Optics Education – A Blueprint for the 21st Century

A project of

Optical Society of America
and
SPIE--The International Society for Optical Engineering

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INTRODUCTION

"Prosperity and the ability to compete in the global arena of knowledge and innovative ideas" remains a strategy for obtaining the Nation's security, even after September 11, 2001. But to produce innovation and high quality research, a nation has to be rich in technicians, scientists, and engineers participating in communities and local economies across the country. Already in several industrial sectors, the growth of technologically advanced industries is creating unprecedented demands for trained people at all levels. Likewise, the optics industry is growing increasingly concerned about workforce supply and development issues (see Appendix 1).

Written by SPIE—The International Society for Optical Engineering in April 2001, a position paper on proposed federal funding of scientific research and development says this about current science and technology workforce issues:

> The role that optics plays in the Nation's bright economic future could be threatened absent adequate workforce development to meet the demands for an amply supplied, first class, technologically prepared workforce. Increasing the immigration quota for foreign engineers and scientists is not the long-term solution for maintaining U.S. leadership and global competitiveness. Without substantially more resources to advance our education goals at a rapid pace, our Nation could be in the process of eroding its competitive position on the cutting edge. Without providing the best possible education for every student, to develop the skills needed to responsibly contribute to an advanced industrial society, the Nation will be at risk of losing its leadership position in shaping and defining our own futures. Increased investments in students, facilities and equipment, curriculum, and especially in faculty for science, technology, engineering, and mathematics (STEM) education, promise to yield the highest return for our Nation.

The position iterated above serves as a description of the professional society's context within which SPIE and the Optical Society of America (OSA) undertook a unique joint venture beginning in June 2000. The venture was to design a comprehensive education initiative addressing the needs of the optical science and engineering community. The venture evolved into a project called *Optics Education – A Blueprint for the 21st Century.* It consisted of a three-part strategic planning workshop series in which invited workshop participants developed recommendations for this "blueprint" (see Appendix 2). The "blueprint" becomes a guide for the optics community in creating a national optics education effort to be cooperatively implemented by SPIE and OSA, allied with partners who also share a commitment to advancing STEM education for all.

OVERALL RECOMMENDATIONS

Among the recommendations developed through the workshop series in the Blueprint Project "common threads" consistently evolved at every workshop. The "common threads" compose the following set of recommendations, which were identified as overarching themes. The workshop participants viewed these recommendations as either shaping or underpinning the OSA and SPIE programs that will evolve from the Blueprint Project.

- **Collaborating to shape a shared vision.** A strong partnership of OSA and SPIE would demonstrate a sincere commitment to improving science and engineering education. By combining resources, and moving past turf issues, the potential will increase for developing a vital national vision and efficacious leadership platform in the optics education arena. Moreover, the labor- and time-intensive investment that the societies must commit, in order to nurture a productive alliance, will pay off in expertise and credibility in coalition building. A successful SPIE-OSA partnership could be a model transferable to regions and communities where enduring commitments, among all local stakeholders, will be necessary for cost-effective problem solving in science and engineering education across the Nation.

- **Leveraging resources to attain goals.** SPIE and OSA need to become experts in forming alliances/partnerships/coalitions with others who already have the expertise at successfully working to solve various STEM education problems. Tapping extant venues and contributing to others' existing assets and resources, rather than starting brand new programs, will produce more results within a shorter time frame and at less expense. And too, optics workforce development issues cannot be separated from the larger education context and continuum. If the optics societies worked with those seeking to improve STEM education in general, once students' interest in STEM education is sparked, optics will be able to recruit and retain its fair share of the prepared workforce.

- **Playing on optics' nature to stimulate an interest in science.** STEM education, a broad perspective, is an appropriate tack to employ for advancing optics education and fulfilling a national long-term goal of building a scientifically literate citizenry and amply supplied, technologically prepared workforce. From telescope to microscope, optics defines science and technology for many people. It is used for the most sophisticated studies in quantum mechanics to the most important applications in technology — information storage, communication, display, and so forth. Light is a mainstay, the key to science and to high technology, and it also is making a difference in most science and technology fields. We can exploit that ubiquity quite easily; for example, by aptly insinuating optics and photonics applications and theory into diverse curricula. Rather than creating new textbooks and courses, optics examples can be infused into other disciplines and media at all educational levels by focusing on optics in everyday life and in service to societal problems.

- **Building competitive advantage by thinking "out of the box".** OSA and SPIE education activities need to focus on those populations that traditionally have not been the target beneficiaries of science and engineering education resources and investments — women and minorities. Businesses recognize that global competitiveness is a strategic priority that succeeds within a diverse context. The workforce is changing. But the shift is yet to take place in science and technology, which is living on imported talent owing to its inability to take advantage of the enormous potential existing in the Nation's population. Within a global sense, local diversity efforts are not ends in themselves. They are tools to pursuing larger, competitive, strategic objectives, such as meeting the increasing demands of the optics workforce. Education intervention strategies (e.g., outreach programs) that succeed with a prototype program that happens to have a target audience of minorities and women easily could be exported to those populations that currently are the main beneficiaries of science education investments.

- **Drawing on optics' greatest resource to generate meaningful change.** Critical strengths in the optics community are its human capital and the eagerness of its members — individual professionals, corporations, and students studying optics — to become involved in education activities. The optics community is primed to be of service within the larger society by developing a well-organized volunteer program. A volunteer program would allow SPIE and OSA to respond to its memberships' desires while stimulating a wide range of innovative, cost-effective remedies for problem solving in education. Owing to the large number of people in the optics community, as well as the enthusiasm and creativity that could be generated, the potential for change could be consequential.

  Moreover, a volunteer program implicitly would highlight the personal characteristics that are inherent within the endeavor of science and engineering. Especially in light of September 11, the need exists to dispel the antiseptic description of the isolated scientist and engineer. In its place, a realistic presentation needs to take hold, showing the humanity, the responsible caring, the diversity, the disciplined hard work, the curiosity and imagination, and the courage and willingness to take risks that make up a scientific professional. Given this particular moment in the nation's history, providing a means through which people in the optics community can reach out in meaningful ways could prove to be a farsighted effort with positive returns not yet envisioned.

