An Engineering Research Program for High School Science Teachers: Feedback and Lessons Learned from the Pilot Implementation

Kumar Yelamarthi, Central Michigan University; Tolga Kaya, Central Michigan University; Brian DeJong, Central Michigan University; Daniel Chen, Central Michigan University; Qin Hu, Central Michigan University; Frank Cheng, Central Michigan University

Abstract

The engineering research program for high school science teachers at Central Michigan University was created through the National Science Foundation's Research Experience for Teachers program with the goals of providing high school teachers with a broad overview of engineering, enhancing their engineering skills through research experience, and assisting them in taking their new skills back to their respective high schools for curriculum development. Seven in-service teachers and five pre-service teachers participated in a six-week research program during which they completed a research project with an underlying theme of *smart vehicles*. Through numerous feedback surveys, reflection sessions and lessons learned during the program, it was found that all participants were able to engage in a meaningful research experience that allowed them to understand and practice the engineering research process and enhance their teaching effectiveness. The overall combination of research and professional coaching sessions created an effective professional development program for high school teachers, thus contributing to the enhancement of K-12 education. In addition to presenting details on the program, this paper includes lessons learned by the engineering faculty with the hope that this information will help others who are planning to initiate a similar program at their respective institutions.

Introduction

In recent years, Science Technology Engineering and Mathematics (STEM) educators, professionals, business leaders and policymakers have recognized and highlighted the requirement to build a strong and technologically trained workforce. This requires a strong K-16 education system with qualified and trained educators. While American college-level educators are willing to train this workforce, the K-12 education system is currently suffering from a crisis of inadequate teacher preparation in STEM disciplines leading to low student preparation and performance [1]. On the top of this, limited opportunities are available for K-12 teachers, and soon K-12 science teachers will be required to follow the Next Generation Science Standards (NGSS) with a strong overarching focus on engineering [2].

As most K-12 science teachers do not have any training in engineering concepts, there is a lack of high-quality curricular materials and professional development programs in this area [3]. So, new, inclusive professional development programs for K-12 teachers are required to address the new education standards for improved classroom teaching and learning [4-7]. These professional development programs are a catalyst for K-12 educational reform, and should include technological content and resources that expand educators' knowledge and ability to apply it in their classroom. Some of the key factors for these professional development programs include: 1) active engagement with hands-on activities related to the new science standards; 2) collaboration, sharing and exchange of ideas and practices; 3) interaction with college-level educators; and, 4) active participation in pedagogical workshops.

Based on these key factors and information available in the Council of Chief State School Officers report [8], the National Science Foundation (NSF) Research Experience for Teachers (RET) program at Central Michigan University (CMU) was designed with the following features: 1) Active Learning: High school science teachers were actively involved in an engineering research project with a focus on smart vehicles; 2) Coherence: Activities were built on what they learned and led to more advanced work; 3) Content Focus: Content was designed to help prepare teachers for the new science standards [2] by enhancing their knowledge and skills; 4) Duration: Professional development for teachers extended over six weeks during the summer with a follow-up for lesson-plan development during the school year; 5) Collaboration: In-service teachers (ISTs) worked with pre-service teachers (PST), undergraduate engineering students (ES) and engineering faculty to learn from each other; and, 6) Collective Participation: All participants worked together in teams, met with the entire participant group to discuss strategies and presented their findings at a premier technical conference or published them in a journal.

Previous Work

Identifying the needs and challenges of preparing K-12 teachers, several universities have initiated professional development programs. With the primary theme of biomedical engineering, Vanderbilt University implemented the RET program [9], [10], where participants follow a legacy model of designing instructional resources while in the program and taught them in the following year in their respective classrooms. Similarly, the Georgia Institute of Technology's Physics RET program showed that teachers improved their ability to encourage students to pursue a science or engineering degree [11]. Also, the Texas A&M RET program focused on improving teacher knowledge of careers in engineering [12]. In addition, Tennessee Tech University (TTU) proposed a research program involving ISTs, PSTs, ESs, and a faculty member to work on a research project for five weeks [13]. One other similar RET site present in the literature was from the University of Pittsburgh [14], where ISTs are required to work for eight weeks during the summer on a research project, implement 6-8 week design-based learning modules in their classes, conduct design competitions for students in classes of the RET teachers, and offer summer internships at the university for the winning high school students.

All of these state programs and others [15-19] differ in their unique goals and activities, yet they share the same goal of professional development of K-12 teachers to better prepare the future workforce. Successful implementations of these professional development programs require significant contributions from engineering faculty and the university administrations. The ISTs, PSTs and ESs typically have financial incentives for participation in these programs, such is usually not the case for engineering faculty. These faculty members participate in part because preparing K-12 teachers helps better prepare incoming freshman, and increase student recruitment through publicity at schools of participating teachers.

By evaluating these objectives requires a longitudinal study of the program over an extended period of time, it is the authors' belief that sharing the initial reflections of all of the participants (engineering faculty, ISTs and PSTs) will be beneficial for the engineering education community. Although substantial studies exist to highlight the significance of other RET programs, very few, if any, present the participants' reflections and a qualitative assessment of the respective programs. In light of this limitation, this paper presents an overview of the CMU–NSF RET program, initial reflections of all participants, a qualitative assessment of the initial implementation, lessons learned, and improvements planned for next year.

