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OPTICS PROFESSIONAL DEVELOPMENT IN NORTH CAROLINA

Pamela O. Gilchrist, M.Ed., Joyce Hilliard-Clark, Ph.D., & Tuere Bowles, Ph.D.
The Science House, North Carolina State University, 909 Capability Drive, Raleigh NC, 27695

ABSTRACT

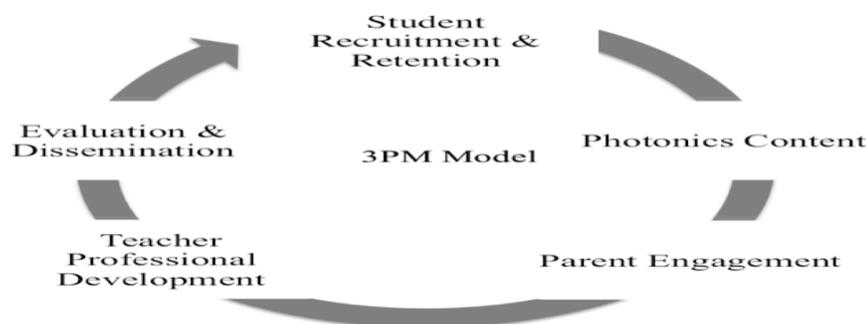
Using the Photonics Leaders (PL2) program model of recruitment and retention, photonics content, parental engagement, internship, and a hybrid virtual format, the session's goal is to inform outreach coordinators and scientists of strategies used to develop teachers' awareness and skills in teaching Optics to ethnically diverse students who lack traditional experiences in the discipline. The National Science Foundation (NSF) Innovative Technology Experiences for Students and Teachers (ITEST) funded program highlights initial findings of a pilot study with middle and high school teachers from The Science House at North Carolina State University sharing lessons learned and future scale-up plans.

Keywords: teacher professional development workshop, optics and photonics outreach, equity, change theory, STEM education, logic model, STEM program model

1. INTRODUCTION

Photonics Leaders II (PL2) program is a year round science and information technology program for 60 high school students, 120 parents and 60 teachers. The program goals are to prepare underrepresented minority high school students for science, technology, engineering and mathematics (STEM) careers and to equip teachers and parents with resources to engage learners in these disciplines. The program model (Figure 1) used to prepare students for STEM opportunities is grounded within five components: (a) recruitment, student selection and retention activities, (b) physics content, (c) teacher professional development, (d) parental engagement, and (e) dissemination and evaluation (see figure 1). Each program component is operationalized through one or more of the guiding principles: (a) immersion in traditional and non-traditional hands-on investigations, (b) engagement in a supportive, safe and challenging environment, (c) participation in leadership and professional development training and (d) integration of professionals from academia, industry and schools.

Figure 1. Photonics Pre College Program Model (3PM)



The program model incorporates synergistic science, technology, engineering and mathematics activities among participants to determine which strategy best predicts student success in STEM areas. These strategies were documented successful in preparing students for the global workforce¹(Hilliard-Clark & Gilchrist, 2007).

This paper will focus on the PL2 teacher professional development program component by describing the program overview, its significance, theory, program evaluation design, and dissemination efforts to achieve the program goals.

2. PHOTONICS LEADERS II (PL2) PROGRAM OVERVIEW

PL2 teacher professional development is a hybrid experiential program for middle and high school teachers funded by the National Science Foundation (NSF) Innovative Experiences for Students and Teachers (ITEST). The 44 plus contact hour program consists of an intensive face-to-face experience (three days) and an online follow-up experience (two days). Program interventions occur within five phases: (i.e., inquiry, internship, technology, implementation and online follow-up). Each participant is required to complete all phases to receive the \$500 stipend and to provide feedback on impact of received program interventions. The program activities occur annually for three years and are reviewed according to the PL2's impact and outcome evaluation plan measure the program implementation fidelity and impact on the primary (teachers) and secondary (students) target populations. PL2 workshop objectives are to:

1. introduce and model instructional strategies for educators on Photonics, STEM careers, and global workforce.
2. enhance teachers skills, knowledge and behaviors towards teaching physics to all students, especially underrepresented minority students (URM).
3. document change in teachers' classroom practices which impact students' STEM outcome.

