Learned Lessons from the First Year Research Experiences for Teachers Program

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Dr. 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. Prior to joining CMU, Dr. Kaya was a post-doctorate associate at Yale University from 2007 to 2010, a research and teaching assistant at Istanbul Technical University from 1999 to 2007. In 2007, he was a consultant at Brightwell Corp. Dr. Kaya was also a senior VLSI analog design engineer and project coordinator at Microelectronics R&D Company in Istanbul from 2000 to 2006, and a visiting assistant in research at Yale University from 2004 to 2005. Dr. Kaya received B.S., M.S. and Ph.D. degrees in Electronics Engineering from Istanbul Technical University in 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 Engineering Education research.

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Dr. Kumar Yelamarthi received his Ph.D. in electrical engineering from Wright State University in Dayton, Ohio in 2008. He is currently an assistant professor of Electrical Engineering at Central Michigan University in Mt. Pleasant, Mich. His research interests are in the areas of embedded systems, mobile robotics, RFID, VLSI design, 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.

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Dr. Shaopeng Cheng, Central Michigan University

Dr. Shaopeng 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.
Mr. Steve Kettler, Alma High School

Steve Kettler has been a Math/Physics teacher at Alma High School in Alma, Michigan for eight years. He has been an advisor for FRC team #3570 for three years which has helped to strengthen his love for STEM education. During the summer of 2012, Steve participated in the Research Experience for Teachers program at Central Michigan University. During the program, Steve learned many new practices and techniques to apply to his own teaching.

Dr. Daniel Chen, Central Michigan University

Dr. Daniel M. Chen received his Ph.D. in Mechanical Engineering from Kansas State University in 1984. Currently, he is a professor at Central Michigan University, where he teaches a variety of courses in both mechanical engineering and mechanical engineering technology. He served as the chairperson of Department of Engineering and Technology from 2001 to 2007. Dr. Chen is a registered professional engineer in the state of Michigan. His research interests include computer-aided design and computer-aided engineering, with a focus on their applications in kinematics, dynamics, and machine design. The current research topic is in constraint-based kinematic/dynamic analysis of machines.
Learned Lessons from the First Year Research Experiences for Teachers Program

Abstract

We have successfully finished our summer program in our National Science Foundation (NSF) supported Research Experiences for Teachers (RET) Site entitled “Multidisciplinary Engineering Research for Rural Michigan's Future.” The summer program was 6 weeks long and hosted 7 in-service teachers (high school science) and 5 pre-service teachers (integrated science majors). Participants are split into 6 groups and teamed up with an engineering faculty and an engineering undergraduate student each. During their 40 hours/week work schedule, participants have worked on faculty supervised research projects for half their time and the rest was reserved for classroom unit plans that participants would work on developing. Several guest speakers and professional coaches helped us during the professional and curriculum development activities. We are currently working on developing follow-up plans during the academic year where pre-service teachers will implement classroom activities under in-service teachers’ supervision and these activities will be used during high school visits to the campus.

In this paper, we will give the details about the RET Site’s management and discuss our experiences from lessons learned during the first year. Weekly survey results will be analyzed and interpreted. Reflections from participants, faculty, and undergraduate students will be presented. External evaluation scheme will be introduced and results will be given. Each project will be briefly introduced and outcomes will be shared. Finally, we will conclude with the overall lessons we learned from this experience and discuss next summer’s plans as a result of our analysis and self-reflections. We hope that our shared experiences (struggles, accomplishments, and mistakes, etc.) will help the engineering education community develop more effective relationships with K-12 by using the models we implemented.

Introduction

One of the biggest challenges for the engineering faculty in college is to teach the freshmen, i.e. students who have just graduated from high school. Student grades decrease in average due to the transition from high school to the college. Engineering programs in particular face the problem even more since the mathematics level of the incoming students are low. Part of the reason behind the struggle of students is social. On the other hand, the gap between the high school science teachers and the engineering faculty plays a significant role on the transition problems of students.
National Science Foundations (NSF) recognizes this issue and offers funding opportunities to universities for outreach programs. A special program, Research Experiences for Teachers (RET) aims to close the gap between high school teachers and the engineering faculty. The goals of the program is to involve high school science teachers in engineering research projects during the summer and expose them into applied sciences with different research methods. Another side of the project is to develop high school science class unit plans with the experience gained from the RET experience.

