Research Experiences for High School Teachers and College Instructors in Mechatronics, Robotics and Industrial Automation

Dr. Sheng-Jen "Tony" Hsieh, Texas A&M University

Dr. Sheng-Jen ("Tony") Hsieh is a Professor in the Dwight Look College of Engineering at Texas A&M University. He holds a joint appointment with the Department of Engineering Technology and the Department of Mechanical Engineering. His research interests include engineering education, cognitive task analysis, automation, robotics and control, intelligent manufacturing system design, and micro/nano manufacturing. He is also the Director of the Rockwell Automation laboratory at Texas A&M University, a state-of-the-art facility for education and research in the areas of automation, control, and automated system integration.
Research Experiences for Teachers in Mechatronics, Robotics, and Industrial Automation

Abstract

U.S. manufacturers are seeking highly skilled workers to hire in industrial automation and control jobs. Encouraging active participation of secondary school teachers and two-year college faculty in university research allows them to learn about recent discoveries and innovations, share about them in the classroom, and thereby encourage and stimulate students to pursue engineering and computer science careers such as industrial automation. The paper will describe program activities, research projects, outcomes, and lessons learned from a National Science Foundation-sponsored Research Experiences for Teachers program. Participants were recruited from science, technology, engineering and math departments in high schools and colleges throughout the U.S. Special effort was made to recruit teachers and instructors from districts and two-year colleges with large numbers of underrepresented minority students. Program objectives were to 1) provide opportunities for participants to actively participate in research and then translate their research experiences and new knowledge into classroom activities; 2) establish long-term collaborative relationships with the Mechatronics, Robotics, and Industrial Automation research community at Texas A&M University; and 3) disseminate findings and instructional materials developed for this program. Participants spent six weeks working on a research project with a mentor and a graduate student. Opinion survey data suggests that participants enjoyed the program and learned from the research experience.

Overview and Objectives

Automation has a profound effect on the way we do work, and mechatronics and robotics are the building blocks for industrial automation. U.S. manufacturers are seeking highly skilled workers to hire for industrial automation and control jobs [1]. To help cultivate a future workforce, it is important to expose students to automation and control concepts at an early age. Encouraging active participation of secondary school teachers and two-year college faculty in university research allows them to learn about recent discoveries and innovations, share about them in the classroom, and thereby encourage and stimulate students to pursue engineering and computer science careers such as industrial automation.

Recent research has studied the characteristics of professional development that effect change in secondary science teachers' classroom practices. Results suggest that the number of teachers providing opportunities for their students to conduct full inquiry increased significantly after their participation in inquiry based research program [2]. In addition, evaluations of National Science Foundation Research Experiences for Teachers (RET) programs have suggested that research experience helps high school teachers to convey engineering concepts in their classroom teaching [3,4,5].

This paper describes an NSF funded RET site focusing on Mechatronics, Robotics, and Industrial Automation theory and applications in different engineering disciplines and presents survey results and lessons learned from hosting the program in the first year. The site allows twelve high school and two-year college faculty involved in career and technology education (CATE) to actively participate in Mechatronics, Robotics, and Industrial Automation research.
and curriculum development at a Tier 1 research university during a six week summer research program with follow-up activities during the academic year.

The goals of the site included: 1) provide opportunities for CATE faculty to actively participate in research and then translate their research experiences and new knowledge into classroom activities; 2) establish long-term collaborative relationships between CATE faculty and the Mechatronics, Robotics, and Industrial Automation research community at Texas A&M University; and 3) disseminate findings and instructional materials developed for this program.

**Teachers/Instructors Recruitment and Selection**

The program targets teachers/instructors who 1) are teaching math, science, or career and technology education (CATE) and/or involved in robotics-related activities such as Boosting Engineering, Science and Technology (BEST) competitions. Instructors from institutions with high percentages of minority and socio-economically disadvantaged students were encouraged to apply. A flyer was designed and direct emailed to over 800 STEM teachers and administrators at school districts and two-year colleges in Texas. In addition, information about the program was distributed via ASEE’s Engineering Technology Division’s listserv (ETD-L) and at the annual High Impact Technology Exchange Conference (HI-TEC).

