2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32521

Training teachers on the Internet of Things (Evaluation)

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Training Teachers on the Internet of Things

Introduction

The traditional concept of internet is based on the connected computers and the extension of this concept is the “Internet of things (IoT)” which consist of a collection of interconnected devices beyond the computers running a browser, including wireless sensors, smart home appliances and personal activity trackers and other wearables. Through technological advances, miniaturized low power consumption devices could be produced at low cost and deployed in various places, enabling ubiquitous computing envisioned by Weiser a few decades ago [1], [2].

National Research Council recommends including engineering and technology in K-12 science education for various reasons. The students are initially introduced to science through lectures and reading assignments from their textbook, but they also need opportunities to see the practical aspects of science in their daily lives and preferably through hands-on exercises [3]. The level of excitement and engagement of the students in science classes are many times as a result of the teachers’ technical abilities and willingness to provide guidance to students throughout their education. Inevitably, the teachers are expected to keep up with the ever-changing technological advances in their prospective fields of science and engineering.

The NSF Research Experiences for Teachers (RET) Site in Collaborative Multidisciplinary Engineering Design Experiences for Teachers (CoMET) discussed here was designed to provide teachers hands-on engineering design experience covering all aspects of the sensor research for the IoT era, from the manufacturing of a sensor, to the hardware and software that allows them to operate. In order to support the STEM educational services for teachers and students in middle and high schools, this site program focused on the creation of lesson plans easily adapted to any classroom and competent teacher trainers who could ensure quality pre-service and in-service teacher education, by providing multi- and transdisciplinary experiences relevant to the current technical development. More specifically, this program provided three main objectives, including: (1) providing transdisciplinary engineering design experiences relevant to cutting edge technical development for teachers; (2) developing teacher-driven lesson plans that could be implemented in the classroom, and (3) disseminating results and developed materials to help teachers in the region and beyond.

In this RET site program, teachers rotated to four different research laboratories with a 1.5-to-3-week duration in each at the University of Central Florida (UCF) campus under the guidance of faculty mentors, graduate students and, in some cases, even undergraduate NSF REU participants [4]. In each of the research labs, the teachers were taught the necessary background of the research topic, had hands-on experiences, and then finally made the connection to their future lesson plans. The uniqueness of the program lay in the engagement of teachers in various facets of scientific and engineering methods based on the Train-the-Trainer model with job rotation in a collaborative team environment. The site program aimed at creating a critical mass of highly qualified teacher trainers who ensure quality of pre-service and in-service teacher education. The program also provided a truly interdisciplinary research experience involving computer science, electrical and computer engineering, civil and environmental engineering and mechanical engineering.

Program Design

The uniqueness of this RET site program existed in the incorporation of teachers' scientific development beyond the standard research experience by using methods based on the Train-the-Trainer model, allowing rotation through multiple research labs rather than restricting to one experience and developing end products of lesson plans for the classroom in addition to research findings.

The objective of the NSF RET site program was to provide at least 30 K-12 teachers with hands-on engineering design experience covering all aspects of the Internet of Things (IoT). To meet this objective, after a detailed orientation, teachers were scheduled to rotate through four modules conducted in research laboratories guided by the project faculty and graduate students. Teachers spent 1.5 to 3 weeks in each lab engaging in a variety of scientific and engineering methods moving them from the manufacturing of a sensor, to the hardware and software that allows it to connect to the internet, all while working collaboratively in a small team environment [5], [6]. Upon completion of the module rotations, teachers were able to produce a report on the research conducted, but more important to the practical goal of the RET, a lesson plan for implementation in their classroom. Throughout the following year, teachers participated in winter and spring meetings to discuss implementation of the lesson plans and prepare to be teacher trainers for the next RET cohort, within their school district or through conference and online dissemination of their lesson plans. The originally designed project components are summarized in Figure 1.