We have successfully been granted with an RET grant and our first year of the program was conducted. In this paper, we will give the specific details of our site and discuss the results from the project.

**Proposed RET Site**

The following paragraph is the description of our RET site that was submitted to NSF:

“This proposed RET Site will involve high school (grades 9-12) science teachers in cutting-edge university research programs with a focus on basic engineering concepts of smart vehicles. Further, the teachers will be supported as they translate their findings and processes into new curriculum initiatives for their own classrooms. Teacher interns and pre-service teachers (senior science education major undergraduates) will be an integral part of the program, rigorously preparing them even before their careers as in-service teachers. Twelve teachers, six engineering faculty and six experienced engineering undergraduate students will be formed into six research teams. During a six-week summer program, each team will conduct intensive work on various aspects of smart vehicle development initiative. Teachers will also work with education professionals to develop classroom activities based on the active research areas in which they are involved. Proposed RET Site will target rural Michigan teachers located northern Lower Peninsula.”

We aimed to:

1. establish a unique collaborative partnership between Central Michigan University (CMU) entities such as engineering faculty; Science/Mathematics/Technology Center (SMTC); and Center for Excellence in Education (CEIE); together with Science and Mathematics
Program Improvement (SAMPI) of Western Michigan University, and high school STEM in-service and pre-service teachers in the northern lower peninsula of Michigan;

2. provide a STEM-based platform on which high school STEM teachers gain exposure to basic engineering concepts such as motion manipulation, signal transmission, energy/power conversion, electricity, and data processing through cutting-edge engineering research projects with a focus on smart vehicles;

3. facilitate the development of high school STEM-based classroom instructional materials with in-service and pre-service teachers who serve rural areas of the northern lower peninsula of Michigan;

These objectives were supposed to be reached through:

- conveying basic engineering concepts based on Fundamentals of Engineering (FE) exam topics through research projects on smart vehicles;
- organizing a comprehensive six-week summer research experience within the School of Engineering and Technology (SET) research laboratories at CMU for high school STEM teachers;
- providing an opportunity for high school STEM teachers to design research-based curriculum projects that are aligned with topics they teach at their respective local schools;
- developing skills, abilities, and attitudes of teachers related to their roles as teacher leaders, curriculum developers, and assessment designers as they plan High School Content Expectations (HSCEs)-aligned experiences for their students;
- coaching by CEIE staff for participating teachers throughout the academic year as they implement the curricula they have planned;
- disseminating the results from both research and curriculum development activities to provide outreach to other teachers and professionals in the area;
- brainstorming between participating teachers and engineering faculty regarding innovative classroom activities and experiments for first-year university students; and
- conducting classroom visits by engineering faculty, CEIE staff, and SMTC staff to provide support to teachers and their students as they implement curricular changes.

Our intellectual focus was described as follows:

“Intelligence has been involved in many aspects of our life through new technologies and innovations. It has become one of the important driving forces in engineering design and
solutions. A smart robot/vehicle provides a common platform where researchers can explore new opportunities of developing, integrating, and implementing existing and new technologies in science, engineering, and technology. This popular theme will help teachers to link basic engineering concepts to the high school curriculum and deliver the classes more efficiently.”

**Recruitment and Management of the RET Site**

NSF notified the PI in February 2012 that the proposed project would likely to be funded provided successfully responding to reviewer’s questions, including budget revision, IRB approval, and detailed recruitment plan. The official award letter was received in April 2012 with the project start date stated as May 2012. Recruitment efforts started in May 2012 by sending fliers to local ISDs, personal contacts, and distributing the information in the EHS where the pre-service teachers were targeted. Phone interviews were carried out to select 12 participants out of 15 applicants.

