Rutgers University Research Experience For Teachers In Engineering: Preliminary Findings

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ABSTRACT

In addressing the nation's need for a more technologically-literate society, the Rutgers University Research Experience for Teachers in Engineering (RU RET-E) is designed to: (1) engage middle and high school math and science teachers in innovative "green" engineering research during the summer, and (2) support teachers in integrating their research experiences into their academic year, precollege classrooms. The current paper addresses the following two questions: (1) To what extent did RU RET-E impact participants? and (2) To what extent did participants implement resulting lesson plans?

During the 2011 summer, seventeen math and science teachers (RU RET-E Fellows) engaged in "green" research alongside faculty and graduate students. Teachers were required to apply to the program in pairs as one math and one science teacher from the same school. The rationale was that the team would develop interdisciplinary lessons and that teachers would have a colleague at their school who shared the same experience as supports during the school year. The paper provides an overview of the summer experiences and the academic year follow-up activities.

Data from the pre- and post-surveys and follow-up questionnaire about lesson implementation are presented. Preliminary data evidences that RU RET-E was successful in enhancing teachers' understanding of engineering and supporting them as they designed lessons for their precollege classrooms. Most notably, teachers' confidence in their ability to define engineering, describe what engineers do, generate challenging problems for advanced students and integrate engineering into their curriculum increased significantly.

Keyword: Engineering; K-12; Professional Development; Engineering Education; Math Education; Science Education; Research

INTRODUCTION

In addressing the nation's need for a more technologically-literate society, the Rutgers University Research Experience for Teachers in Engineering (RU RET-E) is designed to collaborate with K-12 educators to infuse engineering education at the precollege level. The premise of Research Experience for Teachers programs is to develop collaborative partnerships between K-12 educators and engineering researchers that results in new and exciting activities for the precollege classroom (National Science Foundation, 2010). The specific goals of RU RET-E are to: (1) engage middle and high school math and science teachers in innovative "green" engineering research, and (2) support teachers in integrating their research experiences into their precollege classrooms.

The overarching theme of the research projects - "Green Technology" was selected to afford mathematics and science teachers the opportunity to enhance their understanding of green technology from an engineering perspective. The overarching theme of RU RET-E's research projects is "Green Technology." While phrases like "Go Green" and "Carbon Footprint" are ubiquitous in today's vocabulary, the general population may not be aware of the role engineers play in "going green". For the purpose of our RU RET-E project, we will define "green technology" as the application of knowledge to continuously innovate methods and materials that focus on the health of our economy and planet; such as, sustainability, energy, and recycling.

During the 2011 summer, 17 math and science teachers (RU RET-E Fellows) engaged in "green" research alongside faculty and graduate students (description of research activities in Table 2). Teachers were required to apply to the program in pairs as one math and one science teacher from the same school. The rationale was that the team would develop interdisciplinary lessons and that teachers would have a colleague at their school who shared the same experience as supports during the school year. One teacher was accepted without a partner because she taught special needs students and we were interested in supporting her efforts to introduce special needs students to engineering. The 17 participating teachers included 2 middle school math, 2 middle school science, 6 high school math and 7 high school science teachers.

The classroom lessons teachers developed were implemented during the 2011 – 2012 academic year. Members of the RU RET-E management team supported the teachers during the academic year by visiting schools and providing funds for classroom supplies. To broaden the impact of RU RET-E, teacher fellows facilitated an academic year workshop for non-RU RET-E educators on the university campus, wherein RU RET-E fellows showcased their research and resulting classroom lessons to a larger audience during National Engineers Week.

The current paper addresses the following two questions: (1) To what extent did the RU RET-E summer research experience impact participants? and (2) To what extent did participants implement resulting lesson plans? The following outlines the theoretical framework grounding the design of RU RET-E. Next, information about the 2011 program, including the resulting lessons designed by the teachers is provided. Results and discussion of the pre- and post-surveys evaluation, as well as preliminary data collected from classroom observations are presented. Lastly, the paper concludes with a summary.

THEORETICAL FRAMEWORK

The design of RU RET-E is based on a twofold theoretical framework. First, there is a national need to recruit more students into the engineering profession. Second, we recognize that universities and K-12 school districts must work in partnership to recruit more students into the engineering profession (Brophy, Klein, Portsmore, & Rogers, 2008; Tran & Nathan, 2010).

