A Lens into the World

Active Learning in Optics and Photonics: a model teacher workshop for both the developed and developing worlds.

By Priscilla W. Laws

Physics educators who have taught for more than a year or two realize how incredibly challenging teaching introductory physics is. It's no wonder we flock to conferences on Physics Education Research (PER) and sessions on using active learning methods.

Anyone who attends international conferences quickly discovers that physics educators from other countries share many of the same challenges and frustrations. But, in addition, educators throughout the developing world have to cope with severe resource limitations that limit their access to basic equipment, computer technology, and professional development opportunities.

Suppose physics educators who are up-to-date on the outcomes of physics education research were asked to design and teach an ideal professional development workshop for the world's pre-service and in-service introductory physics teachers as well as for those who help train them. What would characterize our ideal workshop?

Based on physics education goals set at the 2005 World Conference on Physics and Sustainable Development (WCPSD) in Durban, South Africa (www.wcpsd.org) and my own experiences with curriculum and professional development, I believe that an ideal workshop would:

1. Be designed by an international team that has broad experience with teaching environments, cultural differences and the educational needs of peoples from many nations;
2. Provide teachers with tools for motivating student learning both because the topics are introduced in a coherent and inherently fascinating way and because the applications of the physics are tied to employment and research opportunities in the global economy;
3. Replace lectures with sequenced activities based on direct engagement with physical phenomena and designed based on current understanding of learning difficulties informed by PER;
4. Use appropriate pedagogical techniques and apparatus that are low-cost and accessible;
5. Provide participants with a PER-based conceptual evaluation that allows teachers to measure student learning; and
6. Provide illustrated and guided inquiry materials for students, teacher guides, and apparatus plans that can be translated into local languages and adapted to meet local needs.

For the past few years, Dr. Minella Alarcon, program specialist for Physics and Mathematics at the United Nations Educational Scientific and Cultural Organization (UNESCO) in Paris has worked with an international team of physics educators to develop a five-day workshop on Active Learning in Optics and Photonics (ALOP). Although UNESCO coordinates and funds the project, additional support has come from the Abdus Salam International Center for Theoretical Physics (ICTP), the International Society for Optical Engineering (SPIE), the American Association of Physics Teachers (AAPT), the National Academy of Sciences, the Association Francaises de l'Optique et Photonique, and Essilor.

UNESCO chose to develop this workshop curriculum on optics and photonics because it is an emerging field in contemporary physics and is relevant and adaptable to research and educational conditions in many developing countries. Photonics is basically applied geometric and physical optics—topics that teachers in developing countries often shy away from due to lack of equipment or familiarity with the topics.

ALOP is the only professional development workshop I have encountered that is targeted specifically to opening up jobs and research opportunities in fields such as optometry, atmospheric physics research, and communications for students in the emerging global economy. In addition it has most of the six attributes outlined above.

Why is the ALOP Workshop a Model for Teacher Training and Professional Development?

1. The ALOP Development Team and Low Cost Equipment Skills
The ALOP team led by Dr. Alarcon includes David Sokoloff (University of Oregon), Zorha Ben Lakhdar (University of

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Tunis, Tunisia), Vasudevan "Vengu" Lakshminarayanan (University of Waterloo, Canada), Ivan B. Culaba and Joel Maquiling (Ateneo de Manila University, Philippines), and Alex Mazzolini (Swinburne University of Technology, Australia). Each member of the team brings a unique set of experiences and talents to ALOP.

Sokoloff has more than 20 years of experience with Physics Education Research and related curriculum development. He is co-author (with Ronald Thornton and me) of *RealTime Physics Active Learning Laboratories,* of which module four is on light and optics. Other members of the ALOP team were introduced to active learning in a series of workshops sponsored by UNESCO's Asian Physics Education Network (ASPEN) in Australia and Korea beginning in 1999.