Each research team included an in-service teacher, pre-service teacher, engineering student, and an engineering faculty. This model was chosen to create a learning and teaching environment within the teams. Pre-service teachers’ enthusiasm and willing to try new strategies, in-service teachers’ experience in teaching and basic science concepts, engineering students’ practical knowledge and experience on the particular project were the main driving forces throughout the program. Engineering students also played a role on bridging the gap between the engineering faculty and the participant teachers.

In the first week of the program, participants were notified that they would be paired to a particular project where the engineering student and the engineering faculty were determined. Each faculty introduced their project and their student assistant. Teachers wrote short descriptions about projects and provided how they could translate each project to their classrooms. The language was carefully selected not to let them choose a project but think hard on each project and their benefits. There were also group activities on understanding each project better by naming the projects (Tour d’ET, Sweat Shop, RoboArm, Joystick, The Recycler, The Vibrating Cell). At the end of the first week, teams were assigned by the PI.

Besides project presentations, first week was mostly orientation sessions; CMU ID cards, parking permits, campus tour, ET building tour, coaching sessions on team building and classroom flipping techniques. Starting from second week, participants spent 20 hours on research, 8 hours on coaching, 4 hours on group reflections and team planning, and 4-8 hours on visiting labs or attending talks (organized particularly for participant teachers). Agenda in Table 1 was followed. Coaching sessions were particularly on effective teaching methods, group exercises, and critical thinking. Furthermore, the NGSS were studied intensively by individually,
in teams, and supported by ISD representative presentations. Towards the end of the program, coaching sessions were dedicated for final report preparations. Also, each in-service teacher spent 2-3 hours with pre-service teachers to share their experiences as teachers. Topics were included but not limited to student teaching, job interviews, classroom practices, lesson plans, etc.

Table 1: Weekly agenda of the summer program.

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>9a – 10a</td>
<td>Research</td>
<td>Coaching</td>
<td>Research</td>
<td>Coaching</td>
<td>Research</td>
</tr>
<tr>
<td>10a – 11a</td>
<td>Research</td>
<td>Coaching</td>
<td>Research</td>
<td>Coaching</td>
<td>Research</td>
</tr>
<tr>
<td>11a – 12p</td>
<td>Research</td>
<td>Coaching</td>
<td>Research</td>
<td>Coaching</td>
<td>Research</td>
</tr>
<tr>
<td>12p – 1p</td>
<td>LUNCH</td>
<td>LUNCH</td>
<td>LUNCH</td>
<td>LUNCH</td>
<td>LUNCH</td>
</tr>
<tr>
<td>1p – 2p</td>
<td>Research</td>
<td>Research</td>
<td>Research</td>
<td>Speakers</td>
<td>Research</td>
</tr>
<tr>
<td>2p – 3p</td>
<td>Research</td>
<td>Research</td>
<td>Research</td>
<td>Speakers</td>
<td>Research</td>
</tr>
<tr>
<td>3p – 4p</td>
<td>Research</td>
<td>Research</td>
<td>Coaching</td>
<td>Speakers</td>
<td>Research</td>
</tr>
<tr>
<td>4p – 5p</td>
<td>Reflections</td>
<td>Reflections</td>
<td>Coaching</td>
<td>Research</td>
<td>Planning</td>
</tr>
</tbody>
</table>

Each participant was required to submit a report as a result of their experience from the summer program. They were strongly encouraged to develop lesson plans that would be based on their experience at CMU. Each participant also prepared a poster and presented the poster in a poster session at the end of the program.

Teachers are required to work on classroom activities during the academic year. In-service teachers are responsible for assigning topics that would fit to their particular classrooms and coaching pre-service teachers. Pre-service teachers, on the other hand, will develop the classroom activities and implement those into in-service teachers’ classrooms. Visits were scheduled in Fall 2012 and Spring 2013.

Participants were also encouraged to submit papers to educational conferences. 4 papers have been accepted so far; ASEE and 2013 Hawaii International Conference on Education.