2.1 TARGET POPULATION AND PROGRAM STAFF

Middle and high school teachers (grades 6-12) who teach Physics concepts from underserved rural areas are the target recruitment audience. PL2 project staff consists of two principal investigators, an external evaluator, technology coordinator, curriculum specialist, program specialist, and support from optics and photonics experts. An estimated program budget of \$69,000 covers the following expenditures (i.e., teachers' substitute pay, lodging, meals, materials, supplies and staffing for a group of 20 teachers). The workshop is offered at The Science House located on Centennial's Campus of North Carolina State University.

2.2 PROGRAM SIGNIFICANCE

PL2 optics and photonics teacher workshop is critically essential due to state and national data documenting dismal numbers of Physics teacher (three teachers produced in North Carolina in 2006) entering the teaching profession and a third of 23, 000 United States high school Physics teachers who enter the field inadequately prepared to teach studentsⁱⁱ. The National Science Foundation and America Physical Society created the Physics Teacher Coalition in collaboration with numerous colleges and universities to enhance teacher education and in-service programsⁱⁱⁱ. An optics study of teachers and students suggested providing modifications in curricula for improvement in optics instructions of high school students and college students in teacher-training programs to enhance their conceptual knowledge of light, vision^{iv}. Also, Physics studies of elementary and middle school teacher education programs indicated limitations in pre-service and in-service teachers' understanding of light concepts, force and motion^v. Therefore, a need exist to prepare middle and high school teachers to teach optics and photonics concepts.

PL2 teacher workshop is based on the premise of providing innovative methods and effective practices with ongoing support of teachers' duty to prepare students for state testing, physics courses, and the global workforce. In the program, we will use real world connections and scientific explanations behind technology (i.e., computers, cell phones, lasers, IPods) to increase teachers' understanding of the importance and relevancy of teaching physics. It is through providing resources, best practices, support and a rich, experiential discourse community that incremental changes occur in teachers that address the ultimate goal of preparing and recruiting students for STEM careers or program of studies.

2.3 PROGRAM EVALUATION DESIGN & MAJOR PL2 RESEARCH QUESTIONS

To measure the program impact and monitor the program processes the following key research questions will guide the evaluation activities:

1. What transformative instructional strategies or classroom practices do teachers learn and integrate within their classroom to impact students learning and STEM pursuit?
2. What strategies will best support teacher and student development for productive participation in the global workplace?
3. To what degree are program interventions linked to student learning outcomes?
4. What monitoring and measuring procedures best support implementation fidelity and program design?

2.4 PL2 LOGIC MODEL & THEORY

The logic model below (Figure 1) outlines the proposed resources, activities, outputs and predicted proximal and distal outcomes of the PL2 Teacher workshop.