SPECIFIC INITIATIVES RECOMMENDED AS "NEXT STEPS"

"This joint SPIE/OSA project may not solve all the problems currently plaguing science and engineering education. But our concerted actions might make a dent in the problems by empowering others, generating a wave, maybe creating a 'virus' of models, or effective intervention strategies that can spread throughout the science and engineering communities."

— MJ Soileau, Principal Investigator for *Optics Education — Blueprint for the 21st Century*, November 10, 2001, Washington, DC, OSA Headquarters.

The first two blueprint workshops identified over 60 issues and needs that contribute, in part, to today's optics education and workforce development problems. For procedural purposes, the 60 issues/needs/gaps were consolidated into the following five topic areas:

- Curriculum development/science literacy
- Informal education/public awareness
- Research and leadership
- Teacher training
- Workforce development/pipeline

Accompanying the issues/needs/gaps, Workshops I & II identified 28 possible intervention strategies or remedies to the problems, and some 23 recommendations for OSA and SPIE consideration.

Workshop III participants reviewed the aggregated five topic areas mentioned above (see Appendix 3). They examined the findings and recommendations of the other workshops, identifying short- and long-term optics education needs, and assessing the resources and capacities of the optics community to meet the needs. Workshop III participants concluded their deliberations agreeing that all the recommendations had value. However, they cited four proposals for SPIE and OSA consideration. These recommendations surfaced as desirable and the most likely for early successes in developing a visible and viable national optics education program:

I. **Write an SPIE/OSA education white paper** that describes a framework for optics curriculum development. The paper would provide guidance about various curriculum issues, such as national education standards and workforce competency standards. The framework itself also would provide a basis for funding curriculum development projects and assessing their outcomes.

II. **Organize a volunteer network of the optics community** — scientists, engineers, technicians, teachers, and students — to provide outreach services for up to 2,000,000 students in the 20 metropolitan areas in which the optics enterprise is strong.

III. **Develop an SPIE/OSA-sponsored, searchable, peer-reviewed Web site of best practices and available resources** at all levels of the education continuum, K-20, and for all involved in optics education (i.e., teachers, students, mentors, administrators, and parents).

IV. Seek funding for **partnership development with OSA, SPIE, corporations, and lead science centers** that would a) increase optics content at science centers; b) use the centers as laboratories for project-based curricula; and c) use the centers for Web-based support for teachers.

These four recommendations were chosen as initial intervention strategies, given the optics community's needs and capabilities and the potential impact that implementation of the recommendations would have versus their costs. Target audiences, necessary resources, and a time frame for implementation were proposed for each recommendation's development. This level of analysis was intended as a "map" of possible next steps, a guide for SPIE and OSA consideration, an impetus for action (see Appendix 4).

CONCLUSION

The *Optics Education Blueprint for the 21st Century* outlines some national needs in and recommendations for meeting inadequacies in optics education and workforce development. It is only one product, a tangible one, that has developed from the commitment of the Optical Society of America and SPIE—The International Society for Optical Engineering to work together ensuring that the optics community's expertise and resources will be tapped to provide maximum value in meeting the Nation's education challenges in optics.

The workshop participants' contributions to the Blueprint Project already have provided critical insight into how the optics community might proceed in their education ventures. The participants' commitment to science, technology, engineering, and mathematics education supports the SPIE and OSA goal to diligently pursue an innovative and determined vision of optics education that could shape the creating of a promising future.

WORKSHOP PARTICIPANTS

In addition to the steering committee members, the workshops brought together a mix of communities with an understanding of the state of education in K-12, and in undergraduate and graduate optics programs. The group also represented expertise in education policymaking, informal education, science and engineering education organizations and associations, recruiting and retaining underrepresented groups in science and engineering, the optics industry and professional societies. Those participants were:

Don Adams, Vail High School
Richard Anderson, Gompers Secondary School
Kenneth Brecher, Boston University
Thea Canizo, Tucson Unified School District
Everett Chavez, American Indian Science & Engineering Society
Debra Colodner, University of Arizona
Peter J. Delfyett, University of Central Florida
Eustace Dereniak, University of Arizona
James Dorsey, Mathematics, Engineering, Science Achievement
Richard Farnsworth, Lawrence Livermore National Laboratory
Rich Fedele, National Oceanic and Astronomical Observatories
Jack Gaskill, University of Arizona
Salvadora Gonzalez, University of New Mexico
Robert Goode, Mathematics, Engineering, Science Achievement
Doug Goodman, Polaroid Corporation
Doug Gorham Institute of Electrical and Electronics Engineers
Lawrence Green, Lincoln High School
John Greivenkamp, University of Arizona
Francisco Guzman, University of Arizona
Fenna Hanes, New England Board of Higher Education
Cheryl A. Hinerman, Intel Corporation
B. Dundee Holt, NACME — The National Action Council for Minorities in Engineering, Inc.
Lazaro Hong, Pima Community College
Stephen D. Jacobs, University of Rochester
Anthony Johnson, New Jersey Institute of Technology
David Marsland, National Science Research Center
Steven D. Moore, Center for Image Processing in Education
Mike Nofziger, University of Arizona
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Kitty Lou Smith, National Science Research Center
Howard Spiegelman, Junior Engineering Technical Society
Jim Stith, American Institute of Physics
Moncef Tayahi, Lucent Technologies
Michael Tomasello, Mathematics, Engineering, Science Achievement
Dominique Foley Wilson, Sandia National Laboratories
Lawrence D. Woolf, General Atomics

The steering committee for Blueprint Project was comprised of the following professionals:

Project Principal Investigator: Marion Joseph (M.J.) Soileau, Jr., University of Central Florida
Project Manager: Janice Gaines Walker, SPIE--International Society for Optical Engineering
Committee Members:

- Bob Basore, Coherent, Inc.
- Jason Briggs, Optical Society of America
- H. John Caulfield, Fisk University
- Aimee Gibbons, Optical Society of America
- Pearl John, Columbia Area Career Center
- Karen Johnston, Momentum Group, (Project Evaluator)
- T. L. Nally, KAR Associates, Inc., (Project Consultant)
- Gloria Putnam, Kodak Co.
- Kathleen Ream, KAR Associates, Inc.,(Project Consultant)
- Duncan Shields, Front Range Community College
- Barry Shoop, U.S. Military Academy
- Margaret Tuma, NASA Glenn Research Center

