AC 2012-3571: RU RET-E: DESIGNING AND IMPLEMENTING ENGINEERING-BASED LESSONS FOR THE PRE-COLLEGE CLASSROOM

Dr. Evelyn Hanna Laffey, Rutgers, the State University of New Jersey

Evelyn Hanna Laffey is the Assistant Dean for Engineering Education with the Office of Student Development at the Rutgers University School of Engineering. She has a bachelor's in mathematics and doctorate in mathematics education from Rutgers University. She has over ten years experience working with K-12 students and teachers. Her research interests are in engineering education at the K-16 level and understanding how to provide an excellent and equitable education to all students.

Prof. Kimberly Cook-Chennault, Mechanical and Aerospace Engineering

Kimberly Cook-Chennault is an Assistant Professor in the Mechanical and Aerospace Engineering Department at Rutgers University and Associate Director for the Center for Advanced Energy Systems (CAES). She holds B.S. and M.S. degrees in mechanical engineering from the University of Michigan and Stanford University, respectively, and a Ph.D. in biomedical engineering from the University of Michigan. Prior to receiving her doctorate, Cook-Chennault worked at Ford Motor Company, Cummins Engine, Visteon, and Lawrence Livermore National Laboratories as a summer intern and Project Engineer. As a product engineer with Ford and Visteon, she designed seat and washer bottle assemblies, and established design criterion for impending product platforms. While at Lawrence Livermore National Laboratory, she created dynamic structural finite element numerical models of containers used to store and transport explosive materials. She also designed experiments to validate the predictions of these models. As a graduate student at the University of Michigan, Ann Arbor, Cook-Chennault developed the first algorithm for the design hybrid power supplies for portable MEMS. This work culminated with the creation of a user-friendly MatLab code, POWER (Power Optimization for Wireless Energy Requirements). This work introduced a new area of research, Hybrid Power Supply Design, which was the base line for the patents Vehicle Hybrid Energy System, United States Patent Application 20080245587, and University of Michigan File 3668 - Hybrid Battery Supply for EV, HEV or PHEV. As an Assistant Professor at Rutgers University, Cook-Chennault's research focuses on two areas: design of hybrid power systems and design of energetic piezoelectric materials for application to smart acoustic dampening, sensors/actuators, and energy harvesting. Design of hybrid power systems is the development of algorithms, techniques, and technology aimed at the rational design of power systems that incorporate more than one energy generating or harvesting device, with an emphasis on alternative energy systems. Cook-Chennault is currently collaborating with Sunlight Photonics, the Maine Maritime Academy, the NASA-Jet Propulsion Laboratory, and the Atlantis Resources Corporation on a Department of Energy (DOE)-funded project to develop a Marine and Hydrokinetic Prototype. For this work, Cook-Chennault will use her expertise in system integration and mechanical engineering to fabricate and analyze the prototype. The prototype will be assembled and tested by the Cook-Chennault group at Rutgers. All modeling work will be supplemented with experiments to validate models. Design of energetic piezoelectric materials focuses on exploring the electrical, mechanical and electromechanical properties of novel composite materials that can be applied to acoustic dampening, dampening, sensors/actuators, and energy harvesting. Cook-Chennault is currently funded through NASA to explore the electromechanical capabilities of three phase piezoelectric materials comprised of a matrix, piezoelectric and conductive material. The envisioned application of these materials is for acoustic liners that are used for attenuating combustion and turbine noise radiated from jet engines. Similarly, Cook-Chennault has been funded through NSF to explore these types of materials for application to sensors and actuators for self powering wireless sensor networks and energy harvesting for portable microelectronics. Inspired by advances in energy storage, generation,l and harvesting technologies, Cook-Chennault co-authored a NSF grant focusing on green technology, which aims to infuse engineering principals pertaining to green energy into pre-college curricula.

Linda S. Hirsch, New Jersey Institute of Technology

RU RET-E: Designing and Implementing Engineering-Based Lessons for the Pre-College Classroom

Introduction

The goals of the Rutgers University Research Experience for Teachers in Engineering (RU RET-E; pronounced "Are you ready?") are 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, pre-college classrooms. The overarching theme of the research projects - "Green Technology" was selected to engage the in-service mathematics and science teachers in the Green Revolution.