Figure 1: RET Program Components

Train-the-Trainer. A critical component of the RET program was the Train-the-Trainer model where teachers who have been through the program use the materials and exercises in the curriculum to disseminate training and content knowledge to teachers in future RET cohorts, at their home schools and planned teacher workshops. Once trained, these expert teachers received continued support, including annual follow up training, and assisted with new teachers each consecutive year. This process provided a way to help trainers stay aware of new material, how to infuse UDL, and sharpen their training skills while at the same time helping with the iterative design of workshops. In addition, project personnel modeled appropriate instructional methods for clear and consistent delivery of content knowledge. Once teachers were successfully trained, they delivered professional development workshops to instructors in their home district thereby enhancing the dissemination and broader impact of the project goals and objectives.

Universal Design for Learning. Instruction should be intentionally planned so that it is personally challenging for all learners. As RET teachers gained experience with module rotations their next step was to design lessons in which instruction was accessible for a variety of learners. To bolster the Train-the-Trainer model researchers leveraged Universal Design for Learning (UDL) [7] framework for the design and implementation of instructional materials meeting the needs of individuals by proactively circumventing curriculum barriers. This was accomplished through careful consideration of the broad range of needs, motivations, and strengths across *all* learners, including traditionally marginalized populations such as English language learners, those with disabilities, and participants with diverse cultural backgrounds to enhance equity.

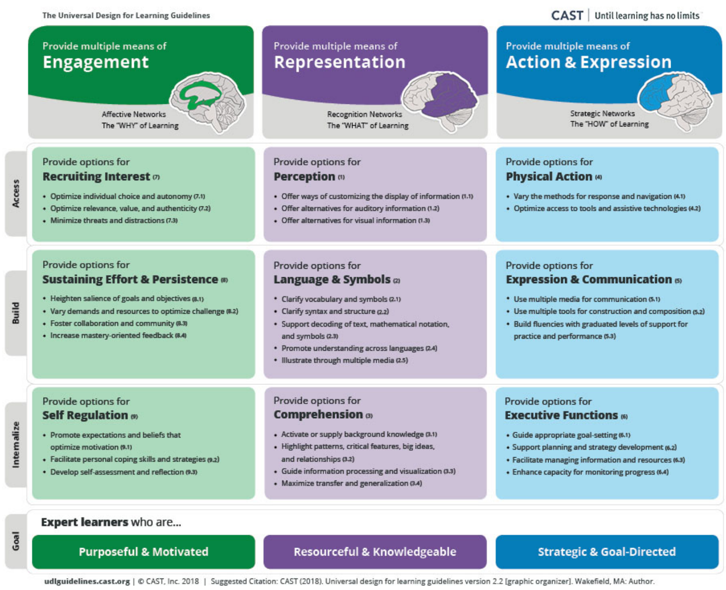

Figure 2: Universal Design for Learning Guidelines

Using UDL (Figure 2), instruction is framed around three guiding principles: (a) multiple means of engagement (i.e., considering how to engage students through a variety of pathways), (b) multiple means of representation (i.e., providing content through multiple methods), and (c) multiple means of action and expression (i.e., providing opportunities for students to demonstrate their understanding in multiple ways [8]. Each principle was further delineated by guidelines and subsequent checkpoints found at the National Center on Universal Design for Learning website (www.cast.org/impact/universal-design-for-learning-udl). Once teachers provided their draft lessons and outcomes to the project team a review of student comprehension, use of evidence-based practice, alignment to state and NGSS standards, and infusing UDL guidelines was completed. Teachers were provided additional feedback and recommendation prior to final project submission and dissemination on the website. The RET team also provided direct feedback on fidelity of implementation to teachers during fall/spring leadership meetings. Updated lesson plans were provided after implementation and feedback sessions.

Implementation and Changes

Based on formative evaluations conducted throughout the program and with appropriate NSF approvals, implementation for the RET Site changed over the three years. Initially scheduled for eight weeks the program was shortened to six weeks while scaling the overall number of participants. The eight-week timeline meant teachers started the program the day after their secondary classes finished and ended the day before they returned to teaching. This allowed no time for teachers to process feedback and make improvements to their lessons, or even take a break. At the same time a faculty member left the institution creating an opportunity for the team to re-think the module structure. While keeping the full original content, the modules were modified and shortened slightly to adjust to a six-week format. The funds saved from the shortened experience were used to increase the total number of annual participants from 10 to 13. Dissemination occurred at two levels, by the research team and by the teachers. After participating in the RET, teachers provided training to other teachers at their own school, within their district and at the statewide Florida Engineering Education Conference (FEEC) sponsored by the Center for Initiatives in STEM (iSTEM) at UCF. Online platforms like TeachEngineering.org [9] were added in years two and three. Each of these areas is discussed in more detail throughout this paper.