APPENDIX 1: Need for aggressive and long-term education initiative

Excerpted from Optics Education – A Blueprint for the 21st Century, a planning grant proposal submitted in November 2001 to the National Science Foundation by The International Society for Optical Engineering

Harnessing Light — Optical Science and Engineering for the 21st Century, a 1998 report of the National Research Council (NRC), assessed the field of optical science and engineering (i.e., optics) by its contribution to meeting national needs. NRC found that optics has a pervasive impact on our daily lives, and promises to play an even more critical role into the 21st century, as light will enable revolutions in diverse areas. Optics, as defined in *Harnessing Light***,** is "the field of science and engineering encompassing the physical phenomena and technologies associated with the generation, transmission, manipulation, detection, and utilization of light." As such, optics is largely defined by what it enables, extending into the fields of computing, communications, defense applications, entertainment, education, electronic commerce, health care, life sciences, transportation, and industrial processing. In addition to its significance in the national and global economies, the NRC report also confirmed that optics is integral to a wide range of scientific and technological disciplines.

Optics' breadth and promise suggest grand challenges to the Nation's abilities to optimize its potential, both in its applications and as a discipline. Recent employment projections from the U.S. Bureau of Labor Statistics call for the number of engineering jobs to continue rapid growth, far outpacing job growth for the labor force overall. From 1998 to 2000, the number of engineering jobs was predicted to increase 36.2%, more than twice as much as the 14.4% growth predicted for all occupations. Where the growth in optics has created, and will continue to create, a greater demand for people trained in the field at all degree levels, the U.S. has not generated enough technicians, scientists, and engineers to ensure our continuing leadership in a technological future.

The field of optics is recognized in the United States and abroad as a distinct discipline with a rapidly maturing industry and an expanding employment base. Only a little over two decades ago, optics was primarily a "cottage industry" with small, entrepreneurial companies doing predominantly government-funded development work and/or supplying products to a few larger systems or instrument companies. Today, many more optics products and suppliers exist. The industry is a major, separately identifiable one with companies ranging from large system manufacturers to small companies supplying components, subsystems, and design and engineering services. The optics market is headed toward another strong growth period, driven by a combination of laser, imaging, display and image/signal processing technologies that enable new devices, instruments, and systems for the previously listed fields and markets, from health care to communications to aerospace.

The following pertinent statistics demonstrate the tremendous growth in the field of optical science and engineering, assuming no restrictions in growth due to workforce supply limitations:

- In 1997, the optics market was estimated to be more than $50 billion, with an annual growth rate of 10% to 20%. The U.S. share was 60% to 70%.
- In optoelectronics (a subset of optics involving semiconductor lasers, displays, and other technologies that integrate electronic and optical technologies), the worldwide production was $12.5 billion in 1995. Of this amount, the U.S. production accounted for $6.4 billion. The Optoelectronics Industry Development Association (OIDA) predicts that the optoelectronics market will continue to grow about 10% per year, resulting in a world market in 2013 approaching $500 billion**.**
- In the 20-year period from 1975 to 1995, the estimated annual market for lasers alone grew from $72 million to $1.2 billion with U.S. manufacturers having a 35% market share.
- The number of optics companies listed in commercial directories increased from 1,300 in 1975 to 4,100 in 1997. Of these, 70% are U.S.-based companies.
- Every state except Alaska and North Dakota has at least one optics company.

- Optics has been on the U.S. Department of Defense's "Critical Technologies List" since the mid-70s.

Despite this bright economic scenario for the U.S. and the high technology industry, threats linger absent adequate workforce development to meet the demands of this growing industrial arena. For example, Travis Engen, the chairman and chief executive of ITT Industries Inc., addressed this dilemma in an August 4, 1999 *USA Today* article entitled, "U.S. Economic Train Needs Engineers". Engen discussed the workforce demand–supply disparity in citing that the total number of U.S. bachelors' degrees increased by more than 18% since 1986. In the same period, however, "the number of students earning undergraduate degrees in engineering decreased nearly 20%". A similar dynamic is reinforced in the recent studies by the U.S. Department of Education's National Center for Education Statistics (NCES) where there was a decline in 1996-97, from the previous year, in U.S. engineering bachelors' degrees.

Although the proportion of U.S. citizens with college education is increasing, it is troubling that the proportion of those with an engineering background is decreasing when technological ingenuity is needed to maintain economic prosperity, environmental quality, and national security. The situation also is worrisome when examining this issue within the global context. The National Science Foundation data show that the total number of U.S. baccalaureate degrees awarded in engineering is 5.4% of the total B.S./B.A. degrees awarded. Whereas, that same comparison of engineering degrees to the overall number of degrees is 45.7%, 32.4%, 21.0%, and 19.6% for China, Russia, South Korea, and Japan, respectively. Maintaining the U.S. competitive edge globally is further questioned when noting that NCES figures indicate that the number of engineering PhDs awarded in 1996-97 declined 3% from the previous year; and that of the engineering PhDs granted, 48% went to non-U.S. residents.

These trends could be positively influenced, and possibly reversed, were all concerned parties — industry, academe, and government — to intervene now in anticipation of the 20% increase in college-age students by 2008. The Educational Testing Service (ETS) recently projected that over the next fifteen years college enrollments will increase from 17 to 19 million. The ETS stated that minorities will account for 80% of the growth, with 50% of their growth in enrollments seen in the five states of Arizona, California, Florida, New York, and Texas. Intervention to attract more individuals to the optics disciplines will require both a change in the public perception of science and engineering, and full participation of the currently underrepresented groups in science and engineering.

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APPENDIX 2: The Proceedings

As of 2001, SPIE and OSA sponsor numerous projects and services at all levels, from kindergarten to continuing education, that promote teaching of optics and raising the visibility of optics and optical engineering as a course of study and as a career. Generally, these OSA and SPIE education efforts reach the formal classrooms and educational institutions as well as the ethnic and gender groups who traditionally make up the U.S. science and technology workforce. The areas where SPIE and OSA have not been as active in the education continuum are informal science education and diversity in science and technology. To fill these gaps, strategically tapping the OSA and SPIE community resources, SPIE and OSA proposed to pursue the following education goals, which were the foci of the workshops:

- increase science and technology literacy for the public, with special understanding of optics as an integrated area of knowledge, cross-cutting numerous disciplinary fields;
- target underrepresented populations in science and technology;
- raise awareness of career options and development in optics;
- create linkages with optics communities, academe and industry; and
- strengthen current programs and integrate new initiatives.