Table 2: Coaching Sessions in the CMU RET Program

<table>
<thead>
<tr>
<th>Activity Title</th>
<th>Activity Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Teaching</td>
<td>A professional coach from CEIE introduced techniques on how to flip the classroom.</td>
</tr>
<tr>
<td>Next Generation Science Standards; Deeper Thinking</td>
<td>A professional coach from CEIE facilitated discussion groups on NGSS. Also, she worked with the participants on how to make the students think deeper, taking the learning process one step further.</td>
</tr>
<tr>
<td>Discovering the Goals</td>
<td>RET program’s goals were discussed with the participants and main objectives were further studied through puzzle activities.</td>
</tr>
<tr>
<td>Event</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Translating research experience into new science standards</td>
<td>A professional coach from CEIE facilitated discussion groups on NGSS with a focus on the implementation of learned experiences from the summer program.</td>
</tr>
<tr>
<td>NGSS Review</td>
<td>An ISD representative shared his vision on NGSS and also presented the history of NGSS.</td>
</tr>
<tr>
<td>Lesson Plan Conversation</td>
<td>A professional coach from CEIE discussed the effective ways of developing lesson plans and facilitated the group work.</td>
</tr>
<tr>
<td>Google use in classrooms</td>
<td>A teacher participant did a workshop on how to work with Google gadgets such as Google docs, Google sites, etc.</td>
</tr>
<tr>
<td>King of the hill competition</td>
<td>An engineering faculty organized a workshop/competition on Lego Mindstorms.</td>
</tr>
<tr>
<td>Time Management</td>
<td>Human Resources department facilitated a workshop on effective time management techniques.</td>
</tr>
<tr>
<td>Report Preparation</td>
<td>Participants worked on their summer report with the supervision of the faculty.</td>
</tr>
</tbody>
</table>

**Reflections from the Faculty**

Each faculty wrote about their experiences from the summer program to reflect on their teams and projects. Below is the list of projects with the reflections from the faculty:

**Autonomous Waste Sorter**

“The project goal of the autonomous waster sorter is to design, build, and test an autonomous system capable of accurately sorting common recyclable materials that include plastics, glass, and ferrous and non-ferrous metals. The team I supervised has completed a physical prototype to operate autonomously for both material identification and waste handling. The system was successfully tested for the sorting and handling of plastic bottles, glass containers, aluminum cans, and tin-coated steel containers.

The main challenge is that the project must be completed in 5 weeks which is such a short time frame for a senior design-type of project. Since the team didn't have all the time to go through the design-build-test cycle, the focus of the project was on only building and testing the prototype. Fortunately, team members' prior experiences in both Lego Mindstorm and woodworking help a lot in these two phases. If it's going to be the project of autonomous waste...
sorter again, it should be divided into a number of subparts with each has an emphasis on the use of more sophisticated sensors and motors/controls.”

**Biomedical Experiments and Simulations**

“One teacher worked on molecular dynamics simulation of Poly(n-isopropylacrylamide) (PNIPAM) and graphene oxide (GO). The expected outcomes for her were to: (a) get familiar with Linux operation system; (b) know chemical structure of Pnipma and GO and use software Avagadro to establish the molecule models; (c) study force fields used in molecular dynamics simulation; (d) use Gromacs in Linux system to run MD simulation and (e) use VMD to visualize molecular structures and analyze the results. Other teacher participant’s project was on electrophoresis and electrorotation of biological cells. The manufacturing of electrophoresis and electrorotation devices were under another faculty’s supervision. The expected outcomes for him are to: (a) understand the mechanism of electrophoresis and electrorotation; (b) design and manufacture the devices for electrophoresis and electrototation; (c) use live cells or microbeads to test the devices and analyze data obtained from the experiments.