RET Program Goals and Hypotheses

The National Science Foundation supports the professional development of K-12 teachers through several programs including, but not limited to, the RET [20]. The NSF's stated primary objective for the RET program is to support the active involvement of K-12 science, technology, engineering, computer and information science, and mathematics (STEM) teachers and community college faculty in engineering and computer science research in order to bring knowledge of engineering, computer science, and technological innovation into their classrooms. Identifying the limited professional development opportunity available for K-12 teachers in the Michigan rural areas, in the fall of 2011, CMU proposed an RET site to engage K-12 teachers of rural Michigan in a six-week research program with the underlying theme of smart vehicles, and was awarded support for three years.

In the summer of 2012, CMU initiated the RET program with the following key aspects: active learning, coherence, content focus, duration, collaboration and collective participation. The primary goals of the CMU–NSF RET program are: 1) establish a collaborative partnership between the various entities of the university, high school STEM ISTs and PSTs, and assessment leaders at an external organization; 2) provide a STEM-based platform through which the ISTs and PSTs can gain exposure to several engineering concepts with a focus on smart vehicles; and, 3) facilitate the development of high school STEM-based classroom instructional materials with ISTs and PSTs who serve rural Michigan areas.

In order to evaluate the program goals, the following questions were asked:

a) Could ISTs and PSTs engage in an engineering research project that would allow them to both implement and understand the research process?
b) Could teachers develop and implement K-12-level instructional materials based on research experience?
c) Could this program positively affect teachers' opinions and attitudes towards engineering and the use of challenge-based instructional materials?
d) How do teachers develop as scientific researchers when immersed in a research project?
e) How well do ISTs and PSTs understand the research process after participation in this program?

Several hypotheses were established prior to beginning of this program. ISTs would have the skills necessary to engage in an engineering research project. ISTs and PSTs would understand the methodology of conducting research to help translate their research experience into classroom instructional resources. All participants would gain an understanding of the research process after participating in this program, and also assist the engineering faculty in advancing their respective research projects.

Program Description

Participant recruitment and program efforts started right after receipt of the RET site award notification in April, 2012. Initially, the principal investigator (PI) worked with the faculty members to develop diverse projects with the underlying theme of smart vehicles. During the same period, the PI and CO-PI drafted the application material for participant recruitment and informed schools in the Intermediate School Districts (ISD) of the opportunity available. From the pool of applications received, 12 (7 ISTs and 5 PSTs) were chosen for the pilot program in summer of 2012. Based on the number of participants recruited, six teams would be formed with each team containing one IST, one PST, one undergraduate ES and one engineering faculty member. This model would bring forward the strengths (teaching experience of basic sciences from ISTs, enthusiasm and willingness to try new strategies from the PSTs, hands-on experience and motivation to engage in research from an undergraduate ES and mentoring skills and technical expertise of an engineering faculty member) of each participant in order to reinforce the learning and teaching environment within each team.

The CMU–NSF RET program was a six-week program that began with a one-week orientation session for all IST and PST participants. This orientation week started with welcome and participant introductions, followed by an explanation of the rationale behind the chosen team model, and engineering faculty members presenting their respective projects. Upon completion of these project presentations, all ISTs and PSTs were requested to write short descriptions of a few projects and how they could adapt each project to their classrooms in order to improve the basic science classes. Accordingly, teams were formed by the end of week one based on this statement and optional professor ratings of the participants' interest in the project. In addition, other sessions attended by the participants include obtaining identification cards, parking permits, CMU campus tours, engineering and technology building tours, coaching sessions on team building, classroom flipping techniques and engineering programs at CMU [21].

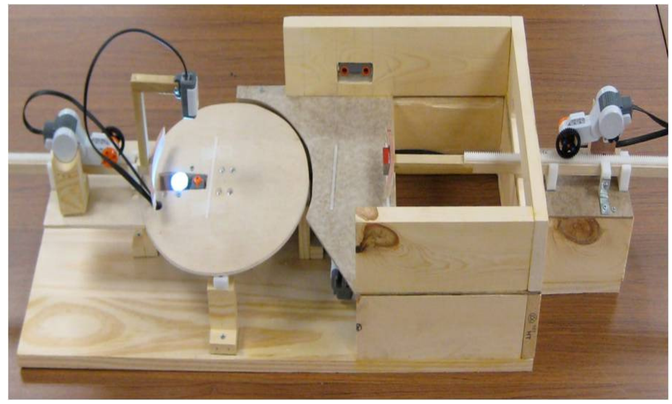
At the beginning of week two, participants spent 20 hours on research, eight hours on coaching (teacher training), four hours on group reflections and team planning, and three hours visiting other research labs and attending talks by various individuals. Some of the research projects that participants were involved in include: i) semi-autonomous tour guide robot [22-24]; ii) automated waste sorter; iii) sensor development for unmanned vehicles [25-26]; and, iv) robot tele-operation, as shown in Figure 1. During the research portion of the program, each participant worked closely with the respective engineering faculty to clearly articulate the goals and expectations, monitor daily and weekly progress and seek assistance as necessary. To accomplish the tasks set forth, ISTs and PSTs were provided extensive assistance not just by the engineering faculty but also by the ESs. Once the initial research training of the participants was completed (mostly in week two), teams focused on their own research projects through project-based modules [27] and problem-based learning [28] for higher knowledge retention. Although each project had its own challenges, participants dealt with several engineering-related research problems that can be classified as: 1) process optimization; 2) circuit design and testing; 3) manufacturing tolerances; 4) literature reading and surveying; and, 5) advanced engineering software usage for material characterization.