The workshop activity was funded in September 2001, in part by the National Science Foundation under Planning Grant No. ESI–013624. The workshops, with approximately 20 participants at each workshop, were held at the following OSA- or SPIE-sponsored meetings:

- July 29, 2001, during SPIE's 46th Annual Meeting, San Diego, California;
- September 16, 2001, in conjunction with SPIE's OPTO Southwest, Tucson, Arizona; and
- November 10, 2001, at OSA Headquarters in Washington, DC.

By holding planning workshops at a total of three locations, the societies attempted to identify unique regional needs and capabilities, as well as elicit a variety of creative problem-solving ideas. A series of workshops also held the promise of developing a diverse base of support while building on and refining the recommendations of the prior workshop(s). Workshops were scheduled for four- to six and one-half hour periods. Each agenda was shaped by evaluations and responses elicited at prior workshops, such that the outcomes of each workshop were tied to the next workshop's agenda.

<u>Workshop I • San Diego</u>

In a too-short, four-hour period, the workshop participants, led by H. John Caulfield, Fisk University (Tenn.), helped identify national education needs, short- and long-term, in science, technology, and optics; discussed the barriers to problem-solving; and developed a list of recommendations for consideration. The participants' "needs assessment" was wide-ranging, reflecting the complexity of the workforce development issues. The proposed remedies also were comprehensive, addressing the multiple levels of education, its various forms, and its numerous components. By necessity, the participants consolidated their list of the optics community's education issues to the following six categories:

- Public awareness
- Research
- Pipeline
- Teacher preparation
- Curriculum development
- National leadership

Workshop II • Tucson

As a group, workshop two participants identified over 40 issues and needs that contribute to today's optics education and workforce problems. They then categorized the issues into six overarching topics:

- Science literacy
- Informal education
- Teacher training
- Optics as a discipline
- Volunteer efforts
- Partnerships

The participants then separated into three discussion groups to consider the information and issues that had been presented in the three highest-ranked topics, and to brainstorm for solutions. One group dealt with the science literacy topics. A second group considered informal education issues. The third group wrestled with teacher training and professional development. Each topical group developed recommendations relevant to their deliberations. All workshop participants finally met to examine the three groups' lists of recommendations and to identify common themes.

Workshop III • Washington, DC

The participants of the final workshop had a new responsibility: to evaluate previous workshop findings and recommendations, and to identify gaps. Issue briefs were used as starting points to initially focus the work of workshop three. In the prior workshops, the participants identified over 60 issues and needs that contribute to the optics education and workforce development problems. They also identified 28 possible intervention strategies as remedies to the problems, and they concluded with some 23 recommendations for SPIE and OSA action. The briefs categorized the original 60 issues/gaps/needs into the following five major topic areas:

- Curriculum development/science literacy
- Informal education/public awareness
- Research and leadership
- Teacher training
- Workforce development/pipeline

The DC workshop began with a review of the briefs to determine whether the five topics compose the "right" slate of problem areas for a final Optics Education Blueprint. The participants were specifically asked:

- Are these the problems that the optics community should be addressing at this time?
- Are there other problems and issues deserving priority attention that if addressed would improve optics education over the next decade?
- Given the context of the optics community and the nation's science and engineering education, what projects/services/activities should be developed to generate worthwhile, achievable outcomes?

Workshop III participants agreed that the five issue areas, as described in the briefs, presented a robust enough context from which reasonable recommendations could be derived for SPIE and OSA deliberation and follow up over the next few years. Thus, the participants' first break-out/analysis session used the 28 possible remedies and 23 recommendations listed in the five issue briefs as springboards to narrowing the list of final recommendations for consideration. By focusing on each recommendation's strengths, vulnerabilities, and possible outcomes, the breakout groups developed the following set of fifteen recommendations, which were found to have a feasible prospect for success:

1. Conduct a needs assessment of teacher content preparation (e.g., to include math and technology skills).
2. Survey teachers about their professional development needs.
3. Develop a teacher extern program through OSA and SPIE members and corporations.
4. Assess existing optics workshops for teachers, and use the data to enrich and expand the offerings.
5. Assure that historically underrepresented gender, race, and ethnic groups in science and engineering are one of the target audiences of every SPIE/OSA education initiative.
6. Create a project that initiates and nurtures the formation of alliances among stakeholders (e.g., academe, employers, education and community organizations, professional societies) to develop on regional levels intervention strategies addressing science education and workforce development issues particular to the locality in which the enduring commitment of the alliance is formed.
7. Seek funding for a partnership of SPIE, OSA, corporations, and lead science centers that would a) increase optics content at science centers; b) use the centers as laboratories for curriculum enhancement; and c) use the centers for Web-based support for teachers.
8. Form partnerships with existing youth organizations (e.g., Girl and Boy Scouts, JETS) to increase the optics content of their respective programming.
9. Help identify and grow student experiential learning opportunities, such as internships, co-operative education, and service learning.
10. Establish a mechanism to recognize effective optics education, K-12, and industry partnership programs.
11. Develop an SPIE/OSA-sponsored, searchable, peer-reviewed Web site of best practices and available resources at all levels of the education continuum, K-20, and for all stakeholders (i.e., teachers, students, mentors, administrators, and parents).
12. Organize a volunteer network of the optics community — scientists, engineers, technicians, teachers, and students — in an effort to provide outreach services to up to 2,000,000 students in the 20 metropolitan areas in which the optics enterprise has a significant toehold.
13. Seek from an industry coalition a statement to legitimize the need for collegiate optics training programs, from the associates to the doctoral degrees.
14. Recognize the technician as an essential optics professional, and begin to develop services and activities that would attract the technician into the professional community.
15. Write an SPIE/OSA education white paper that describes a framework for optics curriculum development (e.g., including national education standards and workforce competency standards), and provides a basis for funding various curriculum development projects.

To focus initial resources for building an OSA/SPIE education blueprint, the DC participants selected four of the above important recommendations (#7, #11, #12, & #15) for further refinement. Target audiences, necessary resources, and a time frame for implementation were proposed for each of the four recommendation's development. This level of analysis created a "map" of next steps, a more detailed guide for SPIE and OSA consideration and action (see Appendix 4), and possible early return on investment.