Modules. Teachers participated in four modules in sequence in the program (Figure 3). Teams of three to four teachers each chose one of three different sensor projects for the first 2 weeks and then spent the remaining time as the full cohort doing 1.5 to 3-week rotations in each subsequent module. Modules consisted of:

1. The **Sensor Device Module (2 weeks)** offered three separate submodules: Design and Fabrication of Environmental Sensors (Chemistry, Physics and Environmental Sciences), Design and Fabrication of Resonant Sensors (Physics) or Digital Manufacturing for Strain Sensors (Chemistry and Physics).
2. The **Interface and Testing Module (3 weeks)** included experiences on Interface Hardware Design for Sensors and Device Testing (Physics, Computer Literacy).
3. The **Software and Networking (1.5 weeks)** introduced the teachers to system software and networking as well as teaching basics in Java programming language and hands-on exercises on Raspberry Pi.
4. The **Mobile Programming (1.5 weeks)** covered mobile operating systems and hands-on experiences on writing Android programs accessing the web.

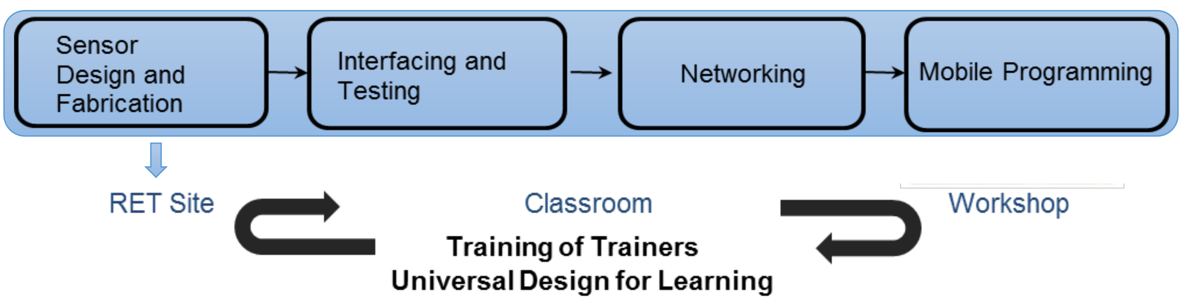

Figure 3: Overview of RET Site: CoMET Program

Selected module highlights. In the *Design and Fabrication of Environmental Sensors Module*, a team of teachers from middle and high schools participated in the design, fabrication and characterization of electrochemical sensors that can be used for water quality monitoring. In order to establish the knowledge basis for their activities, a faculty mentor provided a series of short course lectures each day before teachers began lab work. The working principle of sensors based on electrochemistry was explained so that the teachers could find relevant context for their classroom teaching in chemistry and environmental sciences, for example. Next, two major fabrication techniques of screen printing and photolithography were demonstrated using laboratory instruments. Starting with their drawings, teachers could learn how the patterns are replicated from a template to a substrate – on either a silicon wafer or a flexible polymer sheet. This exercise was then related to the cutting-edge semiconductor devices and flexible electronics. Finally, the devices fabricated by teachers were tested for detection of heavy metal content in water. Data analysis and graphical representations could be correlated to teaching subjects in mathematics and chemistry. In cohort years two and three, a teacher trainer was embedded in a team of three-four teachers so participants could learn from the teacher trainer's experiences and more specifically, foresee how their research at the RET site could be materialized into detailed lesson plans in their classroom setting. Participants were given time to discuss and interact with each other in a wrap-up session toward the end of each day so that teachers could learn from different perspectives depending on their teaching level and subjects. These activities helped synergize their overall research experiences.

> The RET experience helped us see what real engineers and scientists are researching and we were able to interact with it in a way that we could understand and take some of it with us back to the classroom in a way that we could tailor it to our needs and our students' needs. (C. Hobby, personal communication, 2019)

In the first year, this module focused more on the cleanroom microfabrication part in order to offer insight into sophisticated sensor manufacturing. Based on teacher feedback and suggestions, the sensor application part, as well as hands-on screen-printing activities, were expanded in years two and three as teachers found more relevant content in those for classroom implementation.