Figure 2. PL2 Logic Model

Resources	Activities	Outputs	Outcomes	Impact
In order to accomplish our set of activities we need the following:	In order to address our problem or asset we will accomplish the following activities	We expect that once accomplished these activities will produce the following evidence or service delivery	We expect that if accomplished these activities will lead to the following changes in 1-3 then 4-6 years	We expect that if accomplished these activities will lead to the following changes in 7-10 years
Qualified physics or engineering instructors 22 computers Facility for training Housing for participants Funding to cover meals, substitute cost and materials. Three laboratory visits schedule with industry and academia Stipend for Implementation Targets: Primary: Middle and high school teachers and Secondary: Middle and high school students	Inquiry Phase on light, holography, solar cells, spectroscopy, light emitting diodes Internship Phase in Optics-related academic and industry laboratories Technology Phase on visualizations and an online learning management system Implementation Phase within school, pre-college program or school district with integration of one or more strategies Follow-up Phase	Teachers will do inquiry activities and reflect on implementation. Teachers will interact with professionals in the field, learn and reflect on implementation. Teachers will manipulate visualization and orientate with online learning management system Teachers will create an implementation plan, align standards, and carry out plan in one of three options. Teachers will report findings, lessons learned and next steps in online learning management system.	Teachers will develop teaching skills and knowledge of optics, and photonics connections in curriculum. Teachers will utilize different strategies with all students and peers. Teachers will develop a level of comfort using the learning management system and reflect on ways of integrating in their class with students and peers. Provide professional resources to colleagues Recruit teachers to work in optics and photonics program Integrate resources to support specific standard course of study goals Encourage more students to explore area of science through the pre-college program	Teachers will learn how to integrate technology, curriculum and experts to prepare students for global society. Teachers will use the best of face-to-face and online strategies for professional development, student achievement, and reform of STEM education and learning. Teachers will affect policy by document more students pursuing STEM fields as a result of experimental experiences. Increase number of students in STEM field Teachers will use hybrid-learning modules with middle and high school students in all educational settings.

The logic model is grounded in the change theory that posits that experiential staff development will produce change in teachers' classroom practices, beliefs, attitudes and student learning outcomes. It is through motivation and learning

that teacher change impact student outcomes. Gusky (1986) proposed a model of teacher change that relates staff development to change in teachers' classroom practices, beliefs, attitudes and student learning outcomes. Research shows that teacher commitment to change or use of new instructional strategies strengthens after successful implementation and measurable impact with student learning outcomes^{vi}(Gusky, 1986). PL2 teacher workshop is built on the assumption that teachers participating in a professional development experience will implement created plans and new strategies into their classroom to assess the impact on students' learning outcome in science, technology, engineering and mathematics.

2.5 PROGRAM IMPLEMENTATION

The purpose of PL2 implementation evaluation is to assess the fidelity of implemented program activities according to plans as outline in the logic model. PL2 implementation design table (see Table 1) represents the seven steps taken by the project staff and evaluator to implement and monitor service delivery to the target population.

Table 1. PL2 Implementation Design

Step 1: Recruitment and Retention
Step 2: Photonics Content and Inquiry
Step 3: Internship
Step 4: Technology Integration
Step 5: Implementation
Step 6: Hybrid Follow-Up through Elluminate Live
Step 7: Dissemination and Evaluation

The evaluation provide information about strategies or procedures used to a) recruit target population, b) train or hire facilitators for the project activities, c) document number of hours completed by participants, d) communicate with participants, e) record quality of sessions delivered in a face-to-face and virtual mode, and f) determine if all components were implemented as proposed to determine ways of improving or validating the programs proposed program theory.

2.6 IMPLEMENTATION DESIGN RESEARCH QUESTIONS

The following key research questions will be used to assess PL2 program implementation fidelity:

1. What recruitment strategies best aided the staff in informing, recruiting and retaining the target population for the workshop?
2. What methods were used to communicate with the participants?
3. Did the project staff implement all workshop phases (i.e., content, externship, technology, implementation planning, hybrid follow-up and dissemination and evaluation)?
4. What could be done to improved implementation of program components?
5. Were appropriate data sources selected from participants in an ethical manner?
6. Were external data sources collected that address the program implementation model?
7. Are resources used effectively and efficiently, according to established criteria?
8. Does the program effectively coordinate with their academic and industrial partners?