The participants in my team have strong background in their specialized area, which greatly helped advancing the two projects. However, it’s very challenging for them to both understand and utilize engineering knowledge and skills in such short time. I would like to contact with the participants earlier before they officially start the project and would get them prepared better. And at the same time, to thoroughly prepare our student assistant would be a plus to the projects. If a project would be multidisciplinary, collaboration between labs would be discussed and scheduled in advance. The most efficient and successful strategy we applied this time is to give participants step by step tutorial material to practice before starting the real project. The well-trained student assistant plays a critical role in these projects too.”

**Teleoperation**

“The goal of my project was to test whether the alignment of teleoperation interfaces can be simulated on a flat screen, or not. It has been shown that proper physical arrangement (position and angle) of teleoperation video displays can affect the user's mental difficulty and task performance -- properly aligned displays are easier and more efficient to use. Here, we tested whether you could simulate the video alignment by visually distorting the video images on a
single flat screen. I expected my RET team to implement the teleoperation (engineering student and myself), design an experiment (whole team), run the experiment (teachers and student), analyze results (whole team), and write up our findings (whole team). I hoped to have deliverables of experimental data, engineering-education or teacher-education conference paper(s) by the teachers, and research conference and/or journal paper by the student and/or me.

There were some challenges working with the participants, as expected. For example, the teachers did not have the engineering background suited for designing communication, writing code, wiring components, or even analyzing data in excel (or Matlab). A specific example of the contrasting backgrounds is when deciding how to communicate the user which location he was to move the robot to: the teachers suggested a low-tech human-intensive solution of colored stickers and verbal commands, while the student and I suggested overlaying arrows on the video images. The main thing I would do differently next time would be to fully implement the teleoperation prior to the teachers’ arrival -- there were a few days at the beginning where I struggled to find something for the teachers to do, besides "read this paper" or "learn how such-and-such works". However, I am pleased by the process and results of the RET program. The teachers were motivated, punctual, hard-working, better at understanding human-experiment subtleties than the engineering student, and more social with the users. I found it successful to assign technical tasks (coding, wiring, analyzing data) to the student and me, and assign other important tasks to the teachers (experimental design, building of the testing apparatus, proctoring experiments, and organizing data). The teachers seemed to learn a lot about engineering, teleoperation, robotics, data analysis, and coding, and they were very excited about the possibility of conference and journal papers.”

Humidity Sensors

In this project, a humidity sensor prototype is aimed to be developed. Capacitor structures are fabricated using microfabrication techniques and tested their electrical properties with changing humidity conditions. Participants are required to be able to do the whole fabrication and testing processes by themselves and develop the skill of interpreting the results. They are required to write the fabrication procedures as a scientific protocol and provide a detailed report of their experience, which would then be translated into a conference paper.

One of the main challenges was to balance the level of the research among the in-service and pre-service teacher due to the experience difference. Another main challenge was to effectively
teach the main electrical circuit concepts in a limited time. Because of the open ended nature of the project, it was difficult for participants to relate to the project at the beginning. Furthermore, slow progress on the fabrication process was challenging for the participants who are accustomed to getting the work done in a very limited time in their classrooms. I would probably explain the nature of the project better and let them know what the possible road blocks would be in order to lower the anxiety. I would also create a better hierarchy and work load distribution among the experienced and not experienced teachers. Having short meetings with the participants along with the engineering student researcher was effective. Checking their progress regularly but giving them space to take the responsibility and charge was balanced well.”

Robotic

The goal of my project is to control brush and brushless DC (BLDC) motors that power robot joints. The project involves the theories and applications of closed-loop control system, BLDC motor commutation, pulse width modulation (PWM) technique, motor driver design, robot joint motion profile, PID controller tuning and programming. My team consists of one junior electrical engineering student and two high school teachers who have physics background at different levels. The main challenges for the participants are to understand and apply the basic and advanced principles of electrics/electronics, robotics, and control to conduct the project within five weeks. This includes the use of Ohm’s law and Kirchhoff’s law, voltage and current dividers, electromagnetism (i.e. induction and motor action), operational amplifiers (op-amps), solid-state switches (i.e. diodes, transistor, MOSFET), digital and analog position sensors (i.e. potentiometer, encoder), PID control functions, switching control functions (i.e. PWM, H-bridge driver), robot joint dynamics and motion trajectory (i.e. position, velocity, and torque).