A web page was created to allow applicants to see the research projects, mentors, and activities. The application package needed to include (1) a personal information data sheet, (2) an essay describing the applicant’s curriculum design experience, and (3) a recommendation letter. The personal data sheet allowed the project director to group applicants based on their research interests. The project director then worked with each individual mentor to select participants.

**General Program Information**

As described earlier, the program’s goals included: (1) to participate and learn about a research project with a graduate student and mentor; (2) develop a lesson plan for disseminating the research experience into the classroom. To achieve these goals, the following activities were provided:

**Presentations on research methods and areas**

To learn about research methods, teachers/instructors had the opportunity to attend presentations offered by the college on topics such as how to write an abstract, how to do a literature review, how to set up a working hypothesis, and how to conduct statistical testing. Teachers/instructors also attended presentations on mechatronics, MEMS, micro/nano manufacturing, robotics, and automated system design. The presentations were given by the mentors and other faculty members.

**Team research experience**

Participants were formed into teams based on their interest, teaching subjects, and affiliation. Each team worked on a research project or area of common interest with a designated faculty mentor and graduate student. First, the program matched teachers/instructors to projects based on the interest as indicated in the application package. Second, the mentor talked to applicants to
verify their interest and background. Third, the participants were notified about their project and mentor. To ensure each team would receive sufficient attention, each mentor supervised up to two participants per summer and two participants worked as a team with a mentor and graduate student. In addition, the project scope and depth were adjusted by the mentor based on participants’ performance. The first-year research projects included:

- Camera Calibration in Computer Vision
- 3D Object Reconstruction through the use of Projective Geometry
- Remote control of Programmable Logic Controller (PLC)-based automated system
- Experimental Bipedal Walking Robots
- Graph Theory in Everyday Life
- Bridging the Gap: Sensor-Based Automation Across Grade Levels
- Using Piezoelectric Film to Capture Voltage

Project topic areas ranged from theory understanding to practical applications. The research domains included MEMS, computer vision, walking robot design, and PLC-based automated system design. The research tasks included modeling, algorithm design, conducting experiments, and building automated systems using a PLC as the controller. Also, the engineering disciplines included manufacturing, mechanical, computer science, and electrical engineering. The RET program had a very strong interdisciplinary flavor which allowed participants to learn from each other.

Community of active learning

Several actions were taken to facilitate the formation of a community of active learners. First, most RET participants were housed in a dormitory with students from other Research Experiences for Undergraduates (REU) programs. Therefore, they can interact and learn from each other; since they are most likely in different research projects and from different programs. Most importantly, they all have the similar goal: to learn how to do research. Second, at “brown-bag” lunch meetings, RET teams and REU students would present about their project, progress, and difficulties. Third, they were required to write a lesson plan using templates from TeachEngineering.org and prepare a poster and presentation about their research projects. They also attended campus lab tours and presentations related to robotics and industrial automation.

Social activities

RET participants were integrated into the larger Texas A&M research community—over 200 undergraduates were involved in a dozen REU and other formal summer research programs in 2013. Students were housed with students from these other summer research programs in a modern dormitory that included a fitness center, a movie theater, and a pool. The dormitory was within easy walking distance to the College of Engineering. Table 1 provides a sample of scheduled social events, research seminars, and field trip activities.
### Table 1. Schedule of Activities