During the coaching sessions, participants were introduced to various effective classroom teaching activities, critical thinking skills, review of next-generation science standards (NGSS) and hands-on learning activities. During the group reflections and team planning time, all participants gathered and discussed what they had accomplished that respective day/week, and how they could infuse these accomplishments into their classroom teaching. These group reflections provided many advantages such as an opportunity to learn about other projects, share strategies for solving similar problems, and increase rapport among all participants. In addition to participating in research, coaching sessions and group reflections, participants were also introduced to different research activities through other engineering and science faculty presentations and visits to their respective research labs.

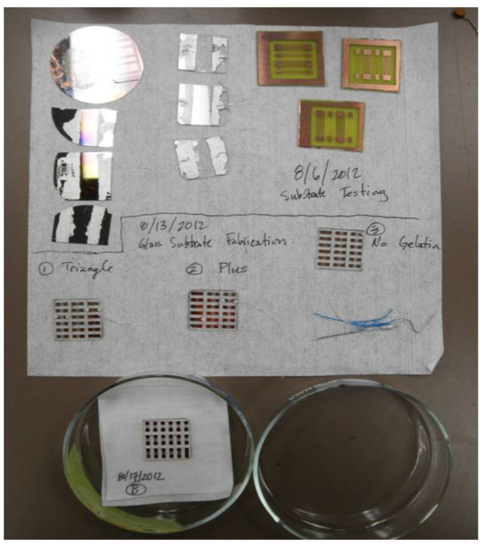
The CMU–NSF RET program concluded with a poster presentation session detailing the research accomplished. During the post academic year, trained academic and leadership coaches from the Science, Mathematics, Technology Center (SMTC) carried out the professional development activities through class visits, coaching and curricular activity development. With one of the challenges faced by ISTs being translating their summer research into high school science classes per the new common-core standards adopted by Michigan, these coaches worked with ISTs and provided guidance to design the necessary lesson plans. Several engineering-related classroom activities were planned and executed with these coaches through the high school visits. ISTs and PSTs worked together on these activities.

In addition, for broader dissemination of knowledge gained, all participants were required to present their findings and experiences at a premier conference or publish them in a journal. Through technical guidance, five papers have been accepted for publication at two international en-

(a) Semi-autonomous Tour-guide Robot



(b) Autonomous Waste Sorter



(c) Sensors Fabricated for Unmanned Vehicles

(d) Tele-operation Robot Testing Different Alignments

Figure 1. Prototype of Projects

gineering education conferences, and two poster presentation sessions have also been delivered for the Michigan Science Teachers Association annual meeting [29-33].

Participant Reflections

In-service and Pre-service Teachers

IST participants were recruited from local Intermediate School Districts (ISD) in the following rural Michigan counties: Clare, Gladwin, Gratiot, Isabella, Iona and Montcalm. PST participants, on the other hand, were recruited from the highly renowned teacher education program at CMU. All IST and PST applicants were required to submit an application packet with the following information: 1) professional statement addressing their career goals and expectations regarding the project; 2) career milestones; 3) active participation in student science activities such as science fairs; 4) teaching and research awards received; 5) previous related experience; 6) courses taught; 7) grade point average for PSTs; and, 8) name and contact information of two references. From the applications received, the RET administrators recruited all participants through a rigorous selection process. Criteria used to select the participants included skills or attitude towards teamwork, motivation for professional development, evidence of knowledge in science and education, willingness to share the knowledge at their home schools through instructional resources, geographic diversity, and support from the participants' home institution.

From the numerous applications received, seven ISTs and five PSTs were selected for participation during the first year of the RET program. Overall, the following summary statistics were found for all participants:

- 7 (58%) IST, 5 (42%) PST
- 12 (100%) Whites
- 8 (67%) Males and 4 (33%) Females

The classroom teaching experience of ISTs ranged from 4 to 19 years, where they had taught a range of high school subjects including, but not limited to, physics, physical science, chemistry, mathematics, wildlife agriscience, biology, biotechnology, anatomy, geology and environmental science. All of the IST participants had a college degree in science or mathematics. In addition, the amount of STEM-related professional development activities they were involved in over the past three years varied from 80 to 250 hours. Some of them had master's degrees in education technology or sciences. A few also had several years' worth of industry experience. As all PST participants were students pursuing teacher-education programs in Integrated Sciences, most participants were recruited from CMU (one student was from Western Michigan University) during the first year of offering the RET program. The amount of STEM-related professional development activities they were involved in over the past three years varied from 10 hours to 150 days.

To evaluate the program goals, participants (ISTs and PSTs) were asked about their experiences during the program. The questions and their respective responses are categorized in the following manner:

1) Were you able to establish a relationship with a university faculty member, CEIE to assist in improving your teaching and interpersonal abilities?
   - Learned new approaches in pedagogy through collaboration
   - Gained networking opportunities
2) Were you able to engage in meaningful STEM-based research projects and understand the research process behind them?
   - Gained exposure to engineering product development
   - Challenges in engineering research
3) Did you gain new skills that would help in the development of STEM-based classroom instructional materials?
   - Learned ways to incorporate engineering into the high school classroom
   - Exposure to clear expectations from a high school teacher

Paraphrased sample responses and feedback obtained from ISTs are presented in Table 1, demonstrating that they had increased their network by establishing relationships with fellow educators, were able to engage in STEM-based research and appreciate the intricacies behind it, and primarily gain new technical skills that foster their ability to improve the STEM-based curricula in their respective high schools. Similarly, paraphrased sample responses and feedback obtained from PSTs are presented in Table 2, demonstrating that they had learned the challenges faced by practicing teachers and engineers, gained an understanding of engineering research and, most importantly, feel more prepared to teach engineering to high school students and encourage them to pursue engineering as a career.