Zohra Ben Lakhdar was awarded the prestigious 2005 L'Oreal-UNESCO Award for Africa, which honors exceptional women in science (www.sciencemag.org/sciext/globalvoices/). Although she won the award for her work on atomic spectroscopy, Zohra is also honored as an outstanding teacher.

Vasudevan "Vengu" Lakshminarayanan is the most "multicultural" member on the team. Although he is a U.S. citizen, he did his undergraduate work in India and is currently teaching in Canada. He is well-known for his research in optometry, optical fibers, and optical engineering.

Ivan Culaba and Joel Maquiling are well-known in physics education circles in the Philippines for their innovative work in developing low cost equipment such as "free" interference and diffraction gratings fabricated using razor blades, pocket mirrors, and discarded CDs. The He-Ne laser pointers that they bring to the workshops are available in Manila for less than 50 cents U.S. apiece. Culaba also has published on optical engineering and the optical properties of thin films.

Australia's Alex Mazzolini, the team's photonics expert, has developed unique hands-on photonics activities and a marvelous inexpensive demonstration of optical multiplexing—a technology that has revolutionized communications.

2. Introducing Basic Topics and Motivational Applications

ALOP's intensive workshop illustrates the pedagogy of active learning through carefully crafted learning sequences that integrate conceptual questions and hands-on activities like those found in the *RealTime Physics Laboratory* curriculum. Topics that require more expensive equipment or extra time on the part of students are presented as Interactive Lecture Demonstrations. Some ALOP curricular materials can be introduced in either interactive lecture or hands-on formats.

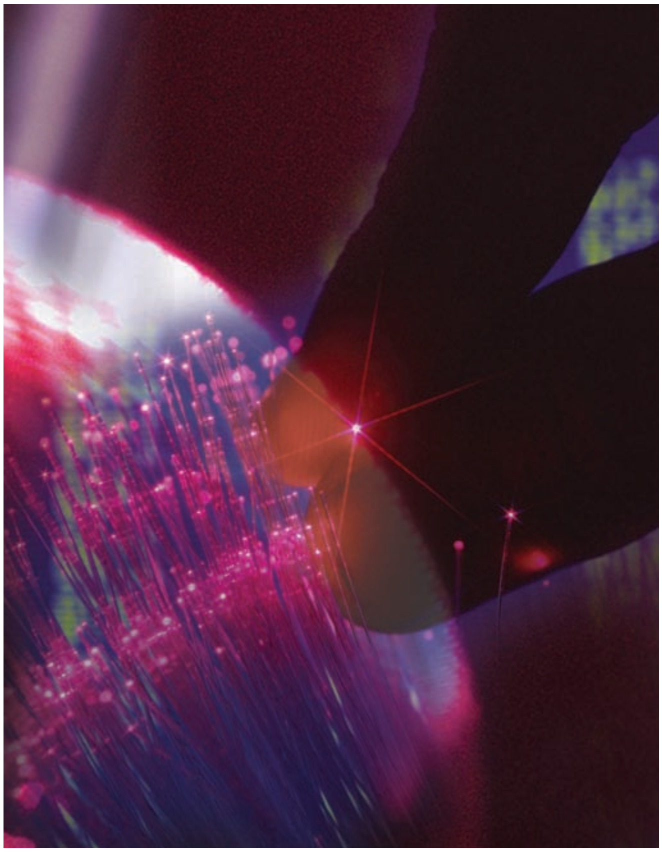
The ALOP Training Manual contains six modules, each of which has embedded applications that are designed to intrigue students and help them realize that basic physics has vital practical applications. The applications better help students understand their everyday world and become aware of career opportunities.