National Need

The latest technological revolution has brought with it a high global demand for technology based jobs, such as engineering, that require scientific and mathematical literacy that far exceed the number of qualified applicants in the United States (National Academy of Sciences, 2005; National Science Board, 2003). In order to compete in the global economy, our nation's universities must attract, retain, and graduate qualified engineers, regardless of their gender, ethnicity, race, or financial need. In President Obama's address to the National Academy of Sciences, he committed "to participate in a public awareness and outreach campaign to encourage students to consider careers in science and mathematics and engineering -- because our future depends on it" (Obama, 2009). In sum, there is a national push for enhanced STEM education at all levels – prekindergarten through graduate studies, as well as STEM-literacy for all individuals.

State Departments of Education are responding to the national need to recruit more engineers by exploring ways to infuse engineering into the precollege classroom. Some states have developed standalone engineering content standards for K-12 (Massachusetts Department of Elementary and Secondary Education, 2001; New Jersey Department of Education, 2009) and designed courses that address those standards. Schools also have the option of adopting packaged engineering education curricula for the P-12 classroom (i.e. Engineering is Elementary (2004) and Project Lead the Way (1997)). Another route is the infusion of engineering into existing curriculum where engineering activities are implemented into existing classes (i.e. Hunter, 2006; Small, 2010). Professional development is available by private, public, research, and community agencies.

The professional development initiatives for pre- and in-service teachers provide opportunities for participants to enhance their understanding of engineering and develop lessons for their classroom based on their experiences (Cejka & Rogers, 2005; Genalo, 2003; Laffey, Cook-Chennault, & Hirsch, 2012). Additionally, teachers may have an opportunity to develop and test relevant lessons/whole modules for precollege classrooms during professional development experiences. To address the national need for more engineers, it is critical to offer and understand the impact of professional development on precollege educators because teacher preparation is part of the engineering education system (Rogers, Wendell, & Foster, 2010). In other words, precollege educators play an important role in promoting the field of engineering and exciting young students about pursuing engineering as a profession.

In their report, "Standards for K-12 Engineering Education?" the National Academy of Engineering (National Research Council, 2010) recommended that engineering education standards be either *infused* or *mapped* into existing core content standards. Infusing or mapping would integrate engineering concepts and skills into state or national standards. With the Next Generation Science Standards (2010) coming online, engineering is explicitly integrated throughout the framework and advocates for the integration of engineering practices and principles into science classrooms.

K-12 and University Partnerships

The 2006 report, *Investing in America's Future* (National Science Foundation, 2006), discussed the need to develop collaborations between engineers and K-12 educators to provide authentic opportunities to build scientific and technological knowledge. Universities and K-12 school districts must work in partnership to achieve this goal (Baartmans & Sorby, 2001; Brophy, Klein, Portsmore, & Rogers, 2008; Tran & Nathan, 2010). Universities are responding to the national call by offering K-12 teachers professional development opportunities on how to prepare the next generation of STEM professionals, as well as enrichment programs for precollege students (i.e. summer programs, college credit courses, etc).

Professional development for pre- and in-service teachers should result in participants leaving with the knowledge to integrate engineering into their precollege classrooms and advise their students about engineering careers (i.e. Akerson & Hanuscin, 2007; Brophy, Klein, Portsmore, & Rogers, 2008; Thompson, Windschitl, & Braaten, 2010). Participants should have the opportunity to learn about the various disciplines and the impact engineering has on our everyday lives. Additionally, during effective professional development opportunities teachers should have an opportunity to develop and test relevant lessons/whole modules for precollege classrooms. Many universities have designed professional development programs in engineering education that provide opportunities for precollege educators to engage in meaningful experiences with education and engineering faculty (i.e. Garet, Porter, Desimone, Birman, & Yoon, 2001; Genalo, 2003; NRC 2010b & 2012). The involvement of education and engineering faculty provide robust experiences to professional development participants that focus on engineering education.

RU RET-E PROGRAM DESCRIPTION

The overarching theme of RU RET-E is "Green Technology." While phrases like "Go Green" and "Carbon Footprint" are ubiquitous in today's vocabulary, the general population may not be aware of the role engineers play in "going green". For our purposes, RU RET-E defines "green technology" as the application of knowledge to continuously innovate methods and materials that focus on the health of our economy and planet; such as, sustainability, energy, and recycling. The following subsections describe the six-week summer research program and academic year follow-up activities.