Table 1. Paraphrased Reflections of In-service Teachers

Question	Reflections
1	• Learned a lot • Learned new approaches to manage my class as well as my life as a teacher • Networking with fellow teachers, and working together to learn and solve technical problems • Gained an appreciation for the hard work of the design team behind the technological advancements
2	• Learned the engineering design process, and how to integrated the same into classroom • Was able to conduct research and enhance technical skills • Learned the intricacies in engineering research
3	• How to integrate scientific research elements into middle and high school classroom • How to incorporate engineering design process into my classroom curriculum • Gained new ideas to promote engineering in high school classroom

Undergraduate Engineering Students

The rationale behind involving undergraduate ESs in this project was based on two factors: assist the ISTs and PSTs in conducting engineering research and engage them in engineering research through teamwork [34]. Reflections of IST and PST participants clearly show that ES were able to successfully assist them in conducting engineering research. In order to assess how participation in this program helped these engineering students, the following questions were asked: 1) Were you able to engage in engineering research projects and gain an understanding of the process behind them; 2) Did you develop any new skills that would help in your education; and, 3) Did this program nourish your motivation to pursue further research? Feedback obtained from the undergraduate ESs demonstrated that, through teamwork, they were able to conceptualize an idea, identify the problem and solve it accordingly. Most importantly, undergraduate ES feel more prepared in solving problems.

Table 2. Paraphrased Reflections of Pre-service Teachers

Question	Reflections
1	• Able to better plan my future in classroom teaching • Gained networking opportunities with ISTs for potential collaboration in the future • Learned new teaching strategies for effective student learning • Learned how to solve problems from an engineering stand point
2	• Gained exposure and appreciation for intricacies involved in engineering research • Learned the engineering design process, and how to incorporate it into K-12 curriculum
3	• Gained familiarity with NGGS and an exposure to what will be expected from school teachers in the near future • More prepared to teach engineering process and encourage students to pursue engineering as a career choice • Gained technical knowledge that would help me design engineering based lessons in middle and high school curriculum

Program Assessment

With the primary goals of establishing a collaborative partnership, providing a STEM-based platform for science teachers and facilitating the development of high school classroom instructional resources, it is crucial to focus on continuous improvement. Accordingly, prior to the beginning of the RET program, a pre-survey was conducted. Some of the aspects assessed during this pre-survey were reasons for participation, expected benefits, expected challenges, perceived benefit for high school students and their perceptions on science and engineering principles, as presented in Tables 3-7.

For the most common reasons to participate, the majority of ISTs stated that opportunities to learn and participate in engineering research and to design new lesson plans were the primary reasons, while PSTs stated that networking and professional development were the primary reasons. While there was a difference in reasons to participate, it is clear that the program could serve not only practicing teachers, but also prospective school teachers. Given the expected benefits from the ISTs having prior teaching experience, their responses focused more on making connections between their experiences and NGSS, updating lessons plans, implementing the same in their classroom and less on networking. Due to the limited teaching experience of PSTs, their responses focused more on learning about engineering, networking and learning from experienced teachers. Undergraduate ESs, the support personnel in this program, gained opportunities to enhance research skills, while at the same time learn about different engineering perspectives.

Table 3. Pre-survey Reasons for Participation

Reasons for Participation	IST	PST	ES
	No.	No.	No.
Opportunity to engage in engineering research	2	-	2
Learn how to teach engineering concepts	2	2	-
Network with fellow educators with similar interests	-	2	1
Learn new teaching strategies	2	2	-
Gain an edge on my resume or job search	-	2	-
Learning experience	2	1	3
Others (Financial, NGGS)	3	1	1

Table 4. Pre-Survey-Expected Benefits

Expected Benefits	IST	PST	ES
	No.	No.	No.
Enhance research skills	-	-	5
Implementation of engineering into my curriculum or classroom	4	1	-
Updated lessons based on NGGS	3	1	-
Gain exposure to engineering and related challenges	2	5	2
Learn effective teaching strategies	-	2	-
Networking	-	2	-
Others	-	1	1

Table 5. Pre-survey of Expected Challenges

Expected Challenges	IST	PST	ES
	No.	No.	No.
Limited exposure to engineering research	3	3	2
Working with teachers	-	-	3
Translate engineering research into high school curriculum	-	2	-
Others (Lack of funding, not sure)	4	1	1

Table 6. Pre-survey of Expected Benefits for High School Students

Ways This Program Will Benefit High School Students	IST	PST	ES
	No.	No.	No.
Prepare them for future careers and college	3	2	4
They will benefit from a well-informed teacher	-	4	-
It will expose them to engineering concepts	3	1	2
Others	2	-	-

Given the expected challenges, all participants stated that unfamiliarity with engineering concepts and research was the primary challenge. Due to their limited classroom teaching experience, the PSTs also stated that finding ways to incorporate engineering into their respective classrooms might also be a challenge, which is answered through the post academic year support provided by the CEIE coaches. When asked how their participation in this program would benefit high school students, both ISTs and PSTs stated that this program would provide them with information and knowledge that would be shared with high school students, resulting in their being more prepared for future careers and college. In addition, ISTs stated that the new instructional resources developed from this program might help expose high school students to engineering practice and research, while PSTs stated that the professional development experience provided by this program would prepare them to be well-informed teachers.

