Solving the Mystery of Physics Technology (SMPT)

Abstract
The majority of the teaching community is considered to be "digital immigrants" (over the age of 35) while most students are considered to be a "digital natives". This is significant considering that teachers' work experience helps shape their skills and pre-college teachers have limited experience with both the technology and the physics behind the technology (i.e. quantum physics). As a result, teachers may use the technology in the classroom, but if a student were to inquire as to how GPS works or why their iPad can sense the touch of their finger, very few teachers could answer with any confidence due to their limited knowledge how classic physics applies to quantum physics. The SMPT project will blend specifically designed professional development (PD) for educators aiming to increase content understanding relating to quantum concepts and provide immediate hands-on practice with students. To gain confidence, teachers need content reinforcement and practice. Teacher confidence in content and pedagogy has been documented to correspond with student success. However, it is often difficult for teachers to gain confidence when they are not given support or opportunities to hone learned skills and content. Providing educators with a deep understanding of content coupled with hands-on practice theoretically should result in a more successful integration of "modern" physics into the classroom.

Objectives
Solving the Mystery of Physics Technology (SMPT) proposes to provide project based professional development (PD) with a focus on understanding basic concepts of connections between classical and quantum physics as well as how physics is related to technology. The project includes a collaboration of secondary in-service teachers and students.

Key Components/Objectives include:

- Provide pre-college teachers with opportunities for professional growth while concentrating on how physics and technology relate to the function of everyday devices. (e.g., how special relativity relates to cell phone use)
- Enhance the educators' disciplinary capabilities, teaching skills, and understanding of current physics related technologies and practices. Provide meaningful ways for these concepts to be taught in their classrooms.
- Measuring changes in student learning outcomes as well as students' perceptions of physics and how it related to their everyday lives.
- Prepare pre-college teachers to facilitate student learning in physics and therefore boost the quality of physics education provided to their students.
- Provide funding to test a professional development model that could be replicated and have a potential impact on the physics community.
- Provide opportunities for pre-college teachers to be more involved in the physics community.

Intellectual Merit (advance knowledge): When comparing pre Next Generation Science Standards (NGSS) and post NGSS, the biggest deficit is the integration of technology and engineering in the core science courses. There are numerous challenges for educators with respect to implementing these changes in the classroom. A major challenge is the limited experience most teachers, even physics teachers, have in applying physics content to current technology. Many educators, both digital immigrants and digital natives, do not have a fundamental understanding of the science behind modern technology. This project will directly address the physics related to modern technology by enhancing the educators' disciplinary capabilities, teaching skills, and understanding of quantum physics. Some of the physics concepts that are fundamental to modern technology include: the quantum nature of the atom (used by temperature sensitive devices in construction), electric and magnetic fields (used in mass spectrometry, forensics, copy machines, etc.), technology in Global Positioning Systems or GPS (used in farming, driving, and

countless other applications), particle nature of light (used in LEDs, semiconductors, computer chips, etc.), and wave-particle duality (used in integrated circuits, TVs, and computers).

Broader Impact (benefit society): In today's technologically advanced world, an understanding and appreciation of the technologies that surround us is vital. This project's short-term goal is to help pre-college educators prepare students to understand our digital age (i.e. quantum physics) and have a deeper understanding of how physics is the foundation for our technology. The long-term goal is to provide a professional development model that could be replicated and increase the number of students interested in physics by helping them understand the applications of physics in job careers as well as everyday technology.

Overview:
The week-long professional development will be conducted at Lee College (Baytown in south Texas and the Fort Worth Museum of Science and History (Fort Worth, in north Texas). Both sites will target local educators and high school students in Texas[1]. The estimated number of participants will be approximately 50 educators and up to 100 students. The institute leaders will include Tom Okuma, Karen Jo Matsler, and master physics teachers from the American Association of Physics Teachers (AAPT) Physics Teaching Resource Agent (PTRA) program. Additional resource leaders will include local business volunteers, professional organizations (TSAAPT, APS), and science coordinators from local school districts

The format for the institutes will be unique in that the time of instruction will be divided between working with the educators and working with secondary students from the local schools. This approach will have the following benefits: 1) working with students allows the educators to practice what they have recently learned, 2) it creates an opportunity to expose students to physics resulting in a deeper understanding of how physics relates to their everyday lives, and 3) it allows the educators an opportunity to work collaboratively (professional learning communities) to increase skill and confidence necessary for classroom implementation. Participants and students attending the summer institutes will be encouraged to attend the Texas Section physics and state science meetings.

