Ref ETOP064

Hands-On Optics: An Educational Initiative for Exploring Light and Color in After-School Programs, Museums, and Hands-On Science Centers

Stephen M. Pompea[1], Anthony Johnson[2], Eugene Arthurs[3] & Constance E. Walker[4]

[1]National Optical Astronomy Observatory, Tucson, Arizona USA
[2]University of Maryland, Baltimore County, Baltimore Maryland USA
[3]SPIE–The International Society for Optical Engineering, Bellingham, Washington USA
[4]National Optical Astronomy Observatory, Tucson, Arizona USA

Abstract

Hands-On Optics (HOO) is a collaborative four-year National Science Foundation funded-program (Principal Investigator A. Johnson) designed to create a sustainable science education program to excite students about science by actively engaging them in optics activities. It will reach underrepresented middle school students in after-school programs and at hands-on science centers across the United States. The project creates and distributes educational modules and provides professional development for educators and optics resource volunteers.

Key Words

Optics education, reflection, telescope, laser, engineering design, problem-solving

Summary

Introduction

The Hands-On Optics (HOO) project builds on the educational efforts of two optics professional societies and the national observatory. The project partners for HOO are SPIE–The International Society for Optical Engineering, the Optical Society of America (OSA), and the National Optical Astronomy Observatory. Science centers, museums, as well as the Mathematics, Engineering, Science Achievement (MESA) programs in several states will help disseminate the project through their extensive after-school science and math programs. This program builds on the 2001 National Science Foundation planning grant, "Optics Education – A Blueprint for the 21st Century".[v] This planning grant was undertaken to address the disconnect between the ubiquity of optics in everyday life and the noticeable absence of optics education in Kindergarten through 12th grade (ages 5-17) curricula and also its absence in informal science education.

Key project elements

NOAO has expertise in teaching optics, developing optics kits, and in science-educator partnerships.[vi,vii] NOAO is designing the HOO instructional materials by creating well-tested formal education activities on light, color, and optical technology for the informal (museum and science center) setting. These inquiry-oriented hands-on, high-interest activities and materials are connected to the National Science Education Standards. These activities serve as the basis for six, three- to six-hour-long optics activity modules that will be used in informal education programs nationally. NOAO also will train the educators, parents, and optics professionals who will work in teams to lead the HOO activities in these informal settings. The Hands-On Optics program is designed to be used in informal science institutions such as museums, planetaria, science and technology centers, and other places where free-choice learning is a central mission. This informal atmosphere encourages exploration of science concepts, experimentation, and the free exchange of ideas in problem-

Ninth International Topical Meeting on Education and Training in Optics and Photonics, edited by François Flory, Proc. of SPIE Vol. 9664, 966425

solving. The HOO program can be used in after-school programs, in summer classes, and in Saturday programs.

Role of optics industry professionnals

A key component of the Hands-On Optics project will be the participation of optics professionals from the two optical societies who currently are engaged in outreach activities and programs. Optics professionals will serve as resource agents teamed with science center and MESA educators, a model very successfully used by the Astronomical Society of the Pacific's Project ASTRO. The work of the optics resource volunteer (ORV) is critical to the program and the training necessary for photonics education collaborations has been explored in a previous paper.[viii] Key elements of the model are:

–Mutual professional respect of Educators and Optics Resource Volunteers: Both are viewed as professional equals in the their respective fields.

–Separation of roles between Educators and Optics Resource Volunteers: Educators handle educational pedagogy and classroom/museum issues while Optics Resource Volunteers provide background into optics, careers, and optical engineering techniques. The educator does not need to become an optics expert and the optics expert does not need to become an educational expert.

–The relationship between the Educator and Optics Resource Volunteer must be facilitated, nurtured, encouraged, and supported: The Educator and Optics Resource Volunteer are trained together to use the Hands-On Optics program and materials kits.