Table 7. Questions on Pre-survey of Perceptions of Science and Engineering

No.	Question
1	You have to study engineering for a long time before you see how useful it is
2	Memorization plays a central role in learning basic science, math, and engineering concepts
3	A lot of things in science must be simply accepted as true and remembered
4	It is important to teach students how to think and communicate scientifically
5	Every student should feel that science is something he/she can do
6	Every student should feel that engineering is something he/she can do
7	I understand science concepts well enough to be effective in teaching them
8	I understand engineering concepts well enough to be effective in teaching them
9	I am typically able to answer students' questions related to science
10	I am typically able to answer students' questions related to engineering

In addition, all participants were asked to rate the degree to which they agreed or disagreed with ten statements about science and engineering, as presented in Table 7. The first three questions were related to participant perceptions of the nature of engineering, science and/or mathematics. The next three questions were related to participant perceptions of the students (or of what students should be expected to do). The last four questions were related to assessing the confidence level of participants. Results obtained from these questions are presented in Figure 2. While the responses of all groups were similar in aspects such as developing significance of science and engineering in students through a can-do attitude, and effective communication, there were some aspects where they differed statistically. For instance, while ISTs stated that they had an in-depth understanding of science concepts to be effective in teaching them and answering students' questions, PSTs stated that they do not. However, when it comes to engineering concepts, ISTs stated they had a mediocre understanding, while the PSTs stated they had very little understanding in order to teach engineering and answer students' questions, demonstrating the need for more engineering experiences.

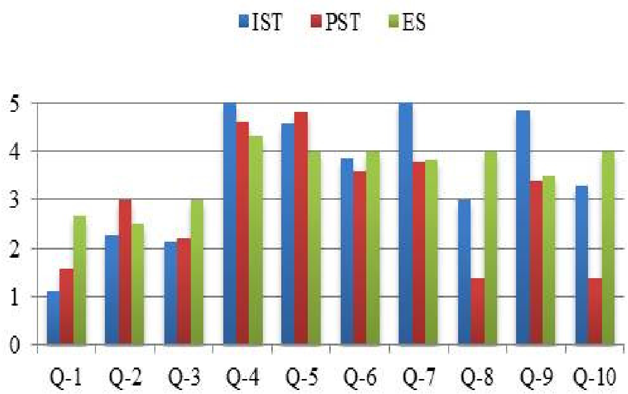


Figure 2. Responses from Participants for the Pre-survey of Perceptions on Science and Engineering

During the last week of the RET program, a post-survey with the following questions was conducted in order to evaluate whether or not the program goals were met: i) Could ISTs and PSTs engage in an engineering research project; ii) Did ISTs gain skills to develop high-school-level instructional materials based on the research experience; iii) Did this program positively affect ISTs' and PSTs' opinions and attitudes towards engineering; iv) How do ISTs and PSTs develop as scientific researchers when immersed in a research project; and, v) How well do ISTs and PSTs understand the research process after participation in this program?

Based on the self-reported scores, it was found that ISTs and PSTs were able to successfully engage in an engineering research project, and were able to convey basic engineering concepts through their respective research projects. In addition, a few stated that they learned the overarching concepts of engineering approaches and problem solving, demonstrating our successful attempts to engage participants in research. Regarding the development of skills, the majority of the participants stated that this program helped develop their skills, abilities and attitudes related to curriculum development and assessment. Furthermore, participants were asked if the professional development sessions on effective teaching were helpful. For this, while the PSTs stated that these sessions were very helpful, there was a mixed response from ISTs. This diverse response from ISTs might be attributed to the different teaching experiences and prior participation in similar projects ahead of time. While a few ISTs stated that information in these sessions was not new, they all agreed that it was a good refresher.

When asked about the effect on the teachers' opinions and attitudes towards engineering, the majority stated that the program had successfully engaged them in engineering research projects, facilitating the development of high school STEM-based classroom instructional materials. In addition, the majority of the participants stated they would redesign lessons and projects, or implement new lessons and projects, based on what they had learned, and that they were equipped to teach engineering principles in high school classes. As these participants were working with CEIE staff (during the academic year) in order to design and implement engineering-based instructional material, further evaluation on this aspect will be done at the end of the academic year.

In addition, to evaluate how well participants understood the research process and developed as scientific researchers, reflection sessions were included during weekly activities. These sessions were tailored for participants to share information on their learning experiences and how they planned to incorporate the same in their high school classroom teaching. During these sessions, faculty observed that participants gained an understanding of scientific research, core engineering skills, and primarily learned the intricacies behind engineering research. Overall, participants rated this reflection session as very useful. Furthermore, to broadly disseminate the knowledge and skills that the participants gained, they were required to present their work at a premier conference or publish in a journal; four papers have thus far been accepted for publication at two international engineering education conferences, and two poster presentation sessions have been planned for the Michigan Science Teachers Association annual meeting.