Summer Program

Table 1 is an overview of a typical week of the six-week RU RET-E summer program. The summer program is designed to introduce K-12 teachers to the fundamentals of engineering, research and experimental design; and provide teachers with opportunities to translate these experiences into lessons for the K-12 mathematics and science classrooms. Following Table 1 is a brief description of each component.

Table 1: Overview of the RU RET-E Program

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 AM					Guest Lecture or Tour
10:00 AM	Nature of Engineering	Research	Research	Research	
11:00 AM					Journal Club and Lunch
12:00 PM	Lunch	Lunch	Lunch	Lunch	
1:00 PM					
2:00 PM	Research	Research	Research	Research	Research
3:00 PM			Lesson Development		
4:00 PM					

Since many of the fellows will have no experience in engineering and/or engineering research, the first week included an Orientation during the Nature of Engineering time slot that focused on engineering as a problem solving discipline and the fundamentals of engineering research. The teachers were introduced to experimental design, principles of measurement and variability, descriptive and inferential statistics, "testable" hypotheses and hypothesis testing and sample size. During weeks 2 – 6, the Nature of Engineering seminars addressed the following themes: Green Revolution; Invention & Innovation; Needs, Problems & Problem Solving; Engineering Education & Grant Writing; and Technology & Society.

One of the primary goals of RU RET-E is to provide a meaningful research experience for fellows. A majority of the teachers' time was spent in a laboratory under the mentorship of engineering faculty and graduate students. RU RET-E management team worked with engineering faculty to design projects that were interesting, novel, and meaningful. A description of each of the research projects is provided in Table 2.

Table 2. Description of Research Projects and Resulting Classroom Lessons

Summer Experience	Resulting Lesson
Solar Cells and Surface Area: Teacher Fellows prepared dye sensitized Gratzel solar cells that incorporated Titanium Dioxide (TiO_2). TiO_2 is a semiconductor and ubiquitous in commercial products. In this project, a paste of nanometer TiO_2 particles and viscous organic compounds is spread onto transparent conductive glass (F-doped SnO_2). A dye is used to absorb the photons. Photovoltaic panels are used to harness the energy from the solar radiation.	Students will create solar cells using various methods. Data will be gathered and analyzed to determine the efficiency of the solar cell created. They will be able to create models of their designs and revisit the models to improve upon their devices. Students will apply their designs and create house-models or other living structures to demonstrate the validity of their design and the marketability of their final product.
Fabrication of Nanocarbon Fibers: Teacher Fellows fabricated fibers that were mechanically strong, conductive and flexible. These fibers incorporated carbon nano tubes and graphene. These fibers can be applied to neural engineering. They are mainly used in neuro recording devices. The application of these fibers can be used in the medical field to repair injury to the body and brain.	Students are presented with a basic recipe for a slime made from white glue (polyvinyl acetate) and a borate solution. After following the stock recipe, students will be asked to synthesize their own slime-making process that produces the bounciest slime. Results will be tested and compared to determine the ideal recipe. Students will explore how different factors affect the final product and how they can be manipulated to achieve the desired results.
Multifunctional and Net Zero Buildings: Teacher Fellows visited the solar facility on Rutgers campus and other local alternative energy facilities, learned the general principles and considerations for using alternative energy systems to design a net zero building and also learned about free resources that are available for analysis and design of energy efficient (net zero) energy buildings.	Students will measure the energy usage of various household and school devices using power meters. They will define a daily power usage profile for a house or school. Students will design an overhang to block sunlight in the summer and allow passive solar heat in the winter. They will design, build, and evaluate a solar reflector for solar thermal and photovoltaic uses. Students will minimize heat loss through walls through optimal building design, estimate power generated by a photovoltaic system and compare system designs using computer software.
Systems Thinking: Teacher Fellows learned about building efficiency and energy reduction for new and existing buildings. This was a great opportunity to work with the Greater Philadelphia Innovation Cluster (GPIC) for Energy-Efficient Buildings. The GPIC focuses on full spectrum retrofitting of existing average size commercial and multi-family residential	Students will build a green roof and test it for water absorption, mass, cost effectiveness, and resistance to heat flow (R-value). Students will then redesign their green roofs to fit on an inclined roof.