To allow my team members to do the project effectively, handouts for conducting eight different lab activities have been used. The prepared materials cover the topics of fundamental of electricity (Lab 1), MOSFET control of DC motor (LAB 2), PWM control of DC motor (Lab 3), creating PWM signal with op-amps (Lab 4), H-bridge driver for DC motor (Lab 5), analog closed-loop control of DC motor position (Lab 6), control of signal BLDC motor with PMD ION/CME motion control driver (Lab 7), and control multiple axis of robot with PMD Prodigy/CME standalone motion control card (Lab 8). Each lab activity has clearly defined objectives and components, as well as in-depth descriptions of related concepts and techniques. With the basic understanding to the subjects (i.e. design problems and tasks), the participants in my team were able to develop a working procedure that leads to feasible solutions and satisfied results (i.e. circuit schematics, values of components, valid system performance). The team experience showed that this step-by-step learning-by-doing approach works effectively as
expected. The similar approach and some of the project results can be directly incorporated into the science class at high school and engineering class at CMU.”

Reflections from the Participants

How do you plan to use the knowledge gained with you students?

- I will be implementing the knowledge in my academy courses and modifying my lesson plans relating to simulation.
- Teach the engineering process and that research is not usually a clear, linear process.
- Use Vernier equipment to teach control systems.
- The basic approach to how research is done is something that I will use in my approach to teaching—state a problem, do background research, use what’s relevant to plan on experiment/solution method, experiment/test, analyze data, and come to a conclusion.
- I plan to use the way of thinking in engineering in my science classroom.
- Having experience with the engineering thought process will help me in the classroom as inquiry based learning becomes more popular.
- I can better understand their learning process; I have the knowledge of circuits that I can teach.
- To encourage them to think like an engineer.
- I plan on redesigning my labs, projects, and lessons with engineering concepts and standards.
- Changing the way I do labs to make them more exploration based.
- Integration of engineering process into classroom is key to NGSS and how that will manifest in the 7-12 classrooms.

4. What would keep you from using information you received in this program with your students?

- The complexity.
- Some of the content was above secondary level, but it all could be used conceptually at the secondary level.
- Not being able to fully explain engineering concepts.
- Nothing, but personal stuff which won’t happen.
- Too advanced at times for middle schoolers.
- Not getting a job. (haha)
- Time crunch of state requirements.
- Time demands of curriculum.
- Nothing. (2)
- Time frame. For me though, I’m not sure as to the flexibility I’ll have in deciding what content I teach. I will make an effort to design instruction more with an engineering flavor, as that is reasonable.

5. What would improve this Professional Development experience for you?
• Different PD-educationally wise.
• Writing applications for conferences or grants.
• Having more teacher/pre-service teacher time.
• More workshop sessions.
• Make it end a week earlier, so we have a week or at least a couple of days off before school starts.
• Learning more about standards.
• Being able to create a research project that could be done in a high school classroom.
• Make it meaningful and useful.
• No response (3)

6. What would you like to see us incorporate into Year 2 of the program?

• Guest engineer speakers.
• Running through lessons designed for high school.
• Better development, new project.
• More workshops and team development.
• Nothing, if I think of something I will let you know.
• More workshops to teach us basic engineering concepts.
• More activities like “King of the Hill”.
• Stronger guidance with increased flexibility on project ideas. This is difficult for a number of reasons, but probably important to think about.
• I will have to think about this and let you know. More variety of PD. Possibly start one week earlier to allow one week between RET and when classes start.
• Exposure to other research projects and exposure to engineering as practiced in industry, government, etc.
• No response (1)