APPENDIX 3: Five Topic Areas in Optics Education Proposed for Problem-solving

1. Curriculum Development/Science Literacy

<u>The Problem and Related Issues/Gaps/Needs</u>

- *Optics as a discipline:* Absent the recognition of optics as a discipline (e.g., ABET accreditation), sufficient funding will not be allocated for curriculum development. [NB: Optics is recognized by the U.S. Department of Defense.]
- *Optics standards:* Optics is only vaguely addressed in today's educational standards. Owing to the standards movement, the process of legitimating optics may be stymied if optics materials are developed without an eye to the extant standards.
- *Knowledge is fragmented:* Optics is not a peripheral topic. Appropriate, relevant photonics applications are missing from current non-optics curricula materials.
- *Photonics materials for precollege:* An understanding of optics is necessary to prepare students for responsible citizenry and for the workforce; yet, there is a lack of appropriate photonics curricula materials in the K-12 grades.
- *Materials for technician education:* Industry has indicated a need for adequately prepared employees, able to perform the diverse tasks and skills of professional technicians.

<u>Barriers</u>

- Curriculum development is a time-, cost-, and labor-intensive undertaking.
- Textbook publishers are key to development and acceptance of curricula materials.
- Education is part of state and local jurisdictions, creating a diverse and complex situation (e.g., varying standards) in which to effect change.
- Lack of optics in the standards.
- Owing to the teachers' time and resource constraints, teachers have few incentives to add an optics course to the curriculum.
- Contemporary curricular materials and education processes produce graduates often having a narrow technical focus and solitary learning style, which make it difficult for the employee to adjust to rapid shifts in the market.

<u>Possible Remedies</u>

- Create materials for optics education that are presented within meaningful contexts. Studies find students disinterested in science, in part, because students fail to see the connection of the topic and lesson to anything meaningful in their lives. Focusing on context for optics applications, such as exploring new technological opportunities or solving societal problems, would advance curriculum development.
- Studying optics applications within wider contexts also can be the goal of inserting optics examples, labs, and demonstrations into courses in other disciplines. This strategy would draw on optics' quality as an "enabling science", and could raise the visibility of optics, possibly generating an appreciation for optics as fundamental to everyday life.
- In lieu of writing textbooks at all educational levels, lab exercises, demonstrations, modules, and multimedia materials, including Web-based instruction, could be developed. Offering alternatives to textbooks may raise the probability of acceptance by publishers and teachers.
- New curricular materials need to be consistent with research-based understanding of effective pedagogy.
- New curricular materials for technicians also need to develop skills in complex problem solving, working in teams, and synthesizing and communicating information.
- Offer a survey course, with few math requirements, in optics/photonics at the secondary and post-secondary levels to increase awareness and interest among students.
- Develop standards and competencies at national and state levels.

OSA/SPIE Resources

- Various optics career and educational resources and information such as career videos and the OSA Optics Discovery Kit.
- SPIE Optics Outreach Kits and resources for optics professionals to use in collaboration with K-12 teachers.

Recommendations

- Develop a joint OSA/SPIE policy statement or white paper about standards. Such a document would exercise leadership in helping practitioners understand how optics fits into current standards, and would help establish expectations for adequately preparing students for responsible citizenship and excellence in the workplace.
- Consolidate curricular resources and make them easily accessible, perhaps through a joint OSA/SPIE Web-based clearinghouse.
- Write a proposal seeking NSF Advanced Technology Education funding to support development of curricula for technician education.
- Sponsor a project to infuse optics (e.g., supplementary modules, hands-on demonstrations, labs, multimedia products) into extant materials and courses at all grade levels and within different disciplines.

2. Informal Education/Public Awareness

The Problem and Related Issues/Gaps/Needs

- *Needs of informed citizen in a technological society:* The scientific and technical understanding of the average citizen is inadequate for full and responsible civic engagement (e.g., lack understanding of personal risk assessment). National discussions about this disparity arise; however, science education represents less than half of one percent of the nation's science and engineering research and development investments.
- *Lack basic understanding of optics:* Optics is robust, and its presence and diverse applications throughout daily life potentially position optics to be taught within contexts that are meaningful to the public. Yet, to the public at large the subject of optics appears abstract and hard to grasp. Generally, today's citizens are underprepared to participate fully in a society that soon may become optics-based.
- *Sustained efforts to reach the public are costly:* Effectively reaching out to a diverse audience of learners in the public, from children to adults, in rural and urban settings, is a resource-intensive venture.
- *Misperception of science and technology:* Although the public's respect for scientists and engineers scores high in surveys, the population tends to perceive science and technology fields as inaccessible, and scientists and engineers as antiseptic and unapproachable. These perceptions may dissuade people from learning about and studying optics.
- *Effective use of optics in extant informal science activities:* The current informal education projects and activities could be better used to generate a larger impact for the investment.

Barriers

- Competing opportunities in terms of allocating education resources (e.g., monies, volunteers, expertise), and of the targeted audiences who have busy schedules.
- "Optics savvy" people, who might be able to insinuate optics into the popular culture, are not in professions that shape the media, such as scriptwriters, producers, journalists.
- Financial, labor, and time costs are high for returns that are difficult to measure.
- Implementation is curtailed unless the innovation is easy to export and import.

Possible Remedies

The list of competitive informal education opportunities was long. It included developing projects such as the following:

- Television programs, big-screen movies, and film clips featuring young, diverse scientists;
- Posters for school and public transportation distribution;
- Children's publications;
- Brochures and direct mailings;
- Science center displays;
- Speaker bureaus;
- Cereal box "ads";
- Public service announcements;
- Web sites with resource links, Web projects and Webcasts; and
- Listservs.