The computer science modules were taught sequentially for the entire cohort rather than splitting the teachers into various groups based on specific research topics as practiced during the engineering modules. The *Networking Module* contained Java programming lessons, theoretical and practical contents about understanding the internet and protocols (i.e., HTTP, TCP, IP). The Linux operating system and operating system concept, in general, were explained in the "Linux" lecture. Lectures in this module, included Internet infrastructure, network protocols, monitoring data traffic, troubleshooting on network connection issues, etc. The teachers had hands-on exercises on these topics through the usage of the command line in Linux. One assignment was writing a report about the outputs of the commands. Researchers observed that the teachers were able to carry on these tasks without much struggle. The *Mobile Development module* contained Java programming lessons and an introduction to Android mobile application development lectures. The last two days of the mobile application development were focused on Raspberry Pi 3 and practical applications of using Raspberry Pi. Raspberry Pi is a single-board computer, small in size, and affordable for small to middle-sized projects, including home automation systems [10], [11], smart walker for visually impaired persons [12]. Raspberry Pi version 3, a magnetic area sensor, and some peripheral devices to connect sensors to the Raspberry Pi were distributed to each teacher at the beginning of the module. Java programming language was selected to be taught due to the Android mobile application development. Hands-on training exercises were given to teachers after each Java lecture to practice what they had learned. The mobile application programming was the most challenging part to teach, as it required some basic proficiency in Java, and the training duration was not sufficient to give teachers enough time to practice their programming skills. Since the teachers were not generally equipped with the necessary basic skill set, it made the training more difficult. The daily activities of the teachers started by reading the assigned academic article, followed by discussing the content. During the research paper discussion session, the faculty and the graduate student mentor summarized the novelty and the technical contributions of the research. They engaged the teachers by asking them about their opinions on how the proposed approach by the authors could be used in our daily lives and how they could incorporate this in their lectures at their schools. After the discussion, the lecture of the day took around 1 hour. In the afternoon, the teachers conducted the assigned hands-on exercises with pairs or alone, asking questions while working on the assignment. There was no dependency between the assignments, and they were expected to be completed by the end of the day. The Java programming assignments were exceptions as the teachers needed to spend additional time to complete and pass the test cases. Based on the difficulty experienced by teachers in this module, a teacher from year one who was proficient in Java assisted his colleagues and was invited back as a teacher trainer in years two and three. This teacher trainer worked with the teachers from week two to five of the program helping them to gain the proficiency needed to complete the computer science modules successfully. In his own words,

> I primarily assist with understanding software and hardware. Some of the participants have clearly taken to the Computer Science portion and I have encouraged them to consider teaching the AP Computer Science Principles course. One of the participants is now doing just that, and another one is considering teaching it starting next year. (J. Ebbert, personal communication, 2020)

Teacher Experience. Per the proposal, each year ten teachers were to be selected for the eight-week summer experience to develop RET-inspired lesson plans, which would be implemented (taught in the classroom) the following school year. Participants received a weekly stipend of $1,000 for the summertime component, plus additional funding for participation in the winter and spring meeting activities. Year one was implemented in the eight-week format with ten teachers. However, it was quickly noted that the eight-week timeframe consumed every week from the time the school year ended in spring until classes began in fall. This meant the only break the teachers received was a two-day break for the July 4th holiday. Accordingly, based on teachers' collective feedback, the RET Site team adjusted the schedule to a six-week program while still covering the same content in a streamlined format. Additionally, because this meant that two weeks of the stipend budget was not being used for each participant, the team received permission from NSF to add more participants to each of years two and three. The RET site hosted 11 and 13 participants in years two and three, respectively, for a six-week program. Demographics for the selected RET teachers are found in Table 1 [6].

