A 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 the high-school teachers a broad overview of engineering, enhancing their engineering skills through research experience, and assisting them to take their learning’s 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 the 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 has created an effective professional development program for high-school teachers, thus contributing towards 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 the 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 the 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 available for K-12 teachers, soon the 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 their 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 activity 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 pedagogy 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) has been designed with the following features: 1) Active Learning: High-school science teachers were actively involved in a engineering research project with focus on smart-vehicles; 2) Coherence: Activities 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, and follow up for lesson plan development during the school year; 5) Collaboration: In-service teachers (IST) work 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 also published their findings at a premier technical conference or archival journal.

Previous Work

Identifying the needs and challenges of preparing K-12 teachers, several universities has initiated professional development programs. With the primary theme of biomedical engineering, Vanderbilt University has implemented the RET program [9, 10], where participants
followed a legacy model of designing instructional resources while in the program, and taught them in the following year in their respective classrooms. Similarly, Georgia Institute of Technology’s Physics RET program presented that teacher improved their ability to encourage students to pursue a science or engineering degree [11]. Also, the Texas A&M RET program focused on improving teachers’ knowledge about careers in engineering [12]. In addition, Tennessee Tech University (TTU) proposed a research program involving IST, PST, ES, and a faculty member to work on a research project for 5 weeks [13]. One other similar RET site present in the literature is from University of Pittsburgh [14], where ISTs are required to work for 8-weeks during the summer on a research project, implement 6-8 week design based learning modules in their classes, conduct design competition for students in classes of the RET teachers, and offer summer internships at the university for the winning high school students.

While all the above state programs and others published [15-19] differ by their unique goals and activities, 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 administration. While the IST, PST, and ES typically have financial incentives to participate in these programs, that 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.

While 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 participants (engineering faculty, IST, PST) will be beneficial for the engineering education community. Although substantial literature exists to highlight significance of other RET programs, very few, if any, present participant reflections and qualitative assessment of respective programs. Identifying this limitation, this paper presents an overview of the CMU – NSF RET program, initial reflections of all participants, qualitative assessment of initial implementation, lessons learned, and improvements planned for next year.

RET Program Goals and Hypothesis

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 of this program 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 NSF CMU RET program are: 1) establish a collaborative partnership between the various entities of the university, high school STEM IST and PST, and assessment leaders at an external organization; 2) provide a STEM based platform through which the IST and PST 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 IST and PST who serve rural Michigan areas.

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

a) Could IST and PST engage in an engineering research project that would allow them to both do 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 IST and PST understand the research process after participation in this program?

Several hypotheses were established prior to beginning of this program. IST would have the skills necessary to engage in an engineering research project. IST and PST would understand the methodology of conducting research to help translate their research experience into classroom instructional resources. All participants would gain an understanding of 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 have 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. Also during the same time, the PI and Co-PI drafted the application material for participant recruitment, and informed schools in the

The Technology Interface International Journal
Intermediate School Districts (ISD) of the opportunity available. From the pool of applications received, 12 (7 IST and 5 PST) were chosen for the pilot program in summer 2012. Based on the number of participants recruited, it was identified that six teams would be formed with each team comprising of one IST, one PST, one undergraduate ES, and one engineering faculty. This model would bring forward strengths (teaching experience of basic sciences from IST, enthusiasm and willingness to try new strategies from the PST, 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 to reinforce learning and teaching environment within each team.

The CMU 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 explaining the rationale behind 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 translate each project to their classrooms to improve the basic science classes. Accordingly, teams were formed by end of week-1 based on this statement and optional professor’s ratings of the participant’s interest in the project. In addition, other sessions attended by the participants include obtaining identification cards, parking permits, CMU campus tour, engineering and technology building tour, coaching sessions on team building, classroom flipping techniques, and engineering programs at CMU [21].

Beginning week-2, participants spent 20 hours on research, 8 hours on coaching (teacher training), 4 hours on group reflections and team planning, and 3 hours visiting other research labs and attending talks of various individuals. Some of the research projects that participants were involved in are i) semi-autonomous tour guide robot [22-24] ii) automated waste sorter, iii) sensor development for unmanned vehicles [25-26], and iv) robot teleoperation as shown in fig. 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 the 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 week-2), 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 researching problems that can be listed 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 have accomplished that respective day/week, and how they could to infuse these accomplishments into their classroom teaching. These group reflections provided many advantages such as an opportunity to learn about other projects, sharing strategies to solve similar problems, and increased 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 visitation to their respective research labs.

The CMU RET program concluded with a poster presentation session detailing the research accomplished. During the post academic year, trained academic and leadership coaches from 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 IST being translating their summer research into high-school science classes per the new common core standards adopted by Michigan, these coaches worked with IST 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. IST and PST worked together on these activities.

![Prototype of projects: (a) semi-autonomous tour guide robot; (b) autonomous waste sorter; (c) sensors fabricated for unmanned vehicles; (d) teleoperation robot testing different alignments](image-url)
In addition, for broader dissemination of knowledge gained, all participants were required to publish their findings and experiences at a premier conference or journal. Through technical guidance, five papers have been accepted for publication at two international engineering 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 include: 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 IST and five PST were selected for participation during the first year of RET program. Overall, the following summary statistics are 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 IST ranged from 4 to 19 years, where they have taught a range of high school subjects including, but not limited to: physics, physical science, chemistry, mathematics, wildlife agri-science, biology, biotechnology, anatomy, geology, and environmental science. All the IST participants had a college degree in science or mathematics. In addition, the amount of STEM related professional development activities they were involved over the past three years varied from 80 to 250 hours. Some of them had master’s degree in education technology or sciences. Few of them had also several years of industry experience. As all PST participants are 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 (IST and PST) 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 project and understand the research process behind?
- 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 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 have increased their network by establishing relationships with fellow educators, were able to engage in STEM based research and appreciate the intricacies behind it, and

<table>
<thead>
<tr>
<th>Question</th>
<th>Reflections</th>
</tr>
</thead>
</table>
| 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 |
Implementation of engineering research

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

**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 are 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 3,4,5,6,7.