buildings.	
Anaerobic Digestion of Equine Waste: Teacher Fellows learned about the study of methane production and the potential of equine stall waste during anaerobic digestion. The study was conducted on both large (150 L) and small (100 mL) scale. Data collected will be used to estimate potential for energy production on horse farms.	Students will analyze the recycling process at Thorne Middle School. Math students will analyze the present recycling process. By use of the Engineering Cycle in conjunction with the curriculum, students will make decisions about how to improve the recycling program, present ideas to the community and help implement the improvements. Science students will explore the digestion processes through grade level activities and extrapolate the lessons to implementing new types of recycling, such as a building-wide composting program.
Structure and Mechanics of Dental Enamel: Teacher Fellows studied the effect of fluoride on dental enamel. Fluoridation of drinking water is an important issue in public health and its efficacy in treating dental caries will be assessed.	Students build model skyscrapers from a brown bag of provided materials, such as popsicle sticks, rubber bands, and paperclips. They then test the strength of their skyscrapers using a *Leanometer* - a unique device that applies a horizontal force and measures the lateral displacement, or sway, of the skyscraper. Similar to a nanoindenter used in the engineering research lab, the Leanometer stresses the material to measure its performance.
Antimicrobial Biopolymer Nanoparticles: Teacher Fellows learned about the enhancement of biopolymer (chitosan) nanoparticles by surface attachment of peptides and microencapsulation of proteins. Chitosan is a linear polysaccharide composed of randomly distributed β-(1-4)-linked D-glucosamine (deacetylated unit) and N-acetyl-D-glucosamine (acetylated unit). It has a number of commercial and possible biomedical uses.	In the physics classroom, students will apply basic physics concepts to develop a device that will be used to separate the clean water from the impurities. In the mathematics classroom, students will perform graphical analyses of the acceleration felt by suspended particles as a function of their density, fluid's density and applied centripetal acceleration.

Weekly, one half-day sessions were allocated to development of classroom lessons. Teachers applied to RU RET-E as a pair comprised of one math and one science teacher with the goal of developing interdisciplinary lessons. During lesson development sessions, the teacher teams had access to their research laboratories, computer laboratories, university libraries, and Graduate School of Education faculty. Once teachers were ready to test their classroom lesson, they had the opportunity to pilot lessons with groups of students enrolled in summer precollege engineering programs offered by the University. For example, teachers can present a lesson to 24 middle and high school girls who participate in The Academy at Rutgers for Girls in Engineering summer program.

The Friday morning lecture and tour series provided an opportunity for teachers to learn about exciting initiatives in green technology and meet professional engineers who were interested in speaking to precollege students about engineering. For example, an engineering alumna presented an exciting talk about her work with the Environmental Protection Agency (EPA). She shared information about her background in bioenvironmental engineering and the local work conducted by the EPA to detect pollutants in water and soil.

In the Journal Club, the teachers critically read scientific and educational literature germane to their research projects and their lesson development. They were lead in a discussion about the guiding research questions, the theoretical framework, the study design and the data collection and analysis. Additionally, an electronic course management system, Sakai, was used to continue discussion. Specifically, participants posted reflections and questions on the journal readings. Conversations were saved and will be analyzed in future work.

Academic Year Program

During the academic year, the teachers shared their experiences with colleagues at a staff or department meeting early in the fall semester after their summer experience. Teachers then implemented their designed lessons in their classrooms. This occurred at varying times over the year and was dependent on how the lessons fit into their curricula. Detail about varying lesson implementation is described in the Results section.

In celebration of National Engineers Week, RU RET-E hosted a workshop entitled “Green Lessons for the Classroom” for K-12 educators. The RU RET-E teachers presented their research experiences, resulting lessons and shared “lessons learned” at the workshop. The event engaged participants in the designed classroom lessons and discussion on K-12 engineering education.

RESULTS AND DISCUSSION

The goals of the RU Research Experience for Teachers in Engineering were to engage middle and high school math and science teachers in innovative “green” engineering research and to support teachers in integrating their research experiences into their academic year classrooms. As such, the research questions guiding the current paper were designed to measure the extent to which RU RET-E goals were met. Specifically, the guiding research questions are: (1) To what extent did RU RET-E summer program impact participants? and (2) To what extent did participants implement resulting lesson plans? This section provides results from pre- and post-surveys, as well as summary of classroom observations and responses to questionnaire about implementation of lessons. The following section provides a discussion of findings.