During the 2011 summer, seventeen math and science teachers (RU RET-E Fellows) engaged in "green" research alongside faculty and graduate students (description of research activities in Table 1). 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 classroom lessons teachers developed are being implemented during the 2011 – 2012 academic year. Members of the RU RET-E management team support 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 provides a summary of the 2011 summer experience. Specifically, the paper focuses on the components of the summer program that led to the development and implementation of engineering-based lessons for the pre-college classroom. The following outlines the theoretical framework used to design RU RET-E. Next, information about the 2011 summer 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 threefold theoretical framework. First, there is a national need to recruit more students into the engineering profession[1,2]. Second, we recognize that universities and K-12 school districts must work in partnership to recruit more students into the engineering profession[3,4]. Lastly, RU RET-E utilized theories of adult learning[5,6] to design components of the summer and academic year program.

States are responding to the national need to recruit more engineers by developing engineering curriculum standards for K-12[7,8]. Relevant to this paper is the New Jersey Technology Education/Engineering/Design Core Curriculum Content Standards (CCCS)[7]. As stated, the purpose of the standard is to ensure that "All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world, as they relate to the individual, global society, and the environment." Consequently, two components of the summer program were designed to discuss and explore how to integrate the Technology Education/Engineering/Design CCCS into their math and science classrooms. These components were weekly meetings on Wednesday mornings to discuss research experiences and lesson design and weekly meetings on Friday mornings to read and discuss relevant literature on P-12 engineering education. In the sessions, teachers had the opportunity to brainstorm, design, pilot, and redesign lessons based on feedback from fellow teachers and RET management team.

Universities are responding to the national call by offering K-12 teachers professional development opportunities[9,10,11] on how to prepare the next generation of STEM professionals. The 2006 report, *Investing in America's Future*[12], discussed the need to develop collaborations between engineers and K-12 educators to provide authentic opportunities to build scientific and technological knowledge. RU RET-E aimed to provide such an opportunity by immersing teachers in engineering research during the six week summer program. Approximately 80% of teachers' time was spent in the research component.

A review of adult learning theories[5,6] suggests recognizing adult learners as experienced individuals who have valued knowledge, utilizing experience as a learning tool, promoting learning through reflection and inquiry, and providing situated learning contexts. As such, RU RET-E provides opportunity for teachers to share experiences in roundtable discussions on Wednesday and Friday mornings and allocates 80% of teachers' time for learning by doing in engineering labs. Eight projects were offered and teachers worked in pairs or trios on each project under the guidance of faculty and graduate students. The projects and resulting lessons are outlined in Table 1. Additionally, during the academic year, teachers have the opportunity to share experience with implementing lessons during a follow-up professional development day during National Engineers Week. With respect to reflection and inquiry, teachers utilized the University's online course management system to post resources, pose questions for group reflection, and provide feedback on lessons.

The purpose of this paper is to report on the 2011 summer program design and preliminary findings from pre- and post-surveys. Additionally, observations from academic year follow-up are presented to provide preliminary data on actual lesson implementation.

RU RET-E Summer Program

The opening session of the summer program included pre-service physics students who were enrolled in an engineering education summer course with one of the authors. The pre-service teachers spent five-weeks exploring engineering and designing lessons for their future pre-college classrooms. As their final project, the pre-service teaches designed a physics lesson centered on an original, engineering-based hands-on project. For example, one participant designed a lesson around building a toy yo-yo. The goal of his lesson was to have students apply rotational dynamics to understand how a simple and modern yo-yo works. Students were challenged to make yo-yos from various materials (e.g. paper cups, plastic cups, string, straws, etc) and use their knowledge of rotational dynamics to propose explanations for the various designs of their yo-yos. On the first day of the RU RET-E summer program, the pre-service teachers shared their lessons with the RET Fellows and the group engaged in a discussion on how to incorporate engineering into their curriculum by matching existing content to hands-on projects; rather than, overburdening their curriculum with added engineering concepts.