OSA/SPIE Resources

- Science fair sponsorships
- Local and student chapters sponsor career days, speakers bureau, demonstrations
- SPIE Women in Optics Working Group, supplying role models and volunteers to participate in educational outreach

Recommendations

- Provide feedback to and educate media outlets regarding inaccuracies and limitations of their portrayals of scientists and engineers.
- Draw on community-based organizations, including science centers, planetariums, museums, and libraries, to sponsor community-based activities such as contests, field/plant trips, after school programs, science fairs, and career days.
- Hire a professional marketing firm to promote national-level photonics awareness.
- Develop an optics/photonics summer camp model for students and teachers, including activities, materials, resources, and a schedule that could be exported and used nationwide.
- Use science centers and their exhibits more effectively as laboratories. That is, engage in longer-termed, planned activities around exhibits, which would involve depth and investigation, actively teaching about the scientific process as well as about content.
- Similarly, develop proposals for scientists and informal and classroom educators to collaborate in integrating the informal education with the formal by 1) making exhibits tied to classroom instruction and curricula, and 2) using science centers and museums for teacher training.

3. Research and Leadership

The Problem and Related Issues/Gaps/Needs

- *Recreating the wheel*: Reputable studies exist covering the range of science and engineering issues, but the optics community does not have the infrastructure organized to draw on what is already known, determine how what is known is applicable to optics, and then mobilize resources for action.
- *Research needed in optics education:* An investigation into national and state K-12 standards in education as they apply to the study of light/optics is needed. The standards for workforce skills and preparation at each career level also need a comprehensive update and careful study.

Barriers

- The sum of education resource allocations demonstrates the low priority given to these issues compared to other competing interests and concerns.
- Investigations into state education standards would be time-consuming, labor-intensive, and costly.
- Investigations into skill sets for the various optics professions would be difficult as no uniform standards exist for the various professions.

Possible Remedies

- Identify stakeholders in optics education: other optical societies, private and public sector employers, government agencies, scientific and engineering professional societies, women and minority advocacy science societies, education societies and associations, student professional societies, model quality teaching and education enrichment programs, and academic institutions and school districts.
- Identify successful alliances to understand the logistics of creating and sustaining partnerships, and to model relevant education programs.
- Conduct multi-phased research into K-12 state and local education standards, beginning with states having well-developed standards. Examine the influence and impact of the standards, as well as the implications for and relationship to optics education.
- Develop a comprehensive analysis of the diverse optics professions, by describing for each job group its necessary skill sets, education requirements, career options, salary range, and job projections.

OSA/SPIE Resources

- SPIE and OSA are working cooperatively on several areas of K-12 education, and their respective leaderships are dedicated to continuing their close efforts in these areas.
- Collaboration with the Coalition for Photonics and Optics (CPO) and other industry associations to identify programs and resources addressing the optics and photonics workforce shortage.
- Collaboration with MentorNet, the national electronic industrial mentoring network for women in engineering and science, aimed at retaining women in science and engineering degree programs, and the workforce.

Recommendations

- Urge OSA and SPIE to develop a national vision and a convincing leadership in the optics education arena.
- Leverage extant pertinent research, development, and demonstrations, activities, projects, and systems.
- Hold a "*Summit on Partnership in Optics Education*". The summit would bring together OSA, SPIE, and other optics societies and associations with the optics industry, and with other specialized organizations that have model programs and expertise in science education. The summit would expand awareness of mutual interests and model activities, while initiating and nurturing possible alliances, coalitions, partnerships, and collaborations.

4. Teacher Training

The Problem and Related Issues/Gaps/Needs

- *Not "what teachers teach":* Rather, the issue of concern in contemporary teacher training/faculty professional development is about student learning and expectations about student performance. The educational process needs to change so that "effective student learning" becomes the central focus informing teaching methods and shaping curricula development, not the reverse.
- *Outmoded instructional techniques:* There is a severe disconnect between all that is known, regarding the positive impact of research-based learning strategies on student performance, and the implementation of that which is known.
- *Disseminating promising practices and resources:* Quality science instruction has more resource costs (e.g., monies, time, infrastructure, teachers of teachers) than mass-produced lecturing.
- *Skill development:* Teachers need improvements in pedagogical and math skills, as well as in content knowledge and in an understanding of how students interpret and manipulate information.
- *Institutional support:* The professional work of teaching and improved student learning are undervalued within academic and community sectors.
- *Content separated from teaching methods in collegiate education:* Pre-service training connected to K-12 standards and improvements is at a disadvantage owing to the difficulty of changing undergraduate education to either integrate pedagogy and content or to run parallel courses with collaborating departments.

Barriers

- Inertia and an unwillingness to change, as well as a resistance within the academic culture against scholarly research in education.
- Generally little tradition or culture of support for academe within industry.
- Limited access of teachers to resources (e.g., relevant databases and technology to access databases, time and financing for professional development activities).
- Competing budget interests limit resource allocations dedicated to the appropriate level of improvement necessary in education to meet contemporary needs.
- Perception by parents, students, guidance counselors, and teachers that math and science are hard and accessible only to the most able few.

Possible Remedies

- Develop for in-service teachers college credited continuing education courses and graduate degree programs that connect research-based instruction and content in optics applications.
- Redesign for pre-service teacher training new college curricula incorporating science and technology content and research-based methods.
- Change teaching requirements, including those in math.
- Since two-year college faculties are experienced in working with students of widely varying preparation, use that institution as a resource in assisting faculty to work effectively with students of wide-ranging backgrounds.
- Provide scholarships for in-service education opportunities.
- Develop more professional enhancement products, such as videos, CDs, forums for networking with scientists and engineers, and institutes and workshops about various teacher training issues, both for content and for pedagogy.
- Advance a peer-reviewed, Web-based clearinghouse for teacher training activities, programs, services, and other relevant resources.
- Develop a professional journal dedicated to education issues.
- Support a national "Institute for Optics Education" dedicated to research, development, and dissemination.

- Create a support network of specially trained scientists, engineers, and students in the optical sciences to assist classroom teachers.

OSA/SPIE Resources

- SPIE Educators Network, a group of educators and optics experts helping educators develop classroom instructional techniques, providing resources, and answering tough questions via electronic and print communication and other forums.
- K-12 Introductory Optics Workshops for teachers and students held at SPIE and OSA international and regional conferences.
- Various educational professional resources and information such as proceedings from the biennial Education and Training in Optics and Photonics [ETOP] conference, and on-line resource links.
- University student SPIE, OSA, and joint chapters, serving as resources for K-12 teachers and students.