2.7 IMPLEMENTATION DATA COLLECTION

Mixed data collection methods are critical to understanding the extent to which the program design was put into practice to address the intended goals and objectives of the program. Continuous monitoring of program

implementation will occur to provide the staff and stakeholders with formative and summative feedback. For example, during the face-to-face components, daily reflections are collected from participants to monitor the delivery of programming activities and suggestions for improving the proposed interventions. The external evaluator observe and interact with the participants in the workshop to collect feedback through informal surveys and interviews about each component of the teacher workshop to monitor program accountability and management standards. Upon completion of final follow-up teacher session: (a) an online survey is administered to collect summative impact data about the nature of the program activities from the workshop participants, (b) reflections from the facilitators of the sessions, and (c) activities to provide additional program process data.

3. PL2 PROGRAM OUTCOME EVALUATION DESIGN

The goal of the outcome assessment is to determine the impact of the program interventions delivered in the PL2 program and influence on change in teachers' instructional practices, perceptions, and students' STEM outcome. Documentation of listed teacher impact will ultimately lead to determining to what extent are more students entering STEM field of studies, as a result of the teacher professional development experiences. The assessment will measure to what extent does the program activities influence or change target population attitudes, behaviors and skills in regards to teaching Physics, using technology resources, and engaging learners to pursue more STEM opportunities. It will be difficult to generalize any program effects with a small sample size. However, the qualitative data will provide insightful information of the program influence on middle and high school teachers in their respective career locations.

The major research questions below will be answered based upon evidence collected from the impact assessment, which documents the extent of program interventions impact and connection to PL2 overarching program model and four guiding principles stated in the introduction. The questions below serve as a summary of the impact assessment and show how impact evidence will be analyzed to summarize whether the program goals were achieved:

1. What instructional strategies did teachers learn?
2. What strategies do teachers identify as most useful?
3. What strategies are teachers most likely to employ?
4. How effective were teachers in integrating transformative instructional strategies into their courses?
5. How do teacher strategies influence student or teacher interest in STEM?

3.1 OUTCOME DATA COLLECTION METHODS

Quantitative and qualitative data are collected to determine which resource or strategy was most frequently used, how it was implemented, with whom, and participants' response to the strategy or resource through written reflections, teacher lesson plans, online surveys, student outcomes, and semi-structured teacher interviews. Change in participants' knowledge and attitudes towards science will be assessed through a pre- and post assessment and science attitude assessment. The data allow the project staff to determine which strategy or resource was the most useful or effective based on the frequency of application, target populations reactions and documentation of students' outcome in regards to STEM interests, knowledge or pursuit. Implementation guides and reflections will serve as a measure to determine program impact and integration into teachers' respective classrooms.

Several advantages and limitations exist with the PL2 outcome evaluation design. Rossi and Lipsey (2004) put forth that multiple measurements of outcomes provide broader coverage of the concept and allow the strengths of one measure to compensate the weaknesses of another concept. PL2 outcome evaluation will monitor program outcomes from a multidimensional approach to comprehensively account for all components to determine the strengths and weaknesses of the proposed plan in achieving PL2 program goals. The advantage of using multiple data sources (i.e., pre and post assessments, questionnaires, interviews, surveys, document analyses) is to discover linkage between program interventions, change in teachers and student STEM outcome. Also, the various data sources safeguard against underestimating program. However, limitations in the multidimensional PL2 evaluation design do exist. For example, finding consensus in measurement procedures and instruments while measuring change in attitudes, skills, instructional practices or student outcome is often difficult to achieve and require technical expertise in constructing

such measures^{vii}. Ready-made measurement instruments produced by PL2 staff may only collect impact data from the stakeholder's perspective and ignore the evaluator's perspectives.

The major research questions, potential impact categories, indicators, short, intermediate and long-term results of the PL2 impact evaluation design are aligned with the projects objectives. The evaluation design will measure the change in participants' knowledge; skills, attitudes or behaviors and the mediating variables which link casual or influence sequence between proximal (change in teacher classroom practices) and distal outcomes (increased number of students pursuing STEM disciplines)

4. EVALUATION FINDINGS

In two years, PL2 has successfully exposed 37 middle and high school teachers to optics and photonics inquiry, technology, technical, and career awareness resources to impact students' understanding of the relevancy of physics in their world and future career choices. Two cohorts of teachers have participated in the PL2 professional development with Cohort I participants (n=19) completing their experience in February 2010 and Cohort II participants (n=18) entering the program in March 2010. The project staff has provided intended services to the target audience and made several modifications based on summative and formative feedback from participants.

