Collaborative Research: Integrating Curriculum, Instruction, and Assessment in Optical Engineering

BACKGROUND: PROBLEM IDENTIFICATION AND THEORETICAL CONTEXT

Pellegrino (2006) has argued that three key elements exist in the education of the American workforce: curriculum, instruction, and assessment. These elements should be explicitly linked and any investigation of interdependencies between curriculum-instruction-assessment should begin with the exploration of students' conceptions (including their misconceptions) of the subject matter (Pellegrino, 2006).

This proposal aims to develop assessment and curricular materials for college level courses on laser theory based on an investigation of the curriculum, instruction, assessment triangle. Thus, we will address three areas in the cyclic model: conducting research in STEM learning and teaching, creating learning materials and teaching strategies, and assessing learning. Our investigation will result in the following outcomes and deliverables:

1. A concept inventory instrument for assessment of learning about laser theory and summative results from administration of the instrument at multiple campuses
2. Summative results of Delphi studies conducted during the investigation. The Delphi studies will be used to determine:
    - Common areas of difficulty and/or misconception
    - Content for concept inventory instrument
3. A set of suggested teaching strategies and intervention areas for introductory laser theory courses. The suggested strategies will be evidence-based and informed by piloted activities conducted in the 2010 academic year.
4. Recommendations for future areas of research

The successful completion of the prescribed research plan is considered an intermediate step towards the development of a validated concept inventory instrument that would effectively measure student progress toward a deep understanding of laser theory and applications of laser systems.

<u>Special Nature of HBCU Participation</u>

One final point of emphasis is the special benefit that will arise from the implementation of this work at a Historically Black College or University (HBCU) campus. Due to the long-term nature of any research that would generate a valid concept inventory assessment instrument, this proposed work is expected to seed a promising research activity with a long-term horizon. Moreover, the research would presumably involve the NSU students and faculty throughout its duration.

METHODOLOGY

Three research questions drive the project design and methodology:

1. What core concepts are necessary for deep understanding of laser theory content?
2. What are the implications of Question 1 for designing effective curriculum and deploying effective pedagogy in lasers courses and programs?
3. What are the implications of Questions 1 and 2 for appropriate assessment of students' conceptual knowledge of lasers concepts?

The primary activities to be implemented in this investigation include administration of a Delphi study, and administration of the concept inventory instrument at multiple campuses. The final report will provide summative results and analyses of these activities.

The research team will consist of Dr. Patricia Mead, a graduate research assistant, and an undergraduate fellow at NSU, and Dr. Streveler of the School of Engineering Education at Purdue University. This effort will build upon significant preliminary work completed at Norfolk State University. To date, a preliminary review, termed a content analysis, of two leading textbooks used on laser theory courses has been initiated, with the goal of outlining common topical areas for instruction. Second, Dr. Mead has also reviewed the photonics skill standards developed through OP-TEC, a National Center for Optics and Photonics Education, to identify skills standards that are relevant to college level laser courses. Third, an activity whereby students generate short questions on topics within the Lasers and Photonics course for which they are unclear has been on-going since fall 2007. Similar activities began at Old Dominion University in spring 2009. The preliminary work has revealed one primary area for which hands-on lab experiments are expected to be helpful: understanding the impact of laser cavity parameters on laser spectra, particularly multi-longitudinal mode spectra. This proposal requests a small equipment budget to facilitate implementation of an open-cavity laser experiment with real-time spectral monitoring using a scanning Fabry-Perot etalon cavity. The experiments can be implemented in fall 2010. The impact of these activities on student learning will be reported in the final report.

Based on the results of the preliminary activities, the research team will be able to implement a community review of: (1) a straw-man set of topics for which students commonly experience difficulty and/or misconception; and (2) a pilot set of questions for a concept inventory instrument for a laser theory course. The community review will be achieved through a Delphi study collaboration. The Delphi collaborators are being solicited through several relevant groups: participants of the

Education and Training in Optics and Photonics meeting in summer 2009, members of the OP-TEC coalition, partner members of the Center for Integrated Access Networks (CIAN) Engineering Research Center, all five ABET accredited Optical Engineering programs, members of the ASEE Engineering Physics division, all college level Electrical Engineering and Physics programs in the Hampton Roads community. The Delphi participants will consist of experts who will participate in three iterative ranking rounds of core topics for which students experience difficulty, as well as three iterative reviews of the concept inventory instrument. Experts in this case would be considered to be experienced instructors who cover laser theory content in their courses. The goal would be to recruit 30 participants in the Delphi study, with 20% of the participants coming from HBCU campuses and one-third of participants from Physics Departments.

The Delphi study will use a web-facilitated format such as Blackboard so that faculty may participate off-site and anonymously. Participants would be asked to rank concepts on two scales – according to importance and difficulty. They will also be asked to outline the most effective labs or demonstrations used to illustrate the difficult concepts, and they will be asked to volunteer for a multi-campus administration of the concept inventory. We will implement two iterations of the Delphi survey in spring 2010 through summer 2010. A refined concept inventory instrument will be completed for administration in the 2010 academic year. The volunteer participants will administer pre- and post tests of the inventory instrument for an appropriate course on their campus during the 2010 academic year. The completed exams will be forwarded to NSU so that cumulative results from the campus locations can be determined. The final project report will be completed in spring 2011.