Background:
Before NGSS, *Project 2061* set out to identify what was most important (i.e. science literacy) for the next generation to know and be able to do in science, math, and technology. The recommendations were integrated into a publication, *Science for All Americans* (SFAA)[2], and laid out principles for effective learning and teaching. In Chapter 3, SFAA implies that the use of technology to change the world to better suit mankind and anticipating the effects of technology is just as important as advancing the capabilities of technology.[3] According to Moore's Law[4], technology is currently the doubling every year, but by 2018 the doubling will be every six months. Since we do not know the future, educators must prepare students with skills that allow them the versatility to perform well in a wide variety of jobs. This can only be accomplished by providing a solid foundation of content and principles that can be applied to a multitude of career choices. "…just as important as accumulated practical knowledge is the contribution to technology that comes from understanding the principles that underlie how things behave—that is, from scientific understanding."[5] Scientific knowledge provides a means of predicting behavior of things before we make or observe them.

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[1] Preferably the student will attend the same school as the participating teacher
[2] http://www.project2061.org/publications/sfaa/online/sfaatoc.htm
[3] http://www.project2061.org/publications/sfaa/online/chap3.htm
[4] Moore's Law, Kurzweil, R., *The Singularity is Near*, 2015. Chapter: Theory of Technology Evolution p. 66-72
[5] http://www.project2061.org/publications/sfaa/online/chap3.htm (Technology and Science, first paragraph)

As technology becomes more sophisticated, the links to physics become more apparent and students need to be able to understand the physics behind the technology they use everyday. Pre-college teachers have not been trained in the physics behind of modern technology because it is changing so rapidly. Most struggle to find creative ways to teach "modern" concepts (ideas which have been around for over 80 years). Therefore the majority of the teaching community is considered to be "digital immigrants" while most students are considered to be a "digital natives". This is significant considering that teachers' work experience helps shape their skills and these teachers have limited experience. Both immigrants and natives use the technology, but few understand how it works, how it is developed, or why it is changing so rapidly. As a result, teachers may use the technology in the classroom, but if a student were to inquire as to how GPS works or why their iPad can sense the touch of their finger, very few teachers could answer with any confidence.

To compound the problems, most resources available to educators do not address the fact that teachers do not have a deep understanding of the physics and how physics relates to technology. In response to this need, the Perimeter Institute[6] recently developed resource materials specifically designed for pre-college teachers. These resource materials have been vetted and distributed around the world. The resources provide videos, activities and background information that helps educators understand concepts such as dark matter, wave particle duality, the expanding universe, curved space-time, relativity, and the photoelectric effect. The *SMPT* leaders, who are also educators, have also been trained in the use of these materials and are familiar with the pedagogy and content necessary to make the institutes useful to educators and students. The *Perimeter Institute* (PI) has had a working relationship with AAPT/PTRA for several years and many PTRAs have been trained in areas relating to quantum mechanics. *Perimeter Institute* provides access to their materials at a reduced rate for educators attending AAPT/PTRA institutes and workshops. Currently there are seven complete modules and others in the development stage. All will be available to participants in this project (itemized in budget).

Dissemination:
The project will blend professional development for educators designed to increase content understanding and immediate hands-on practice with students. Traditional professional development (PD) often targets educators during the summer for an intensive week or two. Unfortunately, by the time school begins teachers have lost confidence with their ability to use what they learned because they did not have the opportunity to immediately practice what they were taught.