Lastly, the third component of the summer program that engaged teachers in exploring and designing engineering lessons for their math and science classroom was a weekly Lesson Development session with faculty from the Graduate School of Education and School of Engineering. Teachers were asked to identify "two big ideas" from their research experiences to guide the development of their lessons. In other words, teachers were asked to select two ideas from their research that linked to their existing curriculum. During the early Lesson Development sessions, teachers discussed their research experience and shared ideas for lessons with colleagues. As the summer progressed, teachers piloted lessons with colleagues and revised lessons based on feedback. Additionally, throughout the Lesson Development sessions, education and engineering faculty shared literature on engineering education, provided feedback on lessons, and shared hands-on engineering projects that are used during summer enrichment programs that are administered annually at the School of Engineering for K-12 students.

Table 1. 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 And 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	Students will build a green roof and test it for water absorption, mass, cost effectiveness, 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 buildings.	resistance to heat flow (R-value). Students will then redesign their green roofs to fit on an inclined roof.
Anaerobic Digestion of Equine Waste: Teacher Fellows learned about the study of methane production potential of equine stall waste during anaerobic digestion will be conducted at 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.

Results and Discussion

The goals of the RU Research Experience for Teachers in Engineering were to: (1) engage middle and high school math and science teachers in innovative "green" engineering research during the summer, and to (2) support teachers in integrating their research experiences into their academic year, pre-college classrooms. To this end, RU RET-E fellows engaged in engineering research, enhanced their understanding of engineering, shared their experience with colleagues, design a grade-appropriate engineering lesson, and implemented the lesson in their classroom. Quantitative and qualitative measures were used to asses the short- and long-term impact of the program. For the purpose of this paper, results from the pre- and post-survey that measured teachers' beliefs about integrating engineering into their classrooms are reported. Additionally, preliminary data from academic year classroom observations are reported.

Two known instruments[13,14] were adapted to create a pre- and post-evaluation survey to measure the fellows' 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. Analysis of pre- and post-surveys evidenced change in teachers' beliefs and attitudes towards engineering in the K-12 curriculum. The survey uses 4 point Likert scales with no neutral point that require teachers to respond to items such as "I can define engineering" on a 4 point Likert scales 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 2 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 a nut shell, 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 2: 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 (See Table 3). Paired t-test 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. And 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 3: 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 (See Table 4) 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.

Table 4: 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

Teachers were also asked to indicate the degree to which they agreed or disagreed with the following five statements:

1. Students should have the opportunity to work on hands-on activities during class
2. It is important to communicate with other teachers about what they are doing in the classroom
3. It is important to use interdisciplinary lessons in the classroom
4. Engineering principles should be incorporated in middle school curriculum.
5. Engineering principles should be incorporated in high school curriculum

All 17 of the teachers either agreed or strongly agreed with each of the five statements. On all but the second questions more than 70% of the teachers strongly agreed with each statement which is extremely positive.

One aspect of the teacher follow up plan for the RU RET-E program is to visit the teachers' school and observe them in the classroom. During an observation teachers will demonstrate the integration of the modules that they have developed based on their research at Rutgers. Since this is the first year of the RET program, we are still actively conducting school visits. Thus far, we have conducted one observation on December 19, 2011, at Park Middle School in Scotch Plains, New Jersey. The modules developed by the math and science teachers were based on their experiences with the Structure and Mechanics of Dental Enamel described in Table 1. Their lesson moduleproject focused on enlisting the entire eighth grade (multiple classes, including a special needs class) to design, build and test the best skyscraper. Student outcomes were evaluated via a class-wide contest. Students were placed into design groups within each class, and groups within a single class competed first. Those teams that were ranked highest within a single class were then able to go on to compete against other eighth grade classes.

The teachers modeled the project after a typical engineering design project, wherein target engineering design objectives/characteristics, materials and budget were articulated at the beginning of the assignment. Examples of design drivers for the project were height specifications, and minimum displacement of the scraper when subjected to a load. The science component of the lesson involved discussion of loading bearing structural members, calculation of force, center of mass, weight, density, measurement, displacement, mechanical drawings, etc. While, the math component focused on data analysis, such as linear regression of data and computation of the arithmetic mean and standard deviation. Data from each team was shared amongst the eighth grade classes for statistical analysis (mean, standard deviation and linear regression). A picture of the load/displacement device that was developed by the teachers over the summer to mimic an indention test device used in Dr. Mann's lab is provided in Figure 1.


Figure 1: "Testometer" designed by teachers during their summer experience.

