

Optics education — a blueprint for the 21st Century

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ABSTRACT

In latter 2001, SPIE—The International Society for Optical Engineering and the Optical Society of America (OSA) will hold a series of three workshops to develop a long-range plan for impacting informal science education in optics in the U.S. The National Science Foundation, with matching support from the societies and industry participants, is funding these workshops. This paper will report out on the workshop results.

The stated goal of the workshops is the creation of *A Blueprint for the 21st Century*. This Blueprint will include an analysis of short and long-term needs in optics education, an assessment of resources and capacities of the optics community to meet these needs, and development of an action plan for a more visible and viable national optics education program. The workshops will be held between July and November 2001 in varying locations around the U.S. Participants in the workshops will include members of OSA and SPIE, and a variety of experts in informal, youth, and minority science education. The workshops will be independently evaluated for their effectiveness in meeting the stated goals of the workshops.

Keywords: Optics education, informal science education, math education, science education, optics workforce, optics workforce pipeline

1. NEEDS IN THE OPTICS WORKFORCE

Most of us in the optics community believe that the role played by optics in the Nation's economic future could be threatened without adequate workforce development to meet the demands for an amply supplied, first class, technologically prepared workforce. Already in several industrial sectors, the growth of technologically advanced industries is creating unprecedented demands for trained people at all levels. 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.

In a proposal to the National Science Foundation, SPIE — The International Society for Optical Engineering and the Optical Society of America (OSA) suggested that these trends could be positively influenced, and possibly reversed. Increasing the immigration quota for foreign engineers and scientists was not thought to be the long-term solution for maintaining leadership and competitiveness. The optics societies wrote in their proposal that a possible remedy to workforce problems relies on the commitment of all concerned parties — industry, academe, and government — to intervene now in anticipation of the 20% increase in college-age students by 2008 in the U.S. Moreover, the proposal continues, "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."

That proposal, entitled *Optics Education — A Blueprint for the 21st Century*, was awarded an NSF planning grant (Grant No. ESI—013624). The proposal was the first tangible product of a unique joint venture that OSA and SPIE undertook to design a comprehensive education initiative addressing the needs of the optical science and engineering community. The funded project consisted of a three-part strategic planning workshop series in which invited workshop participants developed recommendations for a “blueprint”. Our intent was that the Blueprint would become a guide for the optics community, and specifically for SPIE and OSA to implement cooperatively allied with partners who also share a commitment to advancing science, technology, engineering, and mathematics (STEM) education for all.

2. OVERARCHING PROPOSAL GOALS

Currently, 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 courses of study and as careers. OSA and SPIE are jointly working on several areas of K-12 education. Examples of their respective efforts can be found via their Web sites: www.spie.org and www.osa.org.

Generally, these SPIE and OSA education efforts have reached 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 minorities in science and technology. To fill these gaps, strategically tapping the OSA and SPIE community resources, the two societies proposed to pursue the following education goals:

- 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 alliances with optics communities, academe and industry; and
- strengthen current programs and integrate new initiatives.

3. THE PLAN

Acknowledging in June 2000 the need to rapidly respond to the science and engineering education problems, SPIE through the leadership of its Education Committee sought to form an alliance with its sister society OSA. The two societies agreed to collaborate based on common leadership directives and goals, as well as on the strength that would be generated owing to resource consolidation.

SPIE, as the lead administrator for this initial planning activity, requested in November 2000 a planning grant of \$48,725 to partially support the development of a comprehensive education initiative. The planning activity supported a series of workshops, with over 20 participants at each workshop, held at the following venues:

- July 29, 2001, in conjunction with SPIE’s 46th Annual Meeting, San Diego, California. (Workshop I)
- September 16, 2001, in conjunction with SPIE’s OPTO--Southwest, Tucson, Arizona. (Workshop II)
- November 10, 2001, at OSA Headquarters in Washington, DC. (Workshop III)

National Science Foundation funding was confirmed in September 2001. M.J. Soileau of the University of Central Florida served as the grant’s principle investigator. OSA and SPIE members served on the project’s steering committee.

It was important to the planning process that the workshop participants represent a broad spectrum of expertise. Thus, in addition to the steering committee, the participants included those familiar with optics education at all levels and types of academic institutions. Other workshop invitees included educators who were external to the optics community, but who had a background in either K – 12 teaching, recruitment and retention of underrepresented groups in science and engineering, or public outreach programs/informal science education. The mix of communities represented at the three workshops also included individuals with expertise in education policy, workforce development, and the optics industry.

4. WORKSHOP GOALS, LOGISTICS AND ISSUES

By holding planning workshops at three locations, OSA and SPIE 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.

The specific workshop goals were to

- Gain input from key communities to identify national education needs, short- and long-term, in science, technology, and optics;
- Develop a list of ranked recommendations for meeting education needs;
- Determine the feasibility of meeting recommendations by assessing SPIE/OSA community resources and capacities, and by building partnerships both within and outside the optics community; and
- Use input to develop and implement a 10 – year strategic and business plan, or “blueprint”.

The first two blueprint workshops identified over 60 issues and needs that contribute, in part, to today's optics education and workforce development problems. Accompanying the 60 different issues or problems, those two workshops also identified 28 possible intervention strategies or remedies to the problems, and some 23 recommendations for OSA and SPIE consideration. For procedural purposes, the 60 issues with the pertinent remedies and recommendations were consolidated into five briefing papers covering these topics:

4.1. Curriculum Development/Science Literacy

- *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.

4.2. Informal Education/Public Awareness

- *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 which may soon 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.

4.3. Research and Leadership

- *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.