Overall, the pilot CMU–NSF RET program was successful in meeting the goals set forth for all in-service and PST. Though all participants (ISTs and PSTs) worked in teams on the same project, the learning experience of each was different. The unique strength of each group (IST-teaching experience, PST-enthusiasm to learn, exposure to new technology) complimented the limitation of the other, leading to an effective learning experience and, thus, successfully realizing the program goals.

Lessons Learned and Future Directions

Alongside the pilot implementation of the CMU–NSF RET program in the summer of 2012, and conducting program assessment, the engineering faculty learned several lessons that could be of potential use to other engineering educators considering a similar program. As the School of Engineering and Technology at CMU offers only undergraduate degrees, it has to be noted that these lessons are feedback from the engineering faculty, who usually work solely with undergraduate students.

Lesson 1: An RET program can help cultivate a research culture in an undergraduate institution.

The CMU engineering faculty are actively engaged in personal and undergraduate research, but have struggled in the past to maintain a research culture in the building, especially during the summer months. Pilot implementation of the RET program generated an atmosphere of scholarly activity as experienced by program participants, students and faculty. During the course of the RET program, faculty reported that they were able to advance their research, train their research assistants and improve their leadership and management skills, thus gaining the momentum required to sustain research progress in the semesters to follow. Administration and faculty from other departments witnessed this nurturing atmosphere and provided positive feedback during the poster session at end of the program. Overall, the RET program can be a useful tool for stimulating scholarly excitement in departments where opportunities for scholarly activity are limited.

Lesson 2: RET projects must be carefully designed for a mix of backgrounds.

As initially anticipated, the ISTs did not have the engineering background necessary for conducting advanced engineering design or analysis. However, the engineering faculty was pleasantly surprised with the motivation of ISTs, who were very studious in accomplishing the goals compared to undergraduate students. These ISTs came with a "Show me what to do; I'm ready to get involved!" attitude which is less common in engineering students. Accordingly, the RET projects with significant focus on engineering research, design and analysis were not as successful as projects with limited research and analysis (conducted by the ES and faculty members) and more hands-on activities (conducted by ISTs and PSTs). For instance, the teleoperation project involved integrating the robot and interface, writing the control code and designing the human-based experiment, which were primarily accomplished by the engineering faculty and students, and the ISTs and PSTs focused on proctoring the experiments and analyzing the results. In a broad sense, engineering research and engineering implementation projects worked better than engineering design projects.

Lesson 3: Significant preparation is needed prior to the RET weeks.

During the program, all engineering faculty stated that they should have done more preparation prior to the start of the RET program. This limited preparation can be attributed to several factors such as the short time span between the initial RET award notification and program implementation, limited exposure to knowledge and capabilities of ISTs and PSTs, and a lack of graduate students. As the research goals had to be accomplished during the six-week period, the next time this program is offered, the engineering faculty intends to initiate preparation work the month before by training the ES. Also, since the majority of the preparation is design related or technical in nature, and we learned (lesson 2) that ISTs have limited success in design-related activities, this initial preparation work might assist in accomplishing the research goals set forth. In addition, faculty members also plan to set clear expectations and requirements for all participants, and provide background reading material prior to the beginning of the program so that participants can better allocate their time to conduct quality research work.

Lesson 4: An RET program requires a significant time commitment from the faculty or graduate students under the faculty.

The RET program was beneficial for the engineering faculty as it encouraged their research, encouraged them as they saw teachers and students getting excited about engineering, and produced useful research results. But it was also time intensive; in many cases, unexpectedly so. The engineering faculty spent a significant amount of time advising the teachers and students, and often did the design and technical work themselves. Much of this was due to the lack of a graduate program; but even with a graduate program, someone (faculty or graduate student) will need to spend time designing the project, preparing the background materials, setting expectations, directing the students and teachers and disseminating results. The project will have limited success without this effort. Overall, while this program is a good platform to cultivate a research culture in an undergraduate-program-focused institution, it requires a significant time commitment from participating faculty and their respective students.

Based on the results and lessons learned from the pilot program, the following changes are planned for next year:

1. Applications: All participants will be required to draft a personal statement of expectations from this project. This would help the administration identify candidates that would benefit the most from this program. In addition, advertisements will be sent to ISD late in the fall semester in order to encourage broader participation.
2. Project teams: Engineering faculty members will meet early in the spring semester to discuss the projects and set the expectations and goals. Engineering undergraduate students will be notified in advance

and will be asked to initiate the research project in early summer.

3. Lesson plans: All participants will be required to design a unit lesson plan (4-5 hours long for their respective high school classes) during the coaching sessions in the summer, and present it to other participants and faculty members for potential adoption in the same academic year.
4. Conference proceedings: To encourage broader dissemination of knowledge gained and lessons learned, all participants will be required to identify a conference they intend to attend and draft the conference prior to completion of the summer program with guidance from the engineering faculty member.

Conclusion

The pilot implementation of CMU–NSF RET program at CMU proved to be an effective professional development program for both in-service and pre-service teachers. Based on the feedback obtained during the program, it could be stated that the RET program was effective for engaging teachers in meaningful engineering research experiences that allowed them to gain exposure to engineering concepts and the processes behind them. Participants were able to contribute to the overall research goals and were able to complete a small research project. This learning experience, combined with the post academic year coaching, helped them enhance their respective high school classroom curriculum. The overall combination of research and professional coaching sessions created a highly effective professional development program for high school teachers, thus contributing to the enhancement of K-12 education.