Table 1. RET CoMET teacher demographics

Cohort	Male	Female	High School	Middle School	African American	Hispanic
2017	5	5	5	5	3	3
2018	6	5	10	1	4	0
2019	4	9	8	5	1	1

The first day experience consisted of a welcome, schedule, pre-assessment, module pretest, networking, campus tour, library workshop, and lab tour. A program syllabus and a schedule booklet detailing daily commitments within the program were given to the teachers. The teachers were enrolled in an online learning management platform to access handouts, notes and assignments online. For each module, a faculty mentor provided lectures to introduce the research and then had teachers work with the mentors to participate in learning modules to gain the skills and knowledge needed for constructing connected sensor devices by the end of the summer. The teachers participated in the preplanned RET Site activities based on the proposed research modules in sequence as previously described. Throughout the RET Site, the organizing team implemented pre- and post-tests for each module. Each week a faculty mentor presented his/her research during a lunch meeting and workshop. In this meeting, an overview of the foundational research for each module was discussed. Participants were provided the opportunity to share personal take-aways from that week's experiences and updates were communicated for upcoming assignments, deadlines and activities.

Teachers presented their learning outcomes in the final week, as well as their lesson plans for implementation in the classroom. During the implementation phase, the RET Site project team focused on helping the teachers to generate enthusiasm amongst the students in the classroom, assess their progress, and achieve successful transfer. According to the participants:

> The best part of the RET program is the impact it had on my middle school student population. I was able to sit through engineering lectures and experience problem-based learning where I was able to analyze qualitative and quantitative data while navigating through science and engineering practices. This gave insight into how science and math content applies to the real world of engineering, which translated into authentic IoT lessons for my middle school students. I learned about the Internet of Things and was able to enrich my students with the incorporation of single board open faced microprocessors into their science curriculum. (K.Cruz-Deiter, personal communication, 2019)

> The program involved a lot of opportunities to collaborate with other teachers in my area. Local teachers who I could connect with that were teaching some of the same material I was and were struggling with some of the same issues I was. The teachers I got to know in the program were looking for the same things I was looking for, we all wanted to help our students get involved in the modern world and be successful in school and beyond. (C. Hobby, personal communication, 2019)

Teachers returned for a one-evening conference in December and again in April to discuss and assess their implementation efforts and receive a refresher in project research.

Train the Trainer. Once teachers completed the RET, they had the opportunity to continue their learning experience and personal development as trainers. Some chose to provide training to other teachers within their school or to present at an annual teacher development conference while others were invited to return as RET expert teacher trainers. These expert teachers received continued support, including annual follow-up training, and assisted with new teachers each consecutive year. This process provided a way to help trainers stay aware of new material and sharpen their training skills while at the same time helping with the iterative design of workshops. Some teachers even used this experience as a jump start to further professional development:

> Two years after my RET experience, I returned to graduate school to finish my Ph.D. in Science Education. [I was] offered a graduate teaching position where I have the opportunity to instruct pre-service elementary teachers of science and increasing my impact by sharing IoT lessons…I have developed a video that will be uploaded onto YouTube so that I can share my IoT lesson with the rest of the world. RET has helped me develop my goals in preparing authentic IoT lessons that engage our 21st century

> students in science and engineering practices. (K.Cruz-Deiter, personal communication, 2019)

In years two and three, four expert teachers were invited back to serve as trainers for the second cohort. One trainer participated in each of the three *Sensor Design* modules during the first two weeks of the RET. Project personnel and teacher trainers modeled appropriate instructional methods for clear and consistent delivery of content knowledge. Having the returning expert teachers helped new participants understand how RET content could translate into the middle/high school classroom.

> The RET experience helped us see what real engineers and scientists are researching and we were able to interact with it in a way that we could understand and take some of it with us back to the classroom in a way that we could tailor it to our needs and our students' needs…I got to introduce [new participants] to some of the same material that I struggled with the first time around and hopefully smooth their journey for them a bit. I showed them some of the cool engineering projects that I worked on the previous summer and also got to share my lesson plans I made based on the experience with them. (C. Hobby, personal communication, 2019)

The fourth expert teacher worked with participants in weeks three through five as they progressed through the *Interface and Testing* and *Software and Networking* modules.