4.1 RECRUITMENT AND DISSEMINATION FINDINGS

Seventy-five percent of Cohort I teacher participants (n=19) middle and high school teachers from North Carolina, Maryland, and Virginia representing the following counties: Cumberland and Caroline (VA); Wake and Guilford (NC); and, Montgomery (MD) have documented a significant increase in photonics content knowledge, a change in teaching optics and photonics concepts, and materials dissemination broadly to teachers and students. The cohort demographics by gender includes: 61% female and 39% male with the following ethnic backgrounds: 27% African American, 67% Caucasian, and 5% Hispanic.

Thirty-eight percent of Cohort II teacher participants (n=18) middle and high school teachers from eight North Carolina counties (Brunswick, Alamance, Mecklenburg, Chatham, Davie, Durham, Forsyth, and Wake County) have disseminated workshop materials, sought out educational exchange with a partner school in Japan and provided feedback on their initial implementation efforts. The cohort demographics by gender are 67% female and 33% male, with the following ethnic backgrounds were: 17% African-American, 78% Caucasian, and 5% Asian-American.

Dissemination efforts of optics and photonics resources with colleagues, principals, students and informal outreach education settings total 1670 individuals (1000 by Cohort I participants and 670 by Cohort II participants) as a result of the professional development activities and support.

4.2 INQUIRY PHASE FINDINGS

One hundred percent of participants agreed that the photonics inquiry activities could be used and noted they would use these activities in their classroom. They felt that activities would engage students and gain their interest and promote learning that connects to the real world. Participants indicated that hands-on experiments or demonstrations (especially the light, refraction and reflection experiments) could easily be done and would fit well in their curriculum to promote better understanding of the concepts. Many discovered how easily optics and photonics could tie into other science disciplines (i.e., Chemistry – holography, Astronomy – absorption spectrum, Marine Biology – pigments, plants and photosynthesis, Anatomy & Physiology – vision, Environmental/Earth Science – energy momentum and light energy) Teachers indicated they could use the activities to expand and answer questions about optics and photonics careers.

Participants indicated Optics and Photonics activities could be used to peak their students interest and make students aware of new technology, their development as well as careers that are available in this area. Students would learn and

understand principles studied and recognize that physics is everywhere, thus relating concepts to the real world. At the same time they would likely help students utilize resources to increase scientific skills and processes— research and lab notes.

- Seventy nine percent of the participants indicated that they would share the activities and information with their colleagues via presentations, demonstrations, and/or sharing materials.
- Sixty three percent of participants indicated that they would either perform demonstrations and/or use actual labs they performed during the workshop in their classroom.

4.3 LABORATORY AND INDUSTRY TOURS FINDINGS

One hundred percent of the teachers found the hands-on, real-life applications of photonics and optics were most interesting. Participants enjoyed the demonstrations, learning about microscopy worked and especially making a liquid crystal display (LCD) pixel during the laboratory and industry tours.

Participants wanted to know how to incorporate NC State educators and facilities into their classroom as well as how to bring the technology to the classroom at a more appropriate level. They wanted to know more about summer camps and educational opportunities for students and educators to tour laboratories at the university.

They indicated they would be interested in what microscopy applications. They wished to learn more about the tests carried out at manufacturing industries within the Optics and Photonics industry. When asked what laboratories they would prefer to explore and learn more about, the following were highlighted: light luminescence, light & biology and laser labs and their application, more hands-on activities and activities geared for elementary and middle school level.