The teachers were so dedicated to the implementation of the teaching modules, that their excitement stimulated a school-wide momentum, which burgeoned with the inclusion of other classes in the sky scraper project that traditionally are not brought under the umbrella of STEM. Specifically, other classes joined the sky scraper project: Social Studies and English. In the Social Studies class, ancient architecture in Rome was studied, wherein students studied the use of how the ancient Romans advanced the use of arches and dome structures. Students also learned about how engineers of ancient Rome improved the use of concrete and bricks, which *paved* the way for the development of aqueducts that serviced an entire empire. In their English classes, students engaged in journaling their design and project experiences. The most memorable portion of the visit was reading parts of these journals. Many students shared how the project had boosted their confidence. Specifically, many of the students were intimidated with the notion of building their own prototype and constructing their own design plans. Many were delighted to see that their designs could survive multiple loads. And, most importantly, the students whose designs failed, stated with confidence that "their new ones would be better". This sentiment was shared by all of the children in the special need class


Figure 2: Sky scraper projects designed, built and tested by students.

who also participated in the project. Depictions of selected students' designs are provided in Figure 2.

Summary

Based on the results from the pre- and post-evaluation, as well as visits to classrooms, RU RET-E was successful in enhancing teachers' understanding of engineering and supporting them as they designed lessons for their pre-college 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.

The first visit to teachers' classrooms was positive. The designed and implemented lessons enhanced existing curriculum and afforded students the opportunity to learn about engineering as an interdisciplinary profession (i.e. in their science, mathematics, social studies, and English classes). Their engagement in RU RET-E spurred a school-wide adoption of the engineering-based lesson. More visits are scheduled for the spring 2012 semester.

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 classroom visits, as well as administering the post-survey every six months over the next several years.

References

[1] National Academy of Sciences (2005). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future. Washington, D.C.: National Academy Press.

[2] National Science Board (2003). The Science and Engineering Workforce: Realizing America's Potential. Arlington, VA: (NSF 03-69).

[3] Brophy, S., Klein, S., Portsmore, M. & Rogers, C. (2008). Advancing Engineering Education in P-12 Classrooms. *Journal of Engineering Education, 97* (3), 369-387.

[4] Tran, N.A. & Nathan, M.J. (2010). Pre-College Engineering Studies: An Investigation of the Relationship Between Pre-college Engineering Studies and Student Achievement in Science and Mathematics. *Journal of Engineering Education, 99* (2), 143-157.

[5] Trotter, Yvonne D. 2, (2006). Adult Learning Theories: Impacting Professional Development Programs. *The Delta Kappa Gamma Bulletin*, *72*, 8-13.

[6] Laher, S. (2007). Reflections on teaching undergraduate psychology to part-time adult students. *South African Journal Of Psychology*, *37*(2), 383-388.

[7] NJ DOE 2009. New Jersey Technology Core Curriculum Content Standard. Available online at *http://www.state.nj.us/education/cccs/standards/8/8-2-E.htm*.

[8] MA ESE. 2001. Massachusetts Science and Technology/Engineering Curriculum Framework. Available online at *http://www.doe.mass.edu/frameworks/archive.html*.

[9] Tate, D., Chandler, J., Fontenot, A.D. & Talkmitt, S. (2010). Matching pedagogical intent with engineering design process models for precollege education. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 24* (3), 379-395.

[10] Westheider, V. & Brown, P. (2010). University and Urban High Schools Team to Use Lego Robots to Teach Physics. In *Proceedings of the 2010 American Society for Engineering Educators Annual Conference & Exposition,* Louisville, KY.

[11] Cejka, E. & Rogers, C. (2005). Inservice Teachers and the Engineering Design Process. In *Proceedings of the 2005 American Society for Engineering Educators Annual Conference & Exposition*, Portland, OR.

[12] National Science Foundation. (2006). *Investing in America's future: Strategic plan FY 2006–2011.* Arlington, VA: National Science Foundation.

[13] Hirsch, L., S., Kimmel, H., Rockland, R. and Bloom, J. (2006). *Using Pre-engineering Curricula in High School Science and Mathematics: A Follow-Up Study*. Proceedings of the 36th ASEE/IEEE Frontiers in Education Conference, San Diego, CA.

[14] Gibson, S. & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76(4)*, 569-582.