Acknowledgment

This research was conducted under a grant from the National Science Foundation, grant number EEC-1201095. However, this work does not necessarily represent the policy or views of the National Science Foundation. The Science and Mathematics Program Improvement (SAMPI) at Western Michigan University conducted the evaluation.

References

[1] President's Council of Advisors on Science and Technology. (2010). *Prepare and Inspire: K-12 Science, Technology, Engineering, and Math (STEM) Education for America's Future*.

[2] National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.

[3] Kimmel, H., Carpinelli, J., Burr-Alexander, L., & Rockland, R. (2006). Bringing Engineering into K-12 Schools: A Problem Looking for Solutions, *American Society for Engineering Education Annual Conference & Exposition*.

[4] Guskey, T. (1986). Staff Development and the Process of Teacher Change. *Educational Researcher*, *15*, 5-12.

[5] Joyce, B., & Showers, B. (1988). *Student Achievement through Staff Development*. Longman.

[6] Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What Makes Professional Development Effective? Results from a National Sample of Teachers. *American Educational Research Journal*, *38*(4), 915-945.

[7] Bransford, J., Brown, A., & Cockings, R. (2000). *How People Learn: Brain, Mind, Experience, and School*. National Academy Press.

[8] Yoon, K. S., Garet, M., Birman, B., & Jacobson, R. (2006). The Effects of Mathematics and Science Professional Development on Teachers' Instructional Practice: Using Professional Development Activity Log, *Council of Chief State School Officers,* Washington, DC.

[9] Klein-Gardner, S. S., & Spolarich, A. C. (2011). Impacts of the Vanderbilt University Research Experience for Teachers Program 2008-2010: Analysis of Student Surveys Regarding Motivational Impact, *American Society for Engineering Education Annual Conference & Exposition*.

[10] Klein, S. S. (2009). Effective STEM Professional Development: A Biomedical Engineering RET Site Project. *International Journal of Engineering Education*, *25*(3), 523-533.

[11] Conrad, L., Conrad, E., & Auerback, J. (2007). The Development, Implementation and Assessment of an Engineering Research Experience for Physics Teachers, *American Society for Engineering Education Annual Conference & Exposition*.

[12] Autenrieth, R., Butler-Purry, K., Page, C., Hurtado, L.D., & Welch, J. (2009). Enrichment Experiences in Engineering (E3) for Teachers Summer Research Program, *American Society for Engineering Education Annual Conference & Exposition*.

[13] Choate, L. D., Hatipoglu, K., Fidan, I., & Abdelrahman, M. (2011). RET Project in Additive Manufacturing, *American Society for Engineering Education Annual Conference & Exposition*.

[14] Landis, A. E., Schunn, C. D., Rothermel, M. C., Shrake, S., & Niblick, B. (2011). Development of a High School Engineering Research Program: Findings from a Research Experience for Teachers (RET)

Site, *American Society for Engineering Education Annual Conference & Exposition*.

[15] Kapila, V. (2010). Research Experience for Teachers Site: A Professional Development Project for Teachers, *American Society for Engineering Education Annual Conference & Exposition*.

[16] Benson, L., Medders, E., & Cass, C. (2010). Teachers as Scientists: A Qualitative Study of Outcomes for an RET Program, *American Society for Engineering Education Annual Conference & Exposition*.

[17] Carpinello, J. (2011). Translating Research Experiences into Classroom Practice: An RET Project, *American Society for Engineering Education Annual Conference & Exposition*.

[18] Vallas, C. A., & Trail, J. J. (2011). RET Program Yields Elementary, Middle, and High School Teaching Innovations, *American Society for Engineering Education Annual Conference & Exposition*.

[19] Medders, E. G., Cass, C. P., & Bensonn, L. C. (2010). Development of Teachers as Scientists in a Research Experiences for Teachers Program, *National Association for Research in Science Teaching*.

[20] Directorate of Engineering. (2012). Research Experiences for Teachers (RET) in Engineering and Computer Science, *National Science Foundation*.

[21] DeJong, B. P., & Langenderfer, J. E. (2012). First-Year Engineering Students in Newly Accredited Programs: Enrollment and Persistence Demographics. *International Journal of Engineering Education*, *28* (3), 534-544.

[22] Yelamarthi, K. (2012). RFID-Based Interdisciplinary Educational Platform to Improve the Engineering and Technology Curriculums. *Journal of STEM Education: Innovations and Research*, *13*(5), 46-51.

[23] Yelamarthi, K., Sherbrook, S., Beckwith, J., Williams, M., & Lefief, R. (2012). An RFID based Semi-Autonomous Indoor Tour Guide Robot, *IEEE International Midwest Symposium on Circuits and Systems*, 562-565.

[24] Beckwith, J., Sherbrook, S., Lefief, R., Williams, M., & Yelamarthi, K. (2012). CATE: An Indoor Tour Guide Robot. *IEEE International Conference on Electro/Information Technology*.

[25] Hudspeth, M., & Kaya, T. (2012). Collagen as Dielectric Humidity Sensing Material. *Material Research Society Spring Meeting*.

[26] Hudspeth, M., & Kaya, T. (2012). MEMS Capacitive Relative Humidity Sensor Design, Fabrication, and Characterization, *2nd International Advances in Applied Physics and Materials Science Congress*.

[27] Cai, S., & Zhao, Y., (2010). Design Project Based Modules to Promote Engineering Learning and Retention. *Technology Interface International Journal*, *11*(1), 21-25.

