related research experience that they can draw upon to educate their students about engineering career opportunities.

To date, the UH-RET site has hosted 25 participants from 17 schools in nine independent school districts, with another 14 participants expected in the summer of 2006. The diverse nature of the Houston community allows RET participants to subsequently reach a wide range of ethnic and socio-economic groups, including numerous under-represented minorities. Teachers who have participated teach a variety of subjects and levels, including courses in mathematics, physics, biology, chemistry, computing, and technology.

Each teacher works closely with an engineering faculty member and graduate student(s) to conduct independent research, and is also paired with a student participant from our Research Experiences for Undergraduates (REU) program for the summer. Teachers are encouraged to develop ways to include their new-found knowledge and perspective of engineering into their regularly-taught courses.

A week of Infinity Project™ training has been included in the past two programs. The Infinity technology package consists of a desktop or laptop computer linked to a Texas Instruments Digital Signal Processing board coupled together with a graphical software design environment to facilitate student learning. An example of an Infinity module is the demonstration of cell phone technology: teachers explain basic trigonometry principles, which, through simple extensions of sine and cosine waves, are used to create virtual electromagnetic waves that transmit digital voice signals from phone to phone through the air. Teachers may choose to incorporate the Infinity Project™ kit they were given as part of the program into their regular lesson plans. Alternatively, by securing funding for additional kits, their school can establish a separate course using the Infinity Project™ curriculum in its entirety.

In addition to research and Infinity Project™ training, teachers participate in periodic professional development seminars. At the end of the program, teachers are given a $100 gift certificate to the Engineering Education Service Center web-store to purchase engineering-related materials for their classroom.

## Recruitment of Participants

The program is advertised to math and science department chairs in all high schools in the metro-Houston area, as well as high school principals, school district superintendents, and pre-service teachers in the College of Education at the University of Houston. Potential participants can learn more about the program and download an application from our program website (www.egr.uh.edu/ret). Selection of participants is made on the basis of teacher initiative, imagination, creativity, and perseverance as indicated in the letters of recommendation and application materials. Particular emphasis and weight is placed on applicants' interest in designing new course materials.

## Project Descriptions

Each teacher works closely with an engineering faculty member to develop a project that fits his or her interests, abilities, and the time frame of the program. While most teachers take on unique projects that contribute to the faculty member's ongoing research, some teachers opt to spend their time researching an engineering topic that is new to them and will enhance their teaching capabilities. Abstracts from two projects completed by teacher participants in the 2005 program appear below as examples.

*Water Filtration Project: Example of RET Participant Contribution to Ongoing Research*

"A water filter was manufactured by an ion beam lithography process resulting in uniformly shaped and equally spaced pores throughout the filter. Images of the filter were captured using a scanning electron microscope and the pore sizes were measured with Scion imaging software. Statistical analysis of the pore sizes revealed pores that are approximately normally distributed with a small standard deviation. Pores with a 10% over-etch have a mean diameter of 0.8587 microns with a standard deviation of 0.012 microns. Such a narrow distribution of pores suggests the filter will be highly successful in capturing bacteria such as yeast, which have a diameter of 1 micron on the smallest side. The probability of a particle 1 micron in diameter going through any pores in a filter whose pores follow the N(0.8587,0.012) distribution is essentially zero. These filters are being developed for use in developing countries as economical and portable ways to purify drinking water. Water filters with uniformly sized pores will allow for effective retention of pathogens with very high water flow. This results in lower filtration costs for municipalities and biotechnology and pharmaceutical companies."

*Shape Memory Alloy Project: Example of Classroom Instruction Module on an Engineering Topic Developed by RET Participant*

"Shape Memory Alloys, also known as SMAs have been the topic of scientific investigation since the 1930s, when scientists discovered that Ni-Ti (Nitonol) alloys exhibit a "shape memory effect". That is, the alloy is capable of undergoing a change in crystal structure from a malleable martensitic phase to a stiff austentitic one when heated above a narrow temperature transition band. This phase transition does not require diffusion to occur, is rapid, and is readily reversible. Upon heating, the alloy returns to its original shape which has been locked in by processing. Any heat source can be used to achieve this transition, including direct resistance heating (passing a current though the material). Nitonol and other metallic shape-memory alloys are widely used in industry, and have numerous applications, including ones related to medicine. For this project, an "arm" was constructed from wood and Nitonol wire for classroom demonstration purposes. When the wire is connected to a battery, the arm moves, and students are able to see the shape memory effect first-hand. The demonstration is accompanied by a discussion of the SMA theory and applications."