Pre- and Post-Surveys

Two known instruments were adapted to create a pre- and post-evaluation survey to measure the impact of RU RET-E. The surveys measured the teachers’ goals for the program, their attitudes toward teaching and engineering, self-efficacy for teaching and STEM knowledge, knowledge of STEM careers, and STEM professional’s impact on society. Pre-surveys were collected online prior to the start of the summer program. Post-surveys were collected online after the conclusion of the summer program. Sixteen teachers completed the pre-survey. All seventeen teachers completed the post-survey. The survey uses 4 point Likert scales with no neutral point that require teachers to respond to items such as “I can define engineering” where 1=Strongly Agree, 2=Agree, 3=Disagree and 4=Strongly Disagree or indicate confidence in their “ability to integrate engineering into their curriculum” where 1=Not Confident, 2=Confident, 3=Confident and 4=Very Confident.

The first question on the pre- and post- survey asked teachers about their goals for participating in the RU RET-E program. Table 3 is a summary of their answers. The numbers indicate how many of the 16 teachers indicated that each goal statement was one of their goals on the pre-survey and how many of the 17 teachers indicated that the goal was met as a result of their participation. In summary, not all of the teachers indicated that their intended goal(s) for participating in the program (i.e. before participating) were to engage in engineering research, learn about engineering and engineering research and design engineering-based lessons for their classroom, but clearly after participation all but one of the teachers indicated that they had accomplished all of those things. One teacher indicated accomplishing only some. All of teachers also indicated that they had enhanced their knowledge of technology even though it was not a goal for all of them and most even indicated it enhanced their knowledge of their content area.

Table 3: Change in Teachers Goals from Beginning to the End of the Program

Goal	Pre	Post
Meet other teachers	13/16	16/17
Gain professional development hours	3/16	12/17
Enhance my knowledge of my content area	9/16	12/17
Learn about engineering	9/16	16/17
Learn about engineering research	10/16	17/17
Engage in engineering research	12/16	16/17
Enhance my knowledge of technology	11/16	17/17
Design an engineering-based lesson for my classroom	11/16	17/17
Form partnerships with other schools	8/16	8/17

Teachers also responded to questions about their confidence level or motivation (self-efficacy) for various aspects of their teaching (Table 4). Paired t-tests were performed to test for significant changes from before to after the program. Statistical analyses such as this that require numerous tests are often criticized because as the number of test increases so does the chance of false positives (i.e., finding significant differences by chance) so the results are interpreted with caution.

Several significant changes were found which are encouraging. However, many of the questions showed no change. The encouraging point is that the confidences that showed significant change are for attributes that one would expect to change as a result of a teacher's participation in the RET-E program and the attributes that showed only small (non-significant) changes are of the type that would not necessarily change. For example, teachers' confidence in their ability to define what engineering is\what engineers do, generate challenging problems for advanced students or integrate engineering into their curriculum increased significant and should have as those skills were the focus of the program. The fact that no real changes were found for attributes like using standards-based curriculum and Microsoft Excel or making a difference in students' lives is not surprising as they are attributes that were not the focus of the RET-E.

Table 4 identifies questions selected to measure teacher self-efficacy. These questions were adapted from two surveys (Gibson, 1984; Hirsch, Kimmel, Rockland, & Bloom, 2006). Aligned with research on teacher self-efficacy (Fives & Buehl, 2009; Guskey & Passaro, 1994), the questions aim to understand the participants' beliefs about their own ability to achieve positive results in their classrooms.

Table 4: Change in Teachers Self-efficacy from Before to After the End of the Program