Recommendations

The workshop participants recommend that OSA and SPIE

- Combine their energies and resources to become a national leader in advancing faculty development/teacher training in optics education.
- Develop official mission and position statements about the issue to guide the organizations in programming, as well as in providing technical assistance to policymakers in federal and state governments and in school districts.
- Work with AAPT and other partners to identify teacher needs.
- Reach out to teachers, encouraging them to participate in the societies' professional development efforts, seeking their opinions about their self-defined needs and creative strategies for intervention.
- Formulate guidelines for recognizing and rewarding scholarly work in education and learning effectiveness.
- Seek industry partnerships to develop paid internships for teachers. Industry partnerships also were cited as important professional alliances for teachers and their colleagues to provide career guidance.

5. Workforce Development/Pipeline

The Problem and Related Issues/Gaps/Needs

- *Increasing demand in the technical workforce:* Data indicate that the issue may not be a people gap (i.e., labor shortage); so much as it is a skills gap. As business moves away from traditional hierarchical management to a more integrated model, greater expectations are placed on each individual employee. Employers recognize a dramatic need to increase training at every level and for every job group.
- *Human capital is key to sustainable competitive development:* Since global competitiveness is a strategic priority, variety in the organization to match the environment is a principle need. The workforce is changing, but the shift is yet to take place in science and technology.
- *Science and engineering are perceived as unwelcoming to those who traditionally are underrepresented in the fields:* A difficulty facing the nation results from an inability to take advantage of the enormous potential existing in the population.
- *Diversity is a [business] argument about removing barriers to productivity:* Diversity efforts are not ends in themselves, but tools to pursuing larger, competitive, strategic objectives. It is a resource management issue about environments where the full extent of each individual's contribution is realized.

Barriers

- There is no widespread strategic alliance of all stakeholders, including industry, for education issues.
- The perception is that the investment in workforce development is long-term and costly; rather than a fundamental condition of a continuous improvement philosophy.
- Problem solving is limited by the focus on differences rather than on diversity as a creative mix, a resource offering competitive strengths and benefits. The perspective endorsing diversity because it is politically correct lacks urgency and emasculates the issue. That paradigm may address entry issues (i.e., the pipeline theory) but overlooks optimizing each worker's contribution (i.e., career development and empowerment).

Possible Remedies

- A cost-effective intervention with a quick pay-off is to invest further in those students and newly minted graduates who already have chosen optics. Enhance their career development activities by growing more chapters; supporting the chapters through grants and services to the faculty and professional advisors; developing an on-line publication; supporting a student program featuring research, networking, and career services at national and regional meetings.
- Develop a network of volunteers, professionals and students, for the personal outreach and inreach activities, including mentoring, career days, plant tours and field trips.
- Use the network to assist in training parents and K-12 teachers who are science shy, and school administrators and guidance counselors having little understanding of careers in science and engineering.
- Develop research-based curricular materials that engage students in student-centered, active-learning, cooperative models.

OSA/SPIE Resources

- Various optics career resources and information (e.g., print and on-line school directory of educational institutions offering optical engineering and related degrees, career video).
- University students SPIE, OSA, and joint chapters.
- SPIE high school optics clubs.
- Scholarships for high school students entering higher education, and undergraduate and graduate students, and travel grants for college and university student presentations at SPIE and OSA technical meetings.
- Grants to educational institutions for supporting research and other student projects including attendance and presentations at technical conferences.
- SPIE re-entry grants to fund retraining of women and other qualified individuals who have been away from the optics workforce.
- Networking and mentoring for women in optics including collaboration with MentorNet, the national electronic industrial mentoring network for women in engineering and science, aimed at retaining women in science and engineering degree programs, and the workforce.
- SPIE Women in Optics Working Group, supplying role models and volunteers to participate in educational outreach.
- Collaboration with the Coalition for Photonics and Optics (CPO) and other industry associations to identify programs and resources addressing the optics and photonics workforce shortage.
- Numerous career services.

Recommendations

- Write a proposal seeking NSF Advanced Technology Education funding to support a comprehensive technician education program, including curricula development, faculty enhancement, and student pre-professional development activities.
- Enroll the entire optics community in a clearly communicated and enduring commitment to become personally involved in outreach focused on workforce development.
- Establish strategic alliances among all stakeholders, including academe, employers, education organizations, and professional societies and associations to develop various intervention strategies addressing workforce issues.
- Use diversity initiatives as tools for pursuing strategic objectives in teacher training, curriculum development, and informal education.

APPENDIX 4: Some Recommendation Specifics

I. **Write an SPIE/OSA education white paper** that describes a framework for optics curriculum development. The paper would provide guidance about various curriculum issues, such as national education standards and workforce competency standards. The framework itself also would provide a basis for funding curriculum development projects and assessing their outcomes.

Building on the work outlined in Appendix 3's "Curriculum Development/Science Literacy" section, participants at Workshop III determined that a joint a statement would help the optics community as well as the Nation in raising expectations to better prepare its citizens for functioning in an advanced society whose future promises to be optics-based.

The following areas were identified as important points to consider addressing in the paper or during the white paper's development process:

- <u>OSA/SPIE and education standards</u>. The OSA/SPIE goals articulated in the paper could be enhanced if appropriately linked to relevant national education standards. A baseline research effort to investigate national and state K-12 standards in education, with a special focus on K-8, as they apply to the study of light/optics also would benefit curriculum development projects. Linking the standards to optics studies would be most effective if the connections were illustrated through examples of appropriate lessons and applications in the classroom. Owing to the multiplicity of education standards, which are developed under state and local jurisdictions, the "linkage" aspects should focus on standards in states where the optics industry has a strong presence and in high-population states where the impact could be greater.

- <u>Research-based pedagogy</u>. The paper should emphasize the importance of developing curriculum materials that are consistent with a research-based understanding of effective pedagogy. For example, optics classroom and extra-curricular lessons that are student-centered, actively placing the students in hands-on, cooperative learning activities are considered to be models of successful instructional techniques for reaching all students, including women and minorities. Another example is to create materials for optics education that are presented within meaningful contexts. Studies find students disinterested in science, in part, because students fail to see the connection of the topic and lesson to anything meaningful in their lives. Focusing on context for optics applications, such as exploring new technological opportunities or solving societal problems, were seen as advancing curriculum development.