This proposal couples a teacher focused PD with an opportunity for educators to immediately practice what they have learned by bringing students to the institute. The focus is on providing educators with content and experiences appropriate and necessary to implement quantum related activities into their classrooms. Students will come to the site of the PD and the educators will teach the concepts they learned and guide students through learning activities connecting the content to a real world problem or experience.

- The first and second day of the PD will focus on limited carefully chosen content areas (e.g. GPS, wave particle duality, photoelectric effect). The content will be based on material developed by *Perimeter Institute*. Additional topics will be addressed each morning of days 3-5.
- Institute leaders will model effective pedagogy including constructivism and inquiry which allows participants opportunities to collaborate on strategies for successful and appropriate curricular implementation upon return to the classroom. Effectiveness will be documented by using self-reflections and feedback from participants during the school year.

[6] http://perimeterinstitute.ca/

- Days 3-5 will bring secondary students to the site to engage in the activities and projects for half of the day. The activities will correlate to the specific content taught to the teachers on days one and two.
- Day 5 will include a debriefing and future planning for the educators. This will allow them to collaborate on how to implement what they learned upon returning to their classrooms.
- Student participation will be solicited from various resources including local schools, STEM academies, and community centers.
- Participants and students will be encouraged to attend the bi-annual Texas meetings of APS/AAPT. The educators will be encouraged to present evidence as to how this experience impacted their students. This will allow the participants an opportunity to share with their peers and be part of the physics community. Data from PTRA workshops indicates this is a novel opportunity, which they may not have considered. Participants will also be invited to present at the state science conference for the physics strand, which is sponsored by TSAAPT.

Description of Activities

In addition to the description above, below are some of the sample curriculum components from the Perimeter resources that will be used in the Solving Mysteries of Physics Technology institute.

- **Remodeling the Atom--**Students gain deeper insights into the nature of matter, how magnetic and electric fields behave, and how these forces of nature can be harnessed through technology to serve humanity. The *Charged Particles in Magnetic Fields* activity provides students with the basic science necessary to understand mass spectrometry, a technology used by lab technicians from forensics to medicine to determine the chemistry of unknown samples. The *Electric Attraction and Repulsion* activities link to commercial applications ranging from applying paint, to photocopying, to purifying air. The culminating activity is a game that allows student to develop critical thinking and pattern recognition skills as they make the Nobel-prize winning discovery of brand new matter.
- **GPS and Relativity--***Time Dilation* – Explains the basis of the Global Positioning System, a technology used by everyone from farmers, to construction workers, to ecologists and prepares students for the exponentially increasing applications of GPS technology.
- **Revolutions in Science—**Activity $E = m\,c^2$ explains the basis of nuclear energy, using mass defect. *Quantum Nature of the Atom* explains the basis of portable temperature detecting 'guns' used by contractors in the construction industry
- **Measuring Planck's Constant—**The activity *Particle Nature of Light* – Explains the basis of LED lighting, which is being used widely in contexts ranging from home lighting, to street lighting, to automobile headlights. The *Particle Nature of Light* explains the basis of semiconductor physics and how the properties of semiconductors are important to the creation of computer chips and printed electronic circuits.
- **The Challenge of Quantum Reality--** The activity *Wave-Particle Duality* – Explains the basis of automatic sensors including door-opening sensors electron microscopes (particle nature of light), transistors and integrated circuits (wave nature of electrons), and the technology behind TV and computer screens (particle nature of light).

Proposed Budget
Site Directors: Karen Jo Matsler, Tom O'Kuma ($2500 each = $5,000)
Materials & Supplies (lycra material, diffraction glasses, lasers, LEDs, and other resources for teachers to take back to their classrooms) $50/teacher = $2500
Support to send participants or students to state physics meetings = $3,000
Perimeter Resources $75 for 8 modules/participant = $3750
PTRA Leaders-3 per site for $400/day for 5 days = $12,000
Total = $23,250

List of Personnel
Karen Jo Matsler (vitae included)
Tom O'Kuma (vitae included)
6 Physics Teaching Resource Agents--TBD