	Mean	t_{15}	p-value
Your knowledge of the subject matter you teach	.13	1.47	.16
Your knowledge of applications in subject you teach to everyday life	.13	0.69	.49
Your knowledge about the various fields of engineering	.40	1.57	.13
Your ability to advise students about jobs in subjects you teach	.53	1.59	.14
Your ability to use inquire-based curriculum	.07	0.21	.83
Your ability to use Standards-based curriculum	.07	0.23	.82
Your ability to assist students experiencing difficulty	.40	1.31	.21
Your ability to generate challenging problems for advanced students	.40	2.10	.05*
Your ability to develop appropriate and authentic assessment tools	.53	3.23	.01*
Your ability to present at department meeting/professional conference	.40	1.57	.13
Your ability to supervise students interested in engineering research	.60	2.07	.05*
Your ability to integrate engineering into your curriculum	.93	4.09	.01*
Your ability to use Microsoft Excel	.27	0.77	.45
Your ability to integrate Microsoft Excel into your curriculum	.40	1.19	.25
Your ability to use MatLab	.07	0.25	.81
Your ability to integrate MatLab into your curriculum	.07	0.25	.81
I am motivated to expand on the instructional techniques that I use	.07	0.37	.72
I am motivated to use more technology in my teaching	.13	0.69	.49
I consider myself a "subject matter expert" in my main teaching field	.20	1.15	.27
I can define "engineering"	.47	1.82	.08
I can describe engineering work	.67	2.87	.01*
I believe I can make a difference in the lives of the students I teach	.07	0.32	.75
I believe it is important for me to prepare students for the kinds of expectations they will encounter in a work setting	.20	1.15	.27

At the end of the program teachers were asked how much of a change they would make in their classroom techniques or other teaching behaviors (Table 5) after experiencing the RET-E program: None, a minor change, a moderate change or a major change. More than half the teachers indicated they would make moderate or major changes in most areas which is quite positive. More than 70% of the teachers indicated they would make moderate to major changes in encouraging students to explore alternative explanations or methods for solving problems and showing the importance of subject matter to everyday life which are necessary attributes for engineering curriculum (Capobianco, 2011; Rogers & Portsmore, 2004; Yoon & Griffin, 2012). Further analysis, such as individual and group interviews, need to be conducted to gather information on why some teachers reported minor or no change.

Table 5: The Amount of Change Teachers indicated they would make in their classrooms and Teaching Behavior after experiencing the RET-E

	None	Minor	Moderate	Major
Lecture or talk the whole class	2	5	9	1
Ask students to engage in small group discussion	2	5	5	5
Ask students to engage in whole group discussion	1	3	9	4
Give students problems to work on their own	2	5	6	4
Give students problems to work on in groups	2	2	8	5
Encourage students to explore alternative explanations or methods for solving problems	1	1	8	7
Review material from previous class(es)	3	7	5	2
Teach facts, rules, or vocabulary	5	6	4	2
Show the importance of the subject to everyday life	2	3	4	8
Prepare students to take standardized test	4	6	7	0
Give students hands-on activities	2	2	4	9
Keep a teaching journal to reflect on course material	5	3	4	5
Use technology (computer, internet, etc.) in your curriculum	3	5	5	4
Write grants to secure funding	2	5	5	5
Respond to email you receive from students	6	6	3	2
Consult with expert professional scientists/mathematicians	4	6	3	4

Academic Year Follow-Up

At the conclusion of the 2011- 2012 academic year, RU RET-E teachers were asked to respond to the following question regarding implementation of designed lesson. *To what extent did you implement the lesson plan(s) you designed as a result of your RU RET-E summer experience?* Table 6 provides a summary of responses.

Table 6: Responses to Questionnaire on Implementation of RU RET-E Lessons during Academic Year

Summer Experience	Resulting Lesson
Solar Cells and Surface Area	By the school's design, the Algebra teacher and Environmental Science teacher on this RU RET-E team shared a group of students. Therefore, their lesson was designed and implemented as an interdisciplinary effort. The four-part lesson began with review of old and teaching of new concepts in chemistry, physical science, and environmental science. Students constructed, tested, and redesigned solar cells with various fruit dyes. [JP and LJ, 7/9/2012][1]
Fabrication of Nanocarbon Fibers	The lesson was implemented over the course of three double-period chemistry lab sessions (96 minutes each). The first lesson was an introduction to simple organic chemistry and polymers. Students were give the baseline recipe for a slime made from water, white glue (poly vinyl acetate), and a solution of Borax detergent (providing borate ions). Students created their own samples and were required to make observations about the behavior and properties of the slime. During the second session, the students were divided into teams of 3-4 students and given the challenge of modifying the recipe to create a sample that would bounce the highest. Teams were given time to brainstorm strategies and the supplied with chemicals to prototype their ideas. At the end of the lab session, teams were required to submit their best "recipe" for their bouncy slime. During the final session, student teams were instructed to create a 10 gram sample of their final slime submission. These samples were turned in for testing and comparison. From the results, a winning slime was declared and all the recipes were shared to compare and contrast the modifications made by each team. [CS, 8/2/2012]

[1] Indicates initials of teacher(s) submitting summary and date submitted.