- <u>Optics infused in wider contexts</u>. Studying optics applications within wider contexts also can be the goal of inserting optics content, examples and problems, labs and demonstrations into courses in other disciplines. This strategy would draw on optics' quality as an enabling science, and could raise the visibility of optics, possibly generating an appreciation for optics as fundamental to everyday life. Using the "infusion" focus as an initial strategy in optics curriculum development also argues for de-emphasizing the writing of textbooks and providing instead lab exercises, demonstrations, modules, and multimedia materials, including Web-based instruction. Offering alternatives to textbooks may raise the probability of acceptance by teachers who seek flexible ways to integrate new material into their lessons. Alternatives to textbooks also raise the publishers' interest, who are actively seeking Web-based instruction and ancillary materials, which are an untapped niche in which to deliver new subject matter. Web-based curricula and optics content for current non-optics curricula would appeal to the publishers' requirement for value-added options that constantly innovate, possibly leading to increased sales.

- Web-based resource. Consolidating resources and making them easily accessible, such as through a joint OSA/SPIE curriculum Web site, was considered to be a significant action for the societies to implement.

- Faculty development implications. The paper needs to address the fact that innovations in curricula and in its ancillaries are ineffectual absent adequate teacher preparation. One of the critical pressure points identified by the participants for overcoming education problems in optics was professional development. Owing to the extended influence and cascading reach that teachers have, investments in teacher preparation possibly hold the most cost-effective remedy to education problem solving. The importance of the teacher is verbally acknowledged in the science and technology community; yet in practice, the teacher's expertise and role are undervalued, leading to a shortage of adequately prepared science and technology teachers/faculty in the classroom.

- The workshop participants recommend that OSA and SPIE combine their energies and resources in advancing faculty development/teacher training in optics education. The participants suggest that the two societies link the curriculum development white paper to teacher preparation and develop in-depth position statements about the issue to guide the organizations in programming as well as in technical assistance to policymakers in government and in school districts. Other joint efforts regarding teacher preparation suggested investments in development and support of an "Institute for Optics Education" and a professional journal dedicated to education issues. Teacher workshops, including those providing continuing education credits or teaching certification units, should be organized and offered by the societies. A recurring emphasis also was placed on the need to reach out to teachers, encouraging them to participate in the societies professional development efforts, seeking their opinions about their self-defined needs and creative strategies for intervention.

- Audience. The white paper should be disseminated widely throughout OSA and SPIE, as well as to others who are important partners in advancing optics education, such as the math community, employers, relevant science and engineering associations, informal science educators, economic policy development specialists; and to those in academe working on standards and on faculty development. Workshop participants recommend that the white paper also would benefit from the input of these optics education stakeholders.

II. Organize a volunteer network of the optics community—scientists, engineers, technicians, teachers, and students—to provide outreach services for up to 2,000,000 students in the 20 metropolitan areas in which the optics enterprise is strong.

Concerned about the shortage of an adequately prepared teaching workforce, the workshop participants strongly recommended that SPIE and OSA enhance the precollege level of STEM literacy, with a special emphasis on middle schools, by motivating and facilitating a partnership of volunteer society members with local education communities. Workshop participants contended that this sort of outreach also would address the optics education problem of public awareness. One barrier in this area revolves around the potential difficulties of reaching a diverse audience of learners. Reaching out to effectively educate demands considerable resources — financial, long-term time frame, and labor. But by leveraging the OSA and SPIE resource of its members, various education projects and innovations, tailored to unique local needs and resources, could be tested, and, where successful, disseminated as model programs.

The workshop participants also made the following recommendations to further describe this proposed project:

- Audience: Students, teachers, administrators, and parents

- <u>Required resources</u>:

1) OSA/SPIE staff support;
2) Easy to use templates for demos, standard practices, talking points, interactive activities, Web-based resources;
3) Senior-level corporate buy-in and sponsorship (funding, release time);
4) Equipment;
5) Giveaways & leave-behinds; and
6) Ongoing, high quality training in research-based pedagogy for teachers and their OSA/SPIE science and engineering partners and mentors.

- <u>Timeline:</u>

1) Begin developing an inventory of existing outreach programs;
2) Present volunteer network program proposal to corporate members at PW & OFC;
3) Bring on-line preliminary database of teaching and learning resources within a year of proposal approval;
4) Seek other funding sources, especially for equipment needs, immediately after proposal approval; and
5) Maintain on-going program resource and materials development

III. **Develop an SPIE/OSA-sponsored, searchable, peer-reviewed Web site of best practices and available resources** at all levels of the education continuum, K-20, and for all involved in optics education (i.e., teachers, students, mentors, administrators, and parents).

The Web was viewed as an important resource for developing a comprehensive clearinghouse to disseminate all types of optics information, such as the following:

- Teacher resources, including professional development opportunities
- Curriculum materials and ancillaries (e.g., multimedia materials and Web sites)
- Equipment and suppliers
- Demos, labs, interactive lessons, and contests

The Web site would serve students, instructors, optics volunteers, and parents.

To build the Web site infrastructure and to launch it within two years, volunteers will be needed to submit leads regarding available resources to list. Experts also will be needed to review the content of the suggested resource(s). Staff will have to be dedicated to ongoing development, maintenance, and evaluation.

IV. Seek funding for **partnership development with OSA, SPIE, corporations, and lead science centers** that would a) increase optics content at science centers; b) use the centers as laboratories for project-based curricula; and c) use the centers for Web-based support for teachers.

The workshop participants recommended that SPIE and OSA draw on community-based organizations to advance optics education initiatives. In specific, they suggested that the two societies organize a program with science centers to serve as a professional development resource, and as a laboratory for teaching and learning. Regarding the latter, the proposal's dual purpose conceives a hybrid resource that can serve both formal and informal science education goals. The group recommended that by thinking “outside the box”, science centers and their exhibits could be used more effectively as laboratories for extended investigations and instruction tied to curricula.

Other proposal details included:

- Audience: Students, instructors, optics volunteers, and parents.

- Required resources:

  1. OSA and SPIE members, including students, to work with science centers.
  2. A successful, extant, traveling exhibit on optics, to begin the project, that could be disseminated by duplicating it and its activities, materials, and other resources;
  3. Corporate partnerships and other funding sources for its support.

- Strengths: The project is exportable. It also leverages resources for mutual benefit of the optics community and existing science centers. At the centers, it creates more exposure for optics.