4.4 Teacher Training

- *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 is 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.

4.5 Workforce Development/Pipeline

- *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.

5. CONCLUDING WORK AT DC WORKSHOP

To bring focus to the blueprint process, Workshop III participants in DC reviewed the five topic area briefs examining the findings and recommendations of the other workshops. Participants fine-tuned the previous findings by evaluating the issues, identifying short- and long-term optics education needs, and assessing the resources and capacities of the optics community to meet the needs. They also looked at the strengths, vulnerabilities, and possible outcomes of the recommendations generated by the prior workshops.

Participants first narrowed the list of recommendations from the previous workshops to 15 recommendations that they determined held the most feasible prospect for success. Workshop III participants then concluded their deliberations by recommending four proposals for SPIE and OSA to initiate in undertaking the Blueprint Project. 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 OSA and SPIE action.

The following are the four recommendations from Workshop III that surfaced as initial intervention strategies likely for early successes in developing a national optics education program:

5.1. **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.

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:

- OSA/SPIE and education standards. 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.
- Research-based pedagogy. 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.
- Optics infused in wider contexts. 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’s 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.
- 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.

5.2. **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.

5.3. **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

5.4. 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. One strength of the project is that it 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.

6. OVERALL SIGNIFICANT FINDINGS

Among the recommendations developed through the workshop series in the Blueprint Project "common threads" consistently evolved at every workshop. These "common threads" compose the following recommendations, which were identified as overarching themes. The workshop participants viewed these recommendations as either shaping or underpinning the SPIE and OSA 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 together.** 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 tact 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. Light's fundamental ubiquity in and of nature provides a robustness that easily can be exploited. For example, optics and photonics applications and theory can be aptly insinuated into diverse curricula; since optics is a mainstay of science and technology, and also is making a difference in most science and technology fields. 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 creatively.** 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, both very human artifacts. 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.

7. NEXT STEPS IN DEVELOPING THE BLUEPRINT

Cognizant SPIE and OSA Committees will review the Blueprint Project findings within the context of other priorities. Workshop results will be fleshed out by SPIE/OSA Staff and Members, working with expert groups of steering committee members and workshop participants, to complete development of priority issues and themes. They will assess the work in light of available resources and potential partnerships, and will make recommendations to OSA and SPIE leadership for final Blueprint Project approval and implementation.

The Optics Education Blueprint for the 21st Century workshop process intended to generate dialogue, build a base of support, and stimulate action. The Blueprint itself will further these goals by outlining national needs in and recommendations for meeting inadequacies in optics education and workforce development. To further disseminate the findings and recommendations of the planning effort the Blueprint and related materials will be published on the SPIE and OSA Web sites and in SPIE and OSA publications, such as these proceedings of the *Education & Training in Optics & Photonics 2001* conference.

Other tangible outcomes of the Blueprint planning initiative will be various, enduring, cooperative SPIE/OSA community outreach projects. Those efforts initially envisioned included writing an informal science education proposal aimed at increasing public understanding and awareness of optics and the engineer's role in key areas of everyday life. Leveraging resources by forming alliances among industry, communities, and academe, and developing projects to grow minority and women participation in optics will be critical follow-up activities. Also, a common Web site to list the inventory of education materials, programs, and services available in optics education could be an important future resource service.

8. CONCLUSION

"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, or maybe creating a 'virus' of models or effective intervention strategies that can spread throughout the science and engineering communities."

— M.J. Soileau, Principal Investigator

This *Optics Education Blueprint for the 21st Century* 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 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.

9. EVALUATION

Karen Johnston of the Momentum Group, specializing in physical science education evaluation, conducted an independent evaluation for the SPIE/OSA planning initiative.

The evaluation centered on determining the extent to which the project activities addressed the project goals, and focused on two elements: project implementation/process and project outcomes. The evaluation addressed issues related to the process by which the goals of the planning project were addressed through the workshops and in intermediate steps between workshops. In addition, the evaluation provided summative information about the planning initiative, the outcomes, and dissemination of the outcomes. The evaluator, in consultation with the project staff, developed specific questions related to formative and summative components of the evaluation.

The evaluation activities included, the following:

- Review and commentary on all planning documents for the workshops
- Review and commentary on all background documents provided to workshop participants
- On-site observations of individual workshop evaluation
- Development and delivery of post-workshop questionnaires for participants
- Follow-up telephone interviews with sample of workshop participants, where appropriate
- Preparation of interim reports for project staff, where appropriate
- Preparation of final report with executive summary

The following overarching issues were addressed by the evaluation.

1. To what extent did the workshops identify regional needs and capabilities in optics education?
2. To what extent did the sequencing of workshop activities promote the development of a blueprint for optics education?
3. To what extent did the workshop activities, both preparatory and follow-up, promote the collaboration of SPIE and OSA in planning for and addressing the national needs in optics education, in particular for the areas of informal science education and the recruitment and retention of underrepresented groups in optical engineering and sciences?
4. To what extent did the planning grant assist SPIE and OSA in developing short- and long-term plans to: a) increase public understanding of optics, and b) develop awareness of career options in optics-related science/technology fields?
5. To what extent did the planning grant assist collaborative efforts of SPIE and OSA in strengthening current optics education programs and plan for the integration of new initiatives in optics education?
6. To what extent does the dissemination plan for the "product" of this planning grant (i.e. the optics education blueprint for the 21st century) promote and support a collaborative educational agenda for SPIE/OSA in the future?

10. WORKSHOP PARTICIPANTS

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For More Information

To obtain a copy of the *Optics Education Blueprint for the 21st Century*, contact

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