Multifunctional and Net Zero Buildings	Implemented in two different schools. 1. Science Research course at a high school in New York during months of March and April, 2012. Two groups of students worked on the following. "They were dedicated to the following objectives: describing how a composite is more than the sum of its components; fabricating a number of different composites (carbon, fiber glass, wood, and Aluminum-Steel); describing how Young's Modulus could be used to rank the material strength of a group of different composites vis-à-vis by carrying out: load versus strain tests, yield tests, and failure tests; determining the thermal heat properties of the materials; and discussing why composites composed of different quantities of constituent materials may have different mechanical strength and other physical properties. [RW, 6/20/2012] 2. In an AP Calculus class, a Calculus Optimization activity was administered as a homework assignment. The assignment described dimensions of a room design and heat-loss coefficients of each wall. Students were to use calculus optimization techniques to find an optimal construction given those heating specification. 8 of the 20 students created an after-school club to complete the Physics portion of the lesson that involved the design of a Passive Solar Overhang. Students used foam board to construct the south face of a building. There was a variety of pre-established conditions, which had to be followed and the goal was to affix an overhang to block summer sunlight, while allowing winter sunlight to penetrate the window. [MC and JS, 6/3/2012]
Systems Thinking	In a physics course, the students were tasked to build a "green roof" by using a storm drain cut longitudinally to place landscaping material, drainage material (rocks or Styrofoam peanuts), planting medium (soil), and plants (originally supposed to be sedum but this changed to garden plants with colorful flower petals). The class began the year with a unit on measurement and continued into mechanics, following loosely the college prep curriculum, discussing velocity, acceleration, forces, projectiles, and energy. Various engineering projects were used to illustrate concepts and develop the students' engineering design proficiency before having them engage in the green roof project. In constructing and analyzing the green roofs, the class focused on how well the green roofs thermally insulate homes. [BG, 7/23/2012]
Anaerobic Digestion of Equine Waste	Implemented in two different schools. 1. Over the course of four months, high school, chemistry students designed and manufactured a 110 gallon biodigester. Throughout the course, chemistry content was related to the manufacturing of the biodigester. [EP, 8/20/2012] 2. The second school engaged middle school students in math and science class in a two-part project. The math students designed, implemented, and analyzed surveys to assess the recycling efforts of the entire school. In the science class, students related scientific knowledge to design and build composters from everyday materials. The students successfully petitioned the Principal to allow them to build and maintain a composter in the school's quad to assist with recycling efforts. [ET and LR, 5/29/20120]
Structure and Mechanics of Dental Enamel	By design of the school, the math and science teacher shared the same set of students. Therefore, the RU RET-E team designed an interdisciplinary project that was explored and reinforced in math and science class. Interestingly, the entire school was involved in the project and the lesson was integrated into Language Arts, Writing Lab and Social Studies classes. The students designed and created model skyscrapers. The major outcome parameter was a one-meter tall, wind-resistant structure. The students evaluated and analyzed their model's performance by applying a progressively increasing horizontal force while simultaneously measuring horizontal deflection. The models were stressed until excessive deflection was reached (defined as 10 cm from horizontal) or frank structural failure. [CK and RM, 6/4/2012]

Antimicrobial Biopolymer Nanoparticles	In a physics class, students were introduced the fundamentals of the engineering design process, shown examples, and then presented with a problem statement that they would work on in small groups (3 – 4 students). The problem engaged students in designing and build a water filtration system from everyday materials. Designs were tested and results were analyzed by students to select the best water filtration system. [TP, 6/12/2012]

RU RET-E teachers participated as a pair comprised of one math and one science teacher. Designed lessons were developed to cross content areas and reinforce concepts. Based on school structure, teachers were asked to implement designed lessons in the most meaningful way. Responses from questionnaire indicate that 13 of the 17 teachers were successful in implementing their RU RET-E lessons during the 2011 – 2012 academic year.