4.4 TECHNOLOGY PHASE FINDINGS

Ninety-five percent of the teachers' general technology use included web usage to research or show video clips, computer based curriculum, and PowerPoint. Very little was done with use of technologies that allow interaction between students and teachers. The Elluminate and Moodle integration in the professional development extended teachers' comfort zone and instructional perceptions to contemplate ways of integrating these learning tools in their classrooms to support their science classes and interactions with learners.

Forty four percent of the teachers found Elluminate interesting and expressed a desire to integrate the technology into their classroom and school. In conclusion, these reflections indicate that the workshop participants acquired resources and instructional strategies to engage students in investigating optics and photonics in public schools. It also revealed that a limited number of teachers use virtual learning environments in the classroom and this area could be explored further with teachers.

4.5 PROFESSIONAL DEVELOPMENT EXPANSIONS

To address the request of teacher participants and support their efforts in disseminating resources into their classrooms and among their peers, the project staff and curriculum specialist created a solar cell and photonics activity packet with materials for teachers to checkout and pilot in their classrooms. Teachers are required to give feedback on how to improve the activities to increase usability in their classroom both middle and high school. The online content management area was reorganized to provide pertinent program information to teachers (i.e., program schedule, stipend documentation, workshop materials, reflections, implementation guides, free optics and photonics resources, workshop opportunities and blog areas) to increase teachers' use of the technology and visualize how these resources may be used in their classrooms. A STEM module for high school students is undergoing pilot efforts in high schools, with teachers and in informal science education settings to inform practice in all arenas. More work exists to be done in the technology area to fully engage teachers to use Elluminate and Moodle in addition to their current professional duties. Visualization and simulation usage in the program were modified to incorporate manipulative to support the understanding of complex concepts like polarization and interference.

5. CONCLUSION

Multiple stakeholders exist with vested interests in the promotion of Photonics to schools, teachers and students to improve the STEM pipeline. The project staff use of the participatory approach to involve multiple stakeholders in their efforts to address the need of recruiting more students to pursue STEM areas guide their work with teachers. Parents, graduate students, STEM professionals and research scientists from the public and private sector, and public school teachers provide expertise and support for program implementation, assist with recruitment, and leverage resources to support the promotion of STEM careers to high school students, teachers, parents, and preparation for the global workforce.

For example, research scientists with an interests in physics, electrical, and computer engineering would benefit from serving on PL2 advisory committee and provide direction and support in developing classroom content for the teacher development program. Also, engineers and scientist who work at technology corporations (i.e., Cisco Systems, IBM, MCNC or Verizon Business) would provide insight from the corporate setting of 21st century workforce skills requisite for aspiring high school students. Carolina Photonics Consortium representatives who are advocates for STEM initiatives, administrative staff or consultants, from North Carolina Department of Public Instruction, Governmental and state agencies representatives and high school guidance counselor all serve beneficial roles in shaping how the PL2 curriculum is developed, delivered, and evaluated. Using various stakeholders, we have leveraged resources and networks to disseminate program outcomes throughout conferences and publications to make the case for the program as well as inform STEM policy.

The Optics and Photonics teacher professional development integrates the expertise of all stakeholders to impact student outcome in STEM areas and their awareness. Immersion in the PL2 program module provides a rich collaborative, and professional environment for educators to establish connections with fellow teachers, STEM professionals and industrial representatives to understand the demands of the global society and enhance their understanding of optics, photonics, technology implications, and strategies for engaging more learners, especially underrepresented learners to explore the discipline. Rich discourse and formative feedback are byproducts of interaction and engagement of professionals, which expands the current offerings of the PL2 Optics and Photonics workshop to provide loaner kits, activity packets and online sessions which disseminate the work of the project beyond the physical location of The Science House. More exploration of hybrid/blended learning formats impact on teachers' instructional and pedagogical strategies are needed to integrate virtual learning environments and technology into classes as an useful instructional tool.

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