### Table 2. Paraphrased reflections of Pre-Service Teachers

<table>
<thead>
<tr>
<th>Question</th>
<th>Reflections</th>
</tr>
</thead>
</table>
| 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 standpoint |
| 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 |

primarily gain new technical skills that foster their ability to improve the STEM based curriculum in their respective high-schools. Similarly, paraphrased sample responses and feedback obtained from PSTs are presented in Table 2, demonstrating that they have learned the challenges faced by practicing teachers and engineers, gained an understanding of engineering research, and mostly importantly feel more prepared to teach engineering to high school students, and encourage them to pursue engineering as a career.

### Undergraduate Engineering Students

The rationale behind involving undergraduate ES in this project is based on two factors: assist the IST and PST 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 engaged in engineering research project and gain an understanding of process behind, 2) did you develop any new skills that would help in your education, 3) did this program nourish your motivation to pursue further research. Feedback obtained from these undergraduate ES 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 3. Pre-Survey-Reasons for Participation

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

### Table 4. Pre-Survey-Expected Benefits

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

### Table 5. Pre-Survey of Expected Challenges

<table>
<thead>
<tr>
<th>Expected Challenges</th>
<th>IST No.</th>
<th>PST No.</th>
<th>ES No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited exposure to engineering research</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Working with teachers</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Translate engineering research into high school curriculum</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Others (Lack of funding, not sure)</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
For the common reason to participate, while majority of IST stated opportunity to learn and participate in engineering research to design new lesson plans are the primary reasons, PST stated that networking, and professional development are the primary reasons. While there is a difference in reasons to participate, it is clear that the program could serve not only practicing teachers, but also prospective schoolteachers. Per the expected benefits, as the ISTs have prior teaching experience, their responses focused more on making connections between their experiences and NGSS, updating lessons plans, and 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 who were the support personnel in this program gained opportunity to enhance research skills, while at the same time learn about different engineering perspectives.

Per the expected challenges, all participants stated that unfamiliarity with engineering concepts and research is 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 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 information and knowledge that would be shared with high-school students, resulting in them 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 well to be a well-informed teacher.

In addition, all participants were asked to rate the degree to which they agree or disagree with ten statements about science and engineering as presented in Table 7. The first three questions were related to participants’ 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 fig. 2. While the responses of all groups were similar in aspects such as developing significance of science and engineering in student through a can-do attitude, and effective communication, there are some aspects where they differ statistically. For instance, while ISTs stated that they have an in-depth understanding of science concepts to be effective in teaching them and answering students’ questions, PST stated that they do not. However, when it comes to engineering concepts, ISTs stated they have a mediocre understanding, the PSTs stated they have very little understanding to teach engineering and answer students’ questions, demonstrating the need for more engineering experiences.

Table 6. Pre-Survey of expected benefits for high school students

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

Table 7. Questions in Pre-Survey of Perceptions of science and engineering

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

Figure 2. Responses from participants for the pre-survey of perceptions on science and engineering
During the last week of RET program, a post-survey with the following questions was conducted to evaluate if 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? 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 over-arching concepts of engineering approaches and problem solving, demonstrating our successful attempts to engage participants in research. Per development of skills, majority of 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 is not new, they all agreed that it is a good refresher.

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

In addition, to evaluate how well participants understand the research process and develop 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 plan 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 to very useful. Furthermore, to broadly disseminate participant learning’s, they were required to publish their work at a premier conference or an archival journal, and accordingly four papers have 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-RET program has been successful in meeting the goals set forth for all in-service and PST. Though all participants (IST and PST) worked in teams on the same project, the learning experience of each is 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 pilot implementation of the CMU RET program in summer 2012 and conducting program assessment, the engineering faculty has 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: 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 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 RET program, faculty reported that they were able to advance their research, train their research assistant, 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 IST 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 . 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 member) 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 student, and the IST and PST 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 start of the RET program. This limited preparation can be attributed to several factors such as short time span between the initial RET award notification and program implementation, limited exposure to knowledge and capabilities of ISTs and PSTs, and lack of graduate students. As the research goals had to be accomplished in the six weeks, for the next summer when this program is offered, the engineering faculty intends to initiate preparation work the month before by training the ES. Also, since 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 towards accomplishing the research goals set forth. In addition, faculty also plan to set clear expectations and requirements for all participants, and provide background reading material prior to beginning of the program, so that participants can better allocate their time to conduct quality research work.

Lesson 4: 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: 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 significant 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 student and teachers, and disseminating results. The project will have limited success without this effort. Overall, while this program is a good platform to cultivate 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 in late Fall semester to encourage broader participation.
2. Project teams: Engineering faculty members will meet in early spring semester to discuss the projects, 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 plan (4-5 hours long lesson plan for their respective high-school classes) during the coaching sessions in summer, and present it to other participants and faculty members for potential adoption in the same academic year.
4. Conference Proceeding: To encourage broader dissemination of knowledge gained and lessons learned, all participants will be required to identify a conference they intend to attend, draft the conference prior to completion of summer program with guidance from the engineering faculty member.

Conclusion

The pilot implementation of NSF RET program at CMU has 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 has been effective for engaging teachers in meaningful engineering research experiences that allowed them to gain exposure to engineering concepts, and the process behind. 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 helps them enhance their respective high-school classroom curriculum. The overall
combination of research and professional coaching sessions has created a highly effective professional development program for high-school teachers, thus contributing towards 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.

References


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.yelamarti@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