- **Introduction to Geometrical Optics:** How does an understanding of refraction explain how a broken test tube can be tossed in a container of "magic" fluid and brought out whole? How can the concept of critical angle be used to explain why a laser beam can be confined inside a stream of water that moves in a parabolic path? Why does covering half a lens result in a different image than covering half the object?
- **Lenses and Optics of the Eye:** How do spherical and cylindrical lenses focus light? How can spherical lenses be used to model a normal eye? How can external lenses correct near- and farsightedness. How do cylindrical properties of the lenses in the eye cause astigmatism?
- **Interference and Diffraction:** How do we infer that light can behave like waves? How can diffraction and interference be explored with equipment teachers and students can make for themselves at almost no cost?
- **Atmospheric Optics:** Why do clouds sometime appear white or grey or black? How can optical resonance be used to explain why skies are blue and sunsets red? How does scattered light become polarized?
- **Optical Data Transmission:** How can information be carried by light waves? How can light be recoded as an electrical signal? How does total internal reflection allow optical fibers to transmit information?

- **Wavelength Division Multiplexing:** What is optical multiplexing, and how has its use led to a dramatic increase in the information transferred by an optical fiber and decrease in the price of international phone calls and internet communications?

3. A Comprehensive Conceptual Evaluation

At the beginning to the workshop, participants are given a Light and Optics Conceptual Evaluation (LOCE), which contains 50 multiple-choice and one short-answer questions designed to test learning difficulties that have been identified through PER. The goal is to encourage participants to evaluate their own students before and after instruction. This allows instructors to gauge the effectiveness of their instructional strategies when they use the materials with students. [Author's note: The LOCE is under revision and not yet available. For details, contact David Sokoloff at sokoloff@uoregon.edu.]



By 2005 the first, full versions of ALOP had been offered in Ghana and Tunisia. When a group of physics educators who attended WCPSD in late 2005 learned about the virtues of ALOP they pledged to help UNESCO offer further workshops in three developing regions: Asia, Sub-Saharan Africa, and Latin America.

The Current Status of ALOP in the Developing World

Since late 2005, several WCPSD participants and I began working with Dr. Alarcon to raise funds and to provide administrative support for additional ALOP offerings in the three developing regions. These WCPSD participants include: Pratibha Jolly from India, Margaret Samiji from Tanzania, Zohra Ben Lakhdar from Tunisia, Mauricio Pietrocola from Brazil, Julio Benegas from Argentina, Cesar Mora Lay from Mexico, and David Sokoloff from the United States. As a consequence of this work, additional ALOP workshops were offered during 2006 and 2007 in Delhi, India; Dar es Salaam, Tanzania; São Paulo, Brazil; San Luis Potosi, Mexico; and Marrakech, Morocco. Each of the eight workshops given to date hosted between 30 and 60 teachers and teacher trainers.

In spring 2007, the American Association of Physics Teachers joined about a dozen other supporters by contributing a total of $9,000 to ALOP workshops given in Tanzania, Brazil, and Mexico.

UNESCO will focus on offering additional workshops in one of the world's least developed regions, sub-Saharan Africa. This does not mean that other regions cannot take advantage of ALOP through less costly regional adaptations. These "spin-off" workshops that are adapted to meet local needs are essential to the long-term viability of ALOP and similar high impact workshops.

There are efforts underway to augment official ALOP offerings by organizing regional workshops taught primarily by physics educators who have already participated in an official UNESCO sponsored workshop. Souad Lamar and Khalid Barrada are leading the way by translating the ALOP manual into French and by offering a version of ALOP (ALOP française) using regional instructors in Tunisia and Morocco. In addition, Julio Benegas and Cezar Mora Ley are spearheading the organization of ALOP español—a regional effort for teachers and teacher trainers in the southern cone region of South America and, eventually, Mexico. As well as fundraising, the ALOP español organizers (in collaboration with participants from the recent San Luis Potosi ALOP) are translating the manual into Spanish. ALOP español plans to offer the first Spanish language regional workshop in Cordoba, Argentina in 2008.

Over the long term, we need to be able to convene international teams to develop ALOP-like workshop curricula in other topic areas.

The existence of ALOP as a model workshop and its potential to enhance physics education throughout both developed and developing countries reminds us that international collaboration is an essential element of our efforts to improve physics education for all the world's peoples. Δ

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