> I have been invited back each year to assist the new cohorts in a variety of ways. There are many advantages to the "Train the Trainer" model. I help clarify expectations, guide research and lesson plan development, and primarily assist with understanding software and hardware. (J. Ebbert, personal communication, 2020)

During year two, the decision was made to include online platforms as a method for dissemination of teacher lesson plans. One of the first-year participants was invited back at the end of year two and for both the orientation and closing sessions of year three to present his insights on submitting to TeachEngineering.org [9]. The orientation session provided an overview and expectations where the closing session was a just-in-time walk-through of the platform criteria. The sessions assisted teachers in developing lesson plans that could easily fit the submission criteria for online.

Program Evaluation

The goal of the program evaluation was to assess the effectiveness of the RET in achieving the desired objectives. Five measurable objectives were identified for what the project aimed to accomplish: (1) recruit a diverse and talented middle and high school teacher population from counties in the vicinity of (institution); (2) provide the recruited teachers with interdisciplinary engineering design experience relevant to innovative technical development; (3) develop and disseminate to a large-audience teacher-driven teaching modules that can be deployed in the classroom; (4) create a critical mass of highly qualified teacher trainers who ensure the quality of pre-service and in-service teacher education, and (5) disseminate the results of this RET effort to other interested stakeholders in the region and around the nation.

To achieve these objectives, three performance indicators to evaluate the effectiveness of the program were defined as follows. (1) The RET provided three collaborative interdisciplinary engineering design experiences developed to engage the teacher in engineering research practices. For this purpose, the survey data was analyzed by focusing on group data collected from the participating teachers, which informed formative evaluation on the experience of each teacher within the individual modules – using both quantitative and qualitative data. Pre/post tests were also used to assess teacher learning on the expected outcomes of research for each module. Specifically, the abilities and thinking/learning strategies the teachers gained and could utilize for their classroom teaching. The evaluation focused on documenting what skills the teachers developed [6]; to what extent did the research experiences improve their teaching practices. The widely used educational technique train-the-trainer was used, where subject matter experts train less experienced instructors who then can train others. (2) Each participant developed demonstration modules and classroom teaching materials to create teacher-driven modules for classroom deployment. To achieve this, at the end of the six-weeks, oral and written lesson plans of the newly developed teaching modules and prototypes were presented by teachers to the researchers and team members who provided evaluation and feedback. The collected feedback was subsequently discussed with the teacher to elicit continued improvements in the newly created lessons. Then, a written report synthesizing the research conducted and knowledge gained was prepared by the teachers. This feedback was collected and discussed with the faculty to elicit continued improvements in the research modules. Also, through analysis of the module pre/post-test data and evaluation of the new teaching lessons/prototypes, researchers could evaluate the readiness of the middle and high school teachers to effectively utilize the knowledge acquired in this workshop in their classrooms. Finally, the collected survey information from participants through the follow-up conferences was used to investigate the success of an in-class implementation. (3) Results were disseminated by the PIs, researchers and RET teachers to assist teachers in the region and beyond. For this purpose, the RET team planned workshops and conferences in coordination with schools and district offices. The classroom lessons and prototypes were showcased by teachers at workshops and conferences and finally, the findings were presented at national conferences and published in educational journals [4] – [6].

To achieve these objectives an evaluation team was formed. This evaluation team was responsible for developing the required instruments to evaluate the teachers learning outcomes, recognize suitable venues for disseminating the newly created modules, and RET results. For these purposes, the team interacted with external evaluators – Program Evaluation and Educational Research Group (PEER) and College of Community Innovation and Education (CCIE) at UCF – that were responsible for conducting external components. Traditional educational psychology methods of quasi-experiment, incorporating a pre- and post-test design, collecting multiple forms of descriptive information, data on the fidelity of the study, data on the dosage of the intervention, and outcome data were used by PEER.

For example, two post-experience evaluations completed by the teachers in the form of questionnaires are presented in Figure 4. Collected data revealed the perception of the participants related to the learning experience that they had and their overall program rating on the RET site. According to chart c, 55% of teachers expressed they gained a greater understanding of the applications of science, mathematics, and technology in the context of IoT, while 82% (chart b) and 72% (chart d) of teachers expressed their familiarity with new materials and equipment to use and innovative ways to use standard materials in their teaching field, respectively. These measures are closely related to the teachers' scientific knowledge development through the Site research activities and the NSF RET program guideline which prompts teachers to "translate their research experiences and new scientific knowledge into their classroom activities and curricula".