Additional project titles from the 2005 program are shown below:

- *Retroreflection for Detection of Pathogens in Drinking Water*
- *Two Phase Flow for Microgravity Research*
- *Modeling of Infrared Bandpass Filters Using Three-Dimensional FDTD Method*
- *Time Reversal Communication in Wireless Sensor Networks*
- *Identification of Perchlorate Degrading Organism(s) in Salt Tolerant Cultures.*
- *Investigating the Metabolic Pathway of Anaerobic Biodegradation of Unsaturated Hydrocarbons in Marine Sediment*
- *Sources of Fecal Indicator Bacteria in Buffalo and Whiteoak Bayous*
- *Quantum Mechanics in a High School Setting*
- *Media, Storage Capacity and Bit Density*
- *The Use Fractal Dimension in the Characterization of the Level of Branching in Oil Well Wormholes*
- *Combustion Curves Characterize the Ignition Point of Catalytic Converter Reactions in Order to Reduce Cold Start Pollution*
- *Neuronal Sensing and the Visual Response of Locusts*

**Program Evaluation**

The assessment techniques chosen for this program include surveys, final presentations and poster sessions, written and oral interviews, and a tracking system. Assessment goals are based on Kirkpatrick's program evaluation model[1], and can be classified as one of four levels: Reactions, Learning, Transfer, and Results.

*Reactions and Learning— Views of the Program and New Knowledge of Engineering:* At the end of the program, teachers were asked to complete two survey assessment tools. One survey asked participants to rate their agreement with various statements related to program content and administration at the end of the program using a Likert scale (responses included "strongly agree" (5), "agree somewhat" (4), "not sure" (3), "disagree somewhat"(2), "strongly disagree"(1)). The other survey queried participants on how well their expectations were achieved during the program, and asked participants to rate each statement in terms of the extent to which each factor was reflected in their summer experience (a score of 1 indicated that it was not at all reflected, while a score of 5 indicated that it was reflected to the fullest extent) as well as the extent of each statement's importance to them (a rating of 1 indicated it was not at all important, and a response of 5 indicated that the statement was as important as it could possibly be). Both survey instruments concentrated on program content ("Reactions" level) and awareness of engineering research methods and scientific inquiry ("Learning" level). Results from the 2005 program are shown in Figure 1; all 14 participants completed the assessments.

| Item | Level | Statement | Mean Rating [a] ± Standard Deviation | No. With Rating ≥ 4 [d] N=14 | | |
|---|---|---|---|---|---|---|
| 1 | R | I have received an appropriate amount of guidance from faculty or other members of the research team. | 4.7±0.5 | 14 | | |
| 2 | R | I felt comfortable approaching faculty with questions about my research. | 4.8±0.4 | 14 | | |
| 3 | R | I was comfortable in asking any questions that I wanted to pursue with the faculty about graduate study and careers in engineering. | 4.9±0.4 | 14 | | |
| 4 | R | Based on my own RET experience, I would encourage colleagues to apply to the program next year. | 4.8±0.4 | 14 | | |
| 5 | R | The training I received for Infinity Project was worthwhile. | 3.9±0.8 | 9 | | |
| 6 | T | It is likely that I will introduce some aspects of Project Infinity in my high school classes. | 4.1±1.0 | 11 | | |
| | | | Reflected | | Importance | |
| Item | Level | Statement | Mean Rating [b] | No. With Rating ≥ 4 [d] | Mean Rating [c] | No. With Rating ≥ 4 [d] |
| 7 | R | Being able to get "results" during the summer project. | 4.1±1.0 | 10 | 4.1±1.1 | 10 |
| 8 | R | Developing personal relationships and enjoying camaraderie with engineering faculty, students and other RET teachers. | 4.8±0.4 | 10 | 4.9±0.3 | 10 |
| 9 | L | Developing a sense of how our research contributes to scientific knowledge. | 4.6±0.5 | 14 | 4.8±0.4 | 14 |
| 10 | L | Understanding the overall research project and how my work contributes to its success. | 4.4±0.7 | 12 | 4.6±0.7 | 13 |
| 11 | L | Learning more about engineering as a major in college. | 4.7±0.5 | 14 | 4.7±0.5 | 14 |
| 12 | L | Learning more about how science is carried out and funded, and the role of agencies such as the NSF. | 4.3±0.6 | 13 | 4.4±0.6 | 13 |
| 13 | L | Developing my methodological, technological, and instrumentation skills. | 3.6±0.7 | 7 | 3.9±1.1 | 6 |
| 14 | L | Learning how to design an experiment. | 3.3±0.9 | 4 | 3.6±1.2 | 6 |
| 15 | T | Understanding the practical application of my research. | 4.7±0.5 | 14 | 4.6±0.4 | 14 |

Figure 1. “R” refers to Reactions Level, “L” refers to Learning Level, “T” refers to Transition Level of Kirkpatrick’s Evaluation Scheme. Participants were asked to use a Likert Scale to evaluate their agreement with the statements. [a] Ratings of 5-1 were assigned to the responses “strongly agree”, “agree somewhat”, “not sure”, “disagree somewhat”, “strongly disagree”, respectively. [b] a score of 1 indicated that the statement was not at all reflected in the participant’s experience, while a score of 5 indicated that it was reflected to the fullest extent; [c]a rating of 1 means it was not at all important, and a response of 5 means that the statement was as important as it could possibly be [d]Number of participants with rating ≥ 4; N = 14, the total number of teacher participants who completed the survey (100% response rate).