Description of modules

The six modules and associated challenges and contests address basic optics principles and phenomena. Optics challenges and contests have also been created to augment the six modules and are described in a related paper at this conference. The modules are:

Module 1: Laser Challenges

Students use the law of reflection to predict where light will reflect from multiple mirrors. The students arrange mirrors to direct a laser beam to a target, with the laser turned off at first.

Module 2: Kaleidoscope Adventures

Students use multiple mirrors to understand reflection and to construct a kaleidoscope.

Module 3: Magnificent Magnifications

Students form images using a lens or combination of lenses. Students experiment with concave and convex mirrors. A simple refracting telescope is constructed and tested.

Module 4: Crazy Colors and Peculiar Polarizations

Students create a test bed to measure internal stress in plastic using polarizing filters. Students construct artwork using polarizing materials in different orientations.

Module 5: Seeing with Alien Eyes

Students conduct experiments using infrared and ultraviolet light, including experiments with fluorescent materials. Infrared experiments utilize an infrared non-contact probe to measure temperature. This module builds on the work in the educational activities of the *Invisible Universe* GEMS guide coauthored by Pompea and sponsored by NASA.[ix]

Module 6: Laser Transporter

Students work with lasers in order to facilitate communicating over a beam of light. Students study how information can be coded in order to be transmitted over a beam of light.

Module and kit philosophy

The modules are designed to be used in a playful, exploratory way in an informal science education setting such as a museum or an after-school program. Particular attention has been paid to making them interesting to young women, and indeed testing has verified this approach. The module development, testing, and distribution team relies heavily on the work of undergraduate physics majors and science teaching majors from the University of Arizona, which is located adjacent to the National Optical Astronomy Observatory. To date, these students have all been female. Additional expertise has come from graduate students in the College of Optical Sciences and from the Conceptual Astronomy and Physics Education Research team at the University of Arizona.

The modules each consist of an overarching theme (such as simple reflection, or communication over a beam of light) presented through a series of progressive activities designed to build basic skills and basic conceptual knowledge. Each module has a series of demonstrations designed to excite student interest as well as to illustrate concepts. For example, students can demonstrate how light reflects using laser beams and mirrors immersed in water, to make the laser beam more visible.

The successful use of each module relies on a certain level of teacher background knowledge and comfort with the optics concepts. Background knowledge is generally provided by the Optics Resource Volunteers. However, the teacher is expected to build his or her background knowledge through self-study using the National Science Teachers Association book “Light: Stop Faking It” by Bill Robertson. This book is excellent in its discussions of basic optics background material and basic principles about light and color. The book is well-illustrated with diagrams and cartoons. The Hands-On Optics modules are cross-referenced to the basic concepts described in the book. The modules are designed as guides for the educator, but they also have worksheets for the students which can be copied and distributed. In addition to the activity descriptions, the modules contain advice boxes for the educator. These boxes warn of any safety considerations, areas of student difficulty, and also help the instructor on a number of math connections that can be made to the modules.

Summary

Each module represents about 5 hours (average) of instruction for students, making the sequence of modules a 30-hour program. In each of the six modules, we have created “Going Further” activities that create additional time on task and for some modules we have created competitions that significantly increase the time a student’s spends on optics activities. The modules are well-aligned to the US National Science Education Standards, National Council of Teachers of Mathematics (NCTM) Standards, and the National Technology Education Standards. Efforts are underway to completely cross-reference the module activities to all of these standards as well as to the different state science standards for each state in which the modules are currently being used (Alabama, Arizona, California, Maryland, Oregon, Tennessee, Virginia, and Washington). Although the HOO project is primarily for informal science education, by referencing these formal education standards we increase the reach of the project and reinforce its educational validity. Our experience is that the program is proving to be extremely popular with teachers who use it in both informal and formal education settings.

The Hands-On Optics Project is funded by the National Science Foundation ISE program. NOAO is operated by the Association of Universities for Research in Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.