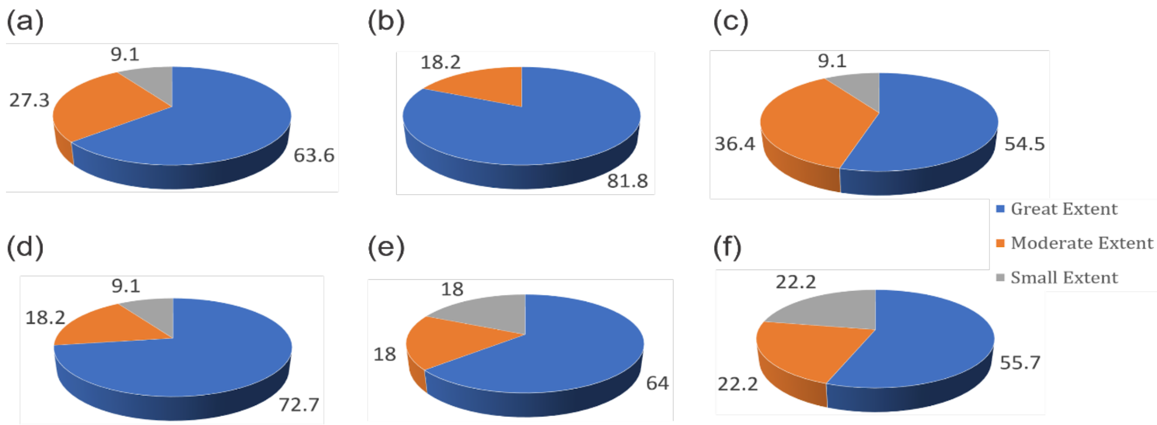

Figure 4: Survey results as the form of percentile: (a) increased knowledge on current issues in STEM; (b) became familiar with new material or equipment; (c) gained a greater understanding of the applications of STEM; (d) learned innovative ways to use standard materials and equipment; (e) acquired greater understanding of fundamental concepts in STEM, and (f) this RET site helped teachers better understand how to do research.

The understanding of STEM in the context of IoT experienced through everyday life, familiarity with the latest software and hardware related to the technological advances are important aspects. The main goal of the RET program was to offer research experiences to middle and high school teachers in various engineering and computer science topics and then provide opportunities for the teachers to enrich their lesson plans with what they learned and experienced in the program. The RET teachers were expected to not only be up to date with the newest technologies but also to have the ability to relate these innovations to everyday life as part of their lectures. Through this, the hope is that students would better understand and appreciate the science and engineering topics and be inspired by their teachers. Teachers with strong technical knowledge along with inspiring lectures can provide further encouragement needed for the students to consider STEM-related fields for their future careers.

The teachers were asked to submit their classroom implementation report with teacher reflection in order to assess the impact of a new lesson plan. Due to the variation of the implementations in a wide range of class topics, standardized assessment data could not be harvested, but Table 2 provides a snapshot of the impact on the students in Physics' classrooms before and after the introduction of a new lesson plan. A noticeable improvement in student performances was observed.

Lessons Learned

In this section, we describe several choices made, the challenges faced because of these choices, and the solutions.

Table 2. Sample data: impact of a new lesson plan on student performance pre/post RET participation

Sample ID	Class	Format	Before	After
Teacher 1	Physics	Open inquiry lab	74% average grade	89% average grade
Teacher 4	Physics	Hands-on lab	61% average grade	76% average grade
Teacher 6	Physics	Project	59% passing grade	72% passing grade

Program duration. The RET Site program was initially scheduled for eight weeks long. The eight-week duration meant that the teachers essentially started as soon as their academic year concluded and were scheduled to start the new academic year as the RET program finished. Even though there was some positive feedback from the teachers, shortening the duration of the program was unanimously recommended by almost everyone. As a result, in the second and third year, the program duration was decreased to six weeks and allowed the team to add two teachers to each cohort. Approval from the NSF program manager was secured before making the change to the program duration.