Overall, all participants reported (either in these surveys or in written and oral exit interviews) a high level of overall satisfaction with their summer experience, and an increased awareness and enthusiasm for engineering. Results for certain aspects of the Learning Level were mixed. While nearly all participants reported understanding their own project and how it contributes to scientific knowledge (item 9), as well as learning about engineering as a college major (item 11), only half the participants felt that they had successfully learned methodological, technological, and instrumentation skills (item 13). Interviews revealed that participants were struck with how broad the field of engineering is, and given the short time period of the program, many left feeling like "there was a lot left to learn". This may have contributed to their lack of confidence in the experimental skills they developed over the summer. Fewer participants agreed that items 13 ("developing my methodological, technological, and instrumentation skills") and 14 ("learning how to design an experiment") were reflected in their summer experience compared to the other measures of learning. In addition, fewer participants agreed that these aspects were important to their experience.

*Transfer—Incorporating Engineering into 9th-12$^{th}$ Grade Classrooms:* Presentations given by participants at the end of the program and follow-ups conducted during the semester following the program indicated that all had incorporated or planned to incorporate the engineering-related topics into their classrooms this academic year. The following activities have been implemented by participants:

- inviting speakers to class
- presenting their summer work to their classes
- showing an "Engineers Can Do Anything" video to their classes
- participating in engineering-related clubs
- using real-world engineering examples (from their research or that of RET colleagues) in their lesson plans
- establishing or advising engineering-related clubs
- assigning engineering-related projects
- using Infinity Project™ lesson plans when they relate to course material
- establishing an Infinity Project™ course in their school
- planning engineering-related field trips

Other results from the "learning" and "transfer" level of assessment point to areas where formative program changes are necessary to ensure better results in future years. One such cause for concern was reflected in written and oral interviews with participants: the feasibility of implementing Infinity Project™ kits into the existing teaching curriculum. Due to the diversity of grade levels, subjects taught, and budget restrictions of their school, our intentions of having this tool be a "take-away" from the program has met with mixed results. While some teachers have indicated that they have the resources and support of their administration for implementation of courses based on the Infinity Project™, it is not feasible for all, or even most, of the past RET participants. Therefore, the 2006 UH-RET program will allow teachers the option of receiving the Infinity Project™ training, but it will not be an essential element of the program.

Another genuine challenge facing our RET participants is the constraints mandated by the State of Texas regarding standardized Texas Assessment of Knowledge and Skills (TAKS) tests. Our teacher participants reported struggling to find time in their already packed curricula to incorporate their new knowledge and enthusiasm for engineering. Follow-up interviews revealed that many teachers are too busy during the academic year to further develop the lesson plans they started as part of the summer program. To this end, we have plans to implement more rigorous guidance for the teachers to incorporate engineering examples and problems into their regular teaching assignments. UH faculty and graduate students will work closely with the teachers on a weekly basis throughout the summer to develop engineering-related modules that fit within the constraints of the participants' teaching assignments. Each teacher will be assigned a graduate student "ambassador" to provide follow-up support and technical advice throughout the academic year.

Two examples of successful classroom "Transfer" from the 2005 program include a Shape Memory Alloy project and a Walter Filtration project. In the "Shape Memory Alloy" project, the participant developed a teaching module for her Integrated Physics and Chemistry course. The module included two classroom demonstrations she created describing the principle behind shape memory alloys, and discussing their commercial use. The teacher built a portable "arm" that allows students to apply a current to a shape memory alloy wire and subsequently see the arm move as a result of the phase transformation. The demonstration is accompanied by a discussion of current and potential uses of the materials.

The second example of classroom transfer comes from the "Water Filtration" project previously described. This participant teaches AP Statistics, and now uses actual pore-size distribution data from the filter she created as part of her RET project in assignments to help students learn the concepts of mean and standard deviation, normal curves, probability, and overlapping curves. The real-life problems are accompanied by a discussion how engineers are working on problems like these to help solve clean-water issues around the globe.

*Results—Recruitment of Students into Engineering Careers:* While the "Results" level of Kirkpatrick's program evaluation model is difficult to measure at this point in the program, the intent of the program is to expose more pre-college students to the field of engineering and therefore recruit more students to engineering careers. No formal assessment of this level of program evaluation has been performed to date.

## Summary

The 25 participants of the University of Houston's Research Experiences for Teachers Program represent a diverse group of talented teachers who, through this six-week summer experience, have achieved increased awareness and enthusiasm for the field of engineering. Participants reported high levels of satisfaction with the program, and all have implemented measures to bring their experience into their teaching. Many participants have reported frustrations dealing with the constraints of state-mandated curricula and lack of time to develop comprehensive lesson plans. As a result of program assessment, plans are underway to provide more structured support throughout the 2006 program and following academic year to help teachers achieve the program goals of introducing engineering to a diverse group of high school students in the greater Houston area.

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### References

1. Kirkpatrick, Donald L., Evaluating Training Programs: the Four Levels, Publishers Group West, 1994.