<table>
<thead>
<tr>
<th>Week</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Welcome Breakfast * Kick-off Meeting and Orientation * Initial meeting with faculty mentor * Work area tour * Tour of University library and seminar on using library resources * Research seminar: <em>Bipedal Walking Robot (Dr. Ames)</em></td>
</tr>
<tr>
<td>Week 2</td>
<td>Field trip: Frito-Lay Potato-Chips, Houston, TX * Research seminar: <em>Photoacoustic Microscopy Based on a Water-Immersible MEMS Scanning Mirror (Dr. Zou)</em>.</td>
</tr>
<tr>
<td>Week 3</td>
<td>Seminar: <em>Engineering Innovation Research</em> <em>Tour: Immersive Visualization Lab</em> <em>Research seminar: From Flocks of Birds to Robot Herds (Dr. Shell)</em></td>
</tr>
<tr>
<td>Week 4</td>
<td>Campus tour:* Cyclotron Institute tour * Field trip to Solectron Texas. L.P., Austin, TX * Research seminar: <em>Microdevices and the Life Sciences (Dr. Han)</em></td>
</tr>
<tr>
<td>Week 5</td>
<td><em>Tour: Offshore Technology Research Center</em> <em>Mid-program assessment</em> <em>Research seminar: 3D Image Reconstruction using Machine Vision (Dr. Song)</em></td>
</tr>
<tr>
<td>Week 6</td>
<td>Final Presentation <em>End-of-program assessment</em> <em>Farewell dinner</em></td>
</tr>
</tbody>
</table>

### Activity Highlights

In addition to working on their research projects, participants attended research presentations, and social activities with other students involved in REU and summer research programs at Texas A&M University. During the last week of the program, they presented their work to the mentors and completed papers summarizing their research. Below are photos and abstracts from the poster session. Figure 1 shows a weekly research presentation. Figure 2 shows the RET site final presentation. Three sample abstracts follow.

![Figure 1. Presenting research to RET cohort.](image)

![Figure 2. Final presentation.](image)

**Experimental Bipedal Walking Robots**

Participants: Samuel Danquah, Norview High School, Norfolk, VA
Stephanie Witherspoon, Waltrip High School, Houston, TX
Mentor: Aaron Ames, Texas A&M University

The number of research and development projects aimed at building and programming bipedal and humanoid robots has been increasing at a rapid rate during the last few years. In this project, we incorporated bipedal robotics research being done in the AMBER Lab at Texas A&M into the Robotics and Automation syllabus taught at the high school level.

Figure 3. Experimental Bipedal Walking Robots project.

Using Piezoelectric Film to Capture Voltage

Participants: Bill Heeter, Porter HS, Porter, TX
Craig Maddux, Porter HS, Porter, TX
Mentor: Dr. Jun Zou, Texas A&M University

Piezoelectric Film is an enabling transducer technology with unique capabilities. Piezoelectric Film produces voltage in proportion to compressive or tensile mechanical stress or strain, making it an ideal dynamic strain gage. It makes a highly reliable, low-cost vibration sensor, accelerometer or dynamic switch element. Piezoelectric Film is also ideally suited for high fidelity transducers operating throughout the high audio (>1kHz) and ultrasonic (up to 100MHz) ranges. The Piezoelectric Film can become a power source that can be used to power another device. By flexing the Polyvinylidene fluoride (PVDF) film a voltage is created, that voltage can then be captured and stored until needed.
Bridging the Gap: Sensor-Based Automation Across Grade Levels

Participants: Creighton Bryan, South Garland HS, Garland, TX
Lee McMains, AIMS Community College, Greeley, CO
Mentor: Sheng-Jen Hsieh, Dept. of Engineering Technology, Texas A&M University

This research explores how to bridge the gap between high school robotics & automation courses and collegiate industrial automation courses. The expectation is that a firm understanding of sensor-based automation in high school better prepares students for college-level topics such as programmable logic controllers (PLCs) and instrumentation.

Dissemination and Follow-up

RET research results were presented in the end of the six weeks program. During the following academic year, participants are expected to implement their instructional modules in the
classroom and assess learning outcomes; and attend a one-day workshop to present results, share materials, and evaluate the program. Findings will be used to improve the summer program for the in-coming summer.