7. Do you have comments for the Engineering faculty?

• Well done and thanks for giving up your time for us!
• Everyone was supportive, understanding and helped us create a meaningful research experience.
• Great job!
• It was a pleasure working with them. I might not have the kind of ideas that they want from me because I am not as knowledgeable as they are.
• Help relating their discipline into classroom material.
• Thank you!
• Thank you for being here this summer to support high school teachers!
• Thank you Tolga and Dr. Hu for the meaningful experience and rare opportunity. I feel like I have accomplished some personal goals.
• No response (3)

8. In what capacity were the undergraduate engineering students’ helpful to you?

• Boyu was essential in helping Jackie and I understand concepts.
- Noah was the best and helped us so much!
- Extra hand for fabrication.
- Boyu was awesome. I enjoyed his company. He was also very knowledgeable and great teacher. I couldn’t have done it without him.
- Matt did all of the programming that I could not have done.
- This project would not have been possible without the help the undergraduate students provided.
- They were key to us making progress and were vital to our success!
- They were very helpful and great teachers.
- Hands on, and Fei was very willing to try new things.
- Ze was absolutely wonderful as a person and co-worker. He definitely is a hard worker, willing to go above and beyond, very intelligent young man. I can’t say enough good things about him!
- No response (1)

External evaluator Comments

With a couple of exceptions (noted below), in-service teachers generally thought that the program objectives were successfully accomplished.

- Though ratings were generally high for “Facilitate the development of high school STEM-based classroom instructional materials for use in rural areas of northern Lower Michigan,” a couple in-service teachers felt that there was room for improvement. Comments suggested that more time could have been used to actually develop lesson plans, and that the professional development related to this objective was sometimes superficial (“placing text resources on tables to pick up and thumb through”).
- More clarity was needed for what was meant by “Recognize ‘scientific language’ and ‘teacher language,’ and know when and how to use each language.” One in-service teacher found the implication of this objective insulting: “This seems to imply that there is a major difference between the terminology we use in the classroom versus what ‘real’ scientists use. I’m a bit insulted by this implication. Much of our job involves translating the language of science for our students to understand.”

With one exception (noted below), pre-service teachers also generally thought that the program objectives were successfully accomplished.

- There needed to be more sensitivity toward the lack of experience and background (especially with Smart vehicles) that pre-service teachers are bringing to the research projects. The mean rating for “Convey basic engineering concepts through research projects on Smart vehicles” was much lower for pre-service teachers than for in-service teachers. An independent sample t-test indicated that this was a statistically significant difference (p-value = 0.037). One pre-service teacher even commented, “We really got an idea of basic engineering concepts, but not so much of Smart vehicles.”

With a couple of exceptions (noted below), in-service teachers perceived program activities as being useful.

- In-service teachers most valued the faculty visits that highlighted research, the social and team-building activities, and the reflection sessions. Comments from in-service teachers...
included: “Most [faculty visits] were very informative and led to an excellent dialogue between high school teachers and college professors,” “It’s always helpful and inspirational to hear from other teachers (including the pre-service “kids”), and “[It was] nice to hear how other groups were working through issues.”

**More coaching may have been needed on curriculum with new standards.** Comments from two in-service teachers indicated that this was lacking. However, the remaining five in-service rated this activity as a “4” or a “5,” suggesting that they did not agree with this assessment.

- **There was a general dissatisfaction with “Professional development sessions on effective teaching.”** Five of the seven in-service teachers rated this as a “3” or lower. Comments supported this. One teacher wasn’t sure that “this happened.” Two others felt that they did not do anything “new.”

- **Pre-service teachers also perceived program activities as being useful.**
  - **Pre-service teachers most valued PD sessions on effective teaching, social and team building activities, and coaching on curriculum development with new standards.**
  - **PD sessions on effective teaching were more highly valued by pre-service teachers than by in-service teachers.** The mean rating for “Professional development sessions on effective teaching” was much higher for pre-service teachers than for in-service teachers. An independent sample t-test indicated that this was a statistically significant difference (p-value = 0.014). This is not surprising given that pre-service teachers do not yet have the background and experience of veteran teachers.

With a couple of exceptions (noted below), in-service teachers were generally satisfied with the program arrangements.