Better structure. Initially, participants were to be given full flexibility to work on their research topics. However, because the teachers would be changing research topics (modules) every couple of weeks and teachers were accustomed to structured daily schedules, the research team realized that a more organized and structured program was needed for the daily activities. It was important to realize that research faculty and middle/high school teachers come from two different cultures when considering work structure. Faculty conducting research are not accustomed to rigid schedules or timelines on a daily basis as one cannot predict exactly when the research will yield substantial results or when one is inspired to write for research papers to peer-reviewed publication. Teachers work by a daily structure with detailed lesson plans, periods and bell schedules meeting prescribed local, state or national standards. In turn, the RET program provided a much more detailed schedule with activities and tasks to be carried out during the day (e.g., reading research papers for 1 hour followed by 30 minutes discussion) with some flexibility to be carried out at the teachers' discretion.

Defining lesson plans versus research findings. This program was not structured like other RET Sites. Rather than guiding teachers through a research project in one particular area or field, this RET was more about introducing teachers to a lifecycle with multiple research experiences, ultimately leading to a lesson plan for the middle or high school classroom. Naturally, the teachers had to learn sufficient background in order to understand and carry out various research projects in engineering and computer science labs. Once caught up with current research in a given area, they had to work on translating what they had learned through the research experience to their classroom lectures. Initially, the teachers had difficulty making the differentiation and transferring the research knowledge into lesson plans in a clear and concise way. During orientation in years two and three, the research team provided teachers with an example of a well-written lesson plan derived from the research findings of a module and directed them to lesson plans created by the year one teachers and posted on the program website. In addition, the returning expert teachers were able to assist the participants in making the connection between the research modules and possible implementation projects for the classroom.

Dissemination. Despite the continuous encouragement and funding support for conference travel, the teachers did not take advantage of the publication opportunities. The most successful method of dissemination was the annual Florida Engineering Education Conference (FEEC). At least two to three teachers from each cohort presented lesson plans while also attending the conference for their personal professional development. After year one, the research team realized that once the teachers finished the program, it was very challenging for them to find time to contribute to the dissemination efforts. In year two, the submission of lesson plans to TeachEngineering.org [9] was added as one of the final deliverables of the RET program. TeachEngineering.org offers free resources to all educators to bring engineering into the classrooms. However, the submission format was a long and arduous process that did not lend itself to being a successful platform for sharing lesson plans online for this particular program. Though teachers were encouraged to continue the TeachEngineering.org process, it was also decided that all lesson plans would be loaded to the RET Site's web page. For future RET programs, more time will be allocated at the end of the program to assist teachers with their submission to TeachEngineering.org prior to completion of the RET as this submission will be part of the program deliverable. Those teachers completing this requirement will receive extra stipend.

Modules. The teachers showed the most improvements in the software and networking module as was observed from the pre- and post-test surveys. The pre-test survey results ranged from 0 to 30 while the post-test survey results were in the range of 25 to 75, out of 100 points. The main reason for such improvements was the fact that the teachers lacked basic knowledge on the software development process in terms of software and hardware components. For instance, many of them had heard of Rasberry Pi, but they did not understand how it differed from a personal computer and its advantages. Similarly, they knew of server computers however, they could not present any application examples that used server computers. The mobile application programming module was the most challenging computer science module due to the lack of basic programming knowledge of the majority of the teachers. The pre-test survey results for this module were significantly better than the software and networking module (scores ranged from 0-80). The post-test results were also significantly better, ranging from 40 to 100 with four out of the eleven teachers scoring full marks. In this module, teachers could relate to the questions much better lending to higher initial results. For instance, almost all of the teachers were able to identify the two examples of the operating systems used in smartphones as well as examples of embedded sensors within smartphones. The question missed by almost everyone was related to a programming aspect within Android application development – which was an expected outcome. The duration of the program was not sufficient to give teachers enough time to practice their programming skills in Java. As a result, changing the programming language to Python would make for a more productive learning experience than Java and allows novice programmers to produce reasonably functional and meaningful programs in a much shorter time, eliminating much of the frustration from the equation.

Acknowledgement
This work was supported by National Science Foundation (EEC-1611019, RET Site: CoMET at University of Central Florida).

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