**Evaluation Results**

As mentioned above, this site has hosted 12 participants thus far from seven high schools and three two-year colleges. Five of the high schools and two of the two-year colleges had more than 50% of students enrolled from underrepresented minority groups. Below are results from a survey completed by the 2014 participants at the end of the six-week program. Completion of the surveys was anonymous and voluntary, and nine of the twelve participants responded. Survey results are summarized Figures 6 to 10 below.

![Figure 6. Average of responses to question about engagement in various types of activities during the RET program (1=not at all; 4=great extent)](image-url)
Figure 7. Average of responses to question about types of learning resulting from participation in RET (1=not at all; 4=great extent)

Figure 8. Average of responses to question about satisfaction with various aspects of the RET experience (1=not at all; 4=great extent)
Responses to the question “In your opinion, what was the primary professional or personal benefit of the RET experience?” included:

- “Research and ability to teach industrial controls to future students.”
- “I think it gave me a deeper understanding of Industrial Automation and how it can be incorporated into my classroom.”
- “Gaining research experience”
• “The primary benefit of the RET experience was to broaden my knowledge in STEM careers and areas of study; as well, to provide connections with other professionals in the field. My RET experience was very successful in all aspects of this benefit!”
• “I gained some new things that I will do in my research and design class.”
• “I have gained a lot more knowledge on the field of mechatronics, robotics and automation and that has boost my confidence level in teaching that course. I have also network with other teachers from various states.”
• “Seeing current and relevant research.”
• “Learning what was expected at the college research level.”
• “Six weeks of research and the possibility to get published.”

Responses to the question “Do you think your RET experience will have an impact on student achievement? Why or why not?” included:

• “Yes. They will gain skills and knowledge local employers are seeking.”
• “Yes, I think that my students will benefit from the lessons I developed. I think the time and commitment spent on creating a quality lesson will always increase student achievement.”
• “Yes I think the lesson and activity that my partner and I developed will have a positive impact on our students’ achievement, it is a well thought out, exciting and innovative. Also being able to share about our experience without students will have a positive impact.”
• “My experience will definitely have an impact on student achievement. The more honest experiences I can provide to my students whether directly in a lesson or just in conversation then the more students will feel a direct link to a program or plan of furthering their own education.”
• “I think there will be an impact on helping prepare kids for research.”
• “Yes, it will have a great impact on the students, because I met other colleagues teaching the same course as mine and we brainstormed on how to effectively improve our teaching skills in the field of robotics, automaton and mechatronics. Besides that, the research experience I had will be incorporated in my syllabus.”
• “Yes, I am able to discuss current research and explain how high school concepts will apply at a college level.”
• “Yes, I want all my students to raise the bar on their work in preparation for college.”
• “I think the lesson plan and activity are good, so yes, I think there will be a positive impact on student achievement.”

Conclusion and Future Directions

Automation has a profound effect on the way we do work, and mechatronics and robotics are the building blocks for industrial automation. U.S. manufacturers are seeking highly skilled workers to hire in industrial automation and control jobs. High school teachers and two-year college instructors can play an essential role in inspiring and preparing the next generation of skilled engineers and technicians needed for US economy.

This paper described program activities, research projects, outcomes, and lessons learned from a National Science Foundation-sponsored Research Experiences for Teachers program in
mechatronics, robotics, and industrial automation. Post-program survey results suggest (1) the research experience enhanced the participants’ capability to teach new concepts such as graph theory and subject such as industrial control; and (2) the lesson plans developed based on the research experience will have a great impact to the students learning new concepts. We plan to maintain communication with these participants as they share their experiences in the classroom and to provide support as needed. We will also have a follow-up gathering so that participants can share their experiences in implementing the lessons and how much students learned, and so that we can learn what worked and what did not work. This information will help us to continue to improve the program effectiveness. Future programs will follow a similar process; data will be aggregated and compared to identify potential trends and best practices.

Acknowledgements

This material was supported by the National Science Foundation’s Research Experiences for Teachers (RET) in Engineering and Computer Science Program (award no. 1300779). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Bibliography