- **In-service teachers appreciated that program staff kept them informed of program activities, that the faculty research team leader was available to answer their questions, and that a collaborative and helpful tone was established.** Comments from in-service teachers included: “Tolga kept us updated,” “[There was] excellent communication by the faculty leader,” and “The undergrad engineering students were amazing and really helped to form the bridge between the teachers and the professors.”

- **The expectation of a poster project needed to be more clearly communicated at the beginning of the summer.** One in-service teacher said that it would have been “beneficial to have more details about the paper and poster at the beginning of the project.” Another wanted to know “well ahead of time about what kind of paper, poster, or presentation” they needed to make at the end. A third was “confused about the poster and research component” and “felt like it ‘got dropped’” on them.

- **Teachers’ responsibilities in the research labs needed to be more clearly explained at the beginning of the summer.** One in-service teacher stated, “I felt like I was wandering aimlessly.” Two others stated that they were unclear at the beginning, but suggested that clarity came with time.

- **Pre-service teachers were generally satisfied with program arrangements.**

Overall, it is difficult to gage the perceptions of the pre-service teachers beyond their ratings, as they almost never made additional comments to explain their ratings. Nevertheless, the only comment that was made by a pre-service teacher about program arrangements was a positive one: “[The faculty leader] was extremely helpful and available throughout the program.”
The summer program successfully engaged teachers in the process of how engineers and scientists communicate their research to peers. All teachers reported that they were planning to attend a scientific conference, and all but one pre-service teacher expressed plans to make a formal presentation of their research work.

Most pre-service teachers expressed plans for eventually getting a master’s degree. However, it was not possible to determine the extent to which these plans were influenced by the program, as teachers were not asked about this. To correct this, evaluators will add the following question to the end-of-year questionnaire that will be administered in spring 2013: “To what extent have your plans for graduate school been influenced by your participation in the program?”

The summer program had several positive impacts on the practices of both in-service and pre-service teachers:

- Several in-service teachers reported that they will redesign lessons and projects, or implement new lessons and projects based on what they learned through the summer program.
- Most of the pre-service teachers stated that they will use the insights that they gained from talking to and networking with experienced teachers.
- Most of the pre-service teachers, and even two of the in-service teachers, wrote that they learned skills for being more effective in the classroom.
- At least one in-service teacher and two pre-service teachers felt that they were more equipped to teach engineering principals or topics.
- At least two in-service teachers stated that they plan to implement lessons that were specifically developed through the summer program.
- One pre-service teacher added a minor in Biology as a direct result of participating in the summer program.

Several useful suggestions were made for improving the program:

- One in-service teacher and two pre-service teachers felt that the last day of the summer program was too close to the start of the school year. This could have been addressed by starting the program a week or so earlier.
- Two in-service teachers felt that professional development sessions were too long. The full comment from one of these teachers was, “Don’t designate entire days to curriculum and teaching methods development. This got to be awfully long and more than can realistically be taken in at one time. Perhaps do a couple hours each morning and then go on to research for the rest of the day rather than doing all development one day and all research the next.”
- Other useful suggestions that project management should consider include: introduce the paper and poster requirement early in the summer, don’t dictate research areas for teachers, and spend more time discussing conferences.

Conclusion

First year of the RET program was completed successfully with thoughts and ideas that would make the program better next year. It was clear that the application process needed to be planned in advance. Therefore, advertisements were sent out late Fall in order to have enough time for the decisions. A personal statement of expectations from participants themselves were required this year. A clear communication with the Engineering faculty will be needed to discuss the projects, set the expectations and goals, and potential team assignments. Engineering undergraduate students...
should also be notified in advance and be asked to start working on the project early Summer, if not late Fall (funding permitted). In terms of summer schedule, research and development times will be clearly specified and participants will be required to focus on the tasks that are assigned. Participants will be required to design a unit plan (4-5 hours long lesson plan) and present the plan in front of other participants during the program. Each participant will prepare a conference paper quality, submission ready report by the end of Summer project. The conference will be discussed with the faculty mentor.