The *Solar Cells and Surface Area* and *Structure and Mechanics of Dental Enamel* teams of teachers were able to implement the lessons in both the science and math classes because the school's structure setup the sharing of students in both the math and science classes. The *Structure and Mechanics of Dental Enamel* team was successful in engaging the entire school by integrating the lesson they designed into the Language Arts, Writing Lab, and Social Studies classes. The *Anaerobic Digestion of Equine Waste* teachers shared some of the same students, but were able to carry out their lessons independently and stir a school-wide effort to enhance their recycling program. The second pair of teachers to implement the *Multifunctional and Net Zero Buildings* lessons began in the calculus classroom and migrated into an after-school club to continue exploration and engage in the physics portion of the lesson.

The first lesson described in the *Multifunctional and Net Zero Buildings*, as well as the *Fabrication of Nanocarbon Fibers*, *Antimicrobial Biopolymer Nanoparticles*, and *Systems Thinking* teams were not able to implement lessons in both the math and science classrooms. These lessons were implemented in only the science classes. Specifically, the first lesson described in the *Multifunctional and Net Zero Buildings* was implemented in a science research class. The *Fabrication of Nanocarbon Fibers* was implemented in a chemistry class. The *Antimicrobial Biopolymer Nanoparticles* and *Systems Thinking* were implemented in physics classes. The first lesson described in the *Anaerobic Digestion of Equine Waste* row was designed and implemented by one science teacher who participated in RU RET-E as an individual. She was selected to participate in the program because she taught special needs students and the management team was interested in supporting her efforts to engage all students in the engineering design process.

DISCUSSION

The guiding research questions are: (1) To what extent did RU RET-E summer program impact participants? and (2) To what extent did participants implement resulting lesson plans? We begin by addressing the first question by discussing results of the pre- and post-surveys. The second question is answered by discussing classroom observations and review of questionnaire.

Question One

Analysis of pre- and post-surveys evidenced change in teachers' beliefs and attitudes towards engineering in the K-12 curriculum. Consistent with literature (i.e. Nathan et al, 2010; Yaser et al, 2006), the pre-surveys evidenced teachers' desire to integrate engineering into precollege classrooms but lower confidence in implementing engineering-based lessons as compared with post-survey results. By the end of the summer program, teachers' confidence in their ability to define what engineering is, what engineers do, generate challenging problems for advanced students or integrate engineering into their curriculum increased significantly. Furthermore, more than 70% of the teachers indicated they would make moderate to major changes in encouraging students to explore alternative explanations or methods for solving problems and showing the importance of subject matter to everyday life which are necessary attributes for engineering curriculum.

Question Two

A majority of the teachers were able to implement the designed lessons during the academic year. While the vision was to design and implement interdisciplinary lessons that crossed the math and science classroom boundaries, the reality of schools structure hindered the proposed implementation. Those that shared the same set of students were able to engage both math and science classes in the RU RET-E lessons. Interestingly, some teachers were successful in engaging the entire school in the engineering-based lessons. More information is needed to understand why the math teachers in *Multifunctional and Net Zero Buildings, Fabrication of Nanocarbon Fibers, Antimicrobial Biopolymer Nanoparticles,* and *Systems Thinking* were not able to implement their lessons. Follow-up will include individual and group interviews with the teachers to understand why the lessons were not implemented.

SUMMARY

Based on the results from the pre- and post-evaluation, as well teachers' responses to lesson questionnaire, RU RET-E was successful in enhancing teachers' understanding of engineering and supporting them as they designed lessons for their precollege classrooms. By the end of the summer program, teachers expressed that their participation afforded them an opportunity to engage in engineering research, learn about engineering and engineering research, and design engineering-based lessons for their classroom.

Most notably, teachers' confidence in their ability to define what engineering is\what engineers do, generate challenging problems for advanced students or integrate engineering into their curriculum increased significantly. Moreover, 70% of the teachers indicated they would make moderate to major changes in encouraging students to explore alternative explanations or methods for solving problems and showing the importance of subject matter to everyday life which are necessary attributes for engineering curriculum.

Many of teachers were able to implement designed lessons. While some teachers implemented the lessons as vehicles to teach content, others utilized the lesson to reinforce previously taught concepts. Furthermore, some teachers were successful in spurring school-wide adoption of the lessons and create an after-school club for students to continue to explore engineering.

Future iterations of RU RET-E will continue to immerse teachers in engineering research by dedicating most of their summer experience to working in an engineering research lab alongside faculty and graduate students. The management team will continue to evaluate the longitudinal impact of RU RET-E by continuing to conduct and evaluate classroom observations, as well as administering the post-survey every six months over the next several years.

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