[28] Dischino, M., DeLaura, J.A., Donnelly, J., Massa, N. A., & Hanes, F., (2011). Increasing the STEM Pipeline Through Problem-Based Learning. *Technology Interface International Journal*, *12*(1), 21-29.

[29] Maison, S. H., Bauer, A. J. P., Shapardanis, S., White, T. W., Zhang, Z., Li, B., et al. (2013). Cell Di -Electrorotation: Studying of Rotation to Characterize Biological Cells and the Connections in Engineering to the Next Generation Standards. *American Society of Engineering Education National Meeting*.

[30] Arnold, L., Zhang, Z., Kaya, T., Li, B., & Hu, Q. (2013). Incorporating Engineering into the High School Chemistry Classroom. *American Society of Engineering Education National Meeting*.

[31] Kaya, T., Yelamarthi, K., DeJong, B., Hu, Q., Cheng, S., & Chen, D. (2013). Learned Lessons from the First Year Research Experiences for Teachers Program. *American Society of Engineering Education National Meeting*.

[31] Koch, J., Hancock, J. B., Pang, F., & Chen, D. (2013). Research Experience for Teachers: LEGO MINDSTORM Waste Sorter. *Hawaii International Conference on Education*.

[33] DeJong, B., Duthie, M., Hazen, J., & Jurek, A. (2013). Mental Stress of Camera Viewpoints for Teleoperation- Research Experiences for Teachers. *Hawaii International Conference on Education*

[34] Stanley, D. L., Sterkenburg, R., & Lopp, D., (2011). Undergraduate Student Participation in Applications-Based Research. *Technology Interface International Journal*, *12*(1), 54-59.

Biographies

KUMAR YELAMARTHI received his Ph.D. degree from Wright State University in 2008. He is currently an Assistant Professor of Electrical Engineering at Central Michigan University, Mt Pleasant, MI. His research interest is in the area of RFID, embedded systems, robotics, integrated circuit optimization, and engineering education. He has served as a technical reviewer for several IEEE/ASME/ASEE international conferences and journals, and has written over 75 publications in both technical and educational fields. He is a member of Tau Beta Pi engineering honor society, and Omicron Delta Kappa national leadership honor society. He may be reached at kumar.yelamarthi@cmich.edu

TOLGA KAYA currently holds a joint Assistant Professor position in the School of Engineering and Technology and the Science of Advanced Materials program at Central

Michigan University (CMU). Prior to joining CMU, Dr. Kaya was a post-doctorate associate at Yale University (2007-2010), a research and teaching assistant at ITU (1999 -2007), a consultant at Brightwell Corp. (2007), Istanbul, a senior VLSI analog design engineer and project coordinator at Microelectronics R&D Company, Istanbul (2000-2006), and a visiting assistant in research at Yale University (2004-2005). He received BS, MS and PhD degrees in Electronics Engineering from Istanbul Technical University, Istanbul, Turkey. His research interests in electrical engineering and applied sciences are analog VLSI circuit design, MEMS sensors and energy harvesting systems. His research is also involved in biomedical engineering where bacterial hydrodynamics are studied under various shear flow regimes to enlighten the bacterial infections in catheterized patients. He is also working in the Engineering Education research. He may be reached at kaya2t@cmich.edu

BRIAN P. DEJONG is an Assistant Professor of mechanical engineering in the School of Engineering and Technology at Central Michigan University, winner of the university's 2010 College of Science & Technology Outstanding Teaching Award. He received his Ph.D. in mechanical engineering from Northwestern University in 2007. His research interests include engineering education, auditory occupancy grids, teleoperation, and human-robot interfaces. He may be reached at b.dejong@cmich.edu

DANIEL M. CHEN received his Ph.D. degree in Mechanical Engineering from Kansas State University in 1984. He is currently a Professor and teaches a variety of courses in both mechanical engineering and mechanical engineering technology programs. He served as the chairperson of Department of Engineering and Technology from 2001 to 2007, and led the departmental efforts in establishing a number of new undergraduate programs in engineering. Dr. Chen is a registered Professional Engineer in the State of Michigan since 1986, and his research interests include computer-aided design and computer-aided engineering, with a focus on their applications in kinematics, dynamics, and machine design. He may be reached at chen1m@cmich.edu

QIN HU received her Ph.D. degree in Electrical Engineering from Old Dominion University, Norfolk. She was a Post-Doctoral Research Fellow and lecturer at Old Dominion University from 2004-2007. She joined the Department of Engineering and Technology of Central Michigan University as an assistant professor in 2007. Her main research interests have been in the area of bioengineering, pulsed power, electrical properties of materials, and software engineering & development. She has authored/coauthored more than twenty journal papers on prestigious, international, peer-reviewed journals and presented at several international and regional conferences. She has supervised several graduate students on their dissertation/thesis and undergraduate students on their design projects. She may be reached at hu1q@cmich.edu

SHAOPENG (FRANK) CHENG received his Ph.D. degree from the University of Cincinnati in 1995. He is currently an associate professor in the School of Engineering and Technology at Central Michigan University. Dr. Cheng teaches courses in the areas of robotics and automation for both engineering and engineering technology programs. He is the coordinator of the Robotics and Automation Laboratory in the school. His research interests include robotics, mechatronics, controls, and industrial automation. Dr. Cheng has published his research developments in refereed journals, proceedings, and book chapters. He is a member of IEEE and IAJC. He may be reached at cheng1fs@cmich.edu