PHOTON2: Optics/Photonics Education Using Web-based Learning

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Abstract. *Funded through a three-year grant (2003–2006) from the Advanced Technological Education (ATE) program of the National Science Foundation (NSF), the New England Board of Higher Education's (NEBHE) Project PHOTON2 built on the highly successful previous professional and curriculum development projects PHOTON and its predecessor FOTEP. The goal of PHOTON2 was to adapt the PHOTON instructional materials and "alliance" model to a web-based professional development course for high school and college science and technology instructors from across the USA. Participating instructors received an industry quality laboratory kit and participated in industry internship to stimulate collaboration with industry.*

Keywords. Alliance, distance-learning, internship, PHOTON2, professional development, web-based.

Introduction.

Photonics technology – the practical application of light – is one of the most pervasive, important new technologies of the twenty-first century. Lasers, optics, fiber optics, CD players, holograms, bar-code scanners, LCDs, and satellite imagery are just a few examples of photonics technology applications. In the same way that electronics changed our lives in the twentieth century, optics will play a critical role in enabling manufacturing, medical, sensing, telecommunications, homeland security, and defense technologies in this century.

PHOTON2 proposed to utilize 21st century web-based technology to deliver a one-semester web-based professional development course "Introduction to Photonics Technology," the content of which had been implemented and field-tested by teachers and faculty in middle, secondary and postsecondary institutions in New England during NEBHE's previous project PHOTON. NSF requested that NEBHE design a project that would prepare educators to introduce photonics education in their classrooms not only in the New England region but also across the country. Web-based technology was at a point where such a goal was achievable and funded NEBHE's proposal.

1. PHOTON2 Web-based professional development model

Distance-learning has proven to be a very useful tool in bringing education to more learners in a time-efficient manner. In comparison to traditional models of professional development (e.g., short courses and workshops), the use of the Internet for delivery of educational materials, instruction and training has several advantages including the ability for learners to learn at their own pace, access information at their own convenience, and communicate asynchronously with instructors and peers [2,3,4,5]. Research shows that collaborative learning results in more learner involvement with the course, more engagement in the learning process, and is more effective than traditional methods in promoting learning and achievement [6].

What follows was described in a paper, *PHOTON2, a Web-based Professional Development Model: a Year in Review*, authored by the PHOTON2 principal investigators and delivered at the SPIE Education and Training in Optics and Photonics Conference, held in October 2005 in Marseilles, France [1]. The PHOTON2 web-based professional development model is grounded in the application of adult learning principles in an online learning environment. Adult learning research shows that adults learn in many different ways and are motivated by many different factors. While a number of theories, models, and frameworks have been developed over the past 30 years, there is still no single unifying theory of adult learning. Analysis of the literature on adult learning does, however, yield a certain set of learner characteristics that can be used to guide the development of professional development programs. These characteristics can be summarized in the following way:

- Autonomy: Adults prefer to work independently and with minimal supervision. They can nevertheless thrive in interdependent, connected and collaborative ways so long as their autonomy is respected.
- Experience: Adults bring a rich background of life experiences to the classroom. They learn best when new knowledge builds on this experience.
- Goal Orientation: Adults tend to be goal-oriented, participating in educational programs to fulfill specific objectives.
- Relevance: Adults prefer educational program that have relevance to their needs and interests.
- Pragmatism: Adults seek to apply what they have learned to their real-world lives in practical ways.
- Internal Motivation: Adults tend to be motivated more by internal factors than by external factors.

The PHOTON2 program addresses these characteristics by engaging learners in an educational experience in which learning is active, continuous, coherent, and collaborative (see Fig. 1) with the goal of building learners' capacity to: (1) apply and adapt both learned photonics content knowledge and learning strategies to their own courses and institution; (2) establish and maintain a collaborative learning community of photonics educators and industry professionals who support learning through synergistic learning activities; and (3) engage in life-long learning through the development of self-regulated learning strategies.

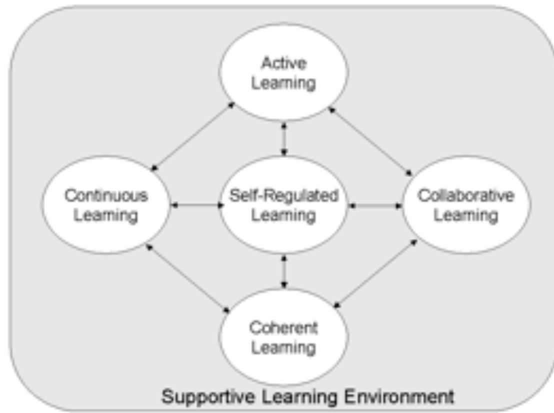

Figure 1. PHOTON2 professional development model

The pedagogical framework used to guide the design and facilitation of learning activities that promote the construction of knowledge and support the skilled application of new knowledge in the classroom was based on five key principles for effective adult learning adapted from Keeton, Sheckley, and Griggs [7].

2.1 The Alliance model

The PHOTON2 project used a model of collaboration NEBHE has chosen to refer to as an "alliance' model. The model required educators who wished to participate in the project to find a partner school and apply to the project as a team known as an alliance. The alliance was generally composed of one secondary school and one college. However, in some cases a college had more than on secondary partner. In most cases, the two or more schools were within geographic proximity of one another.

The purpose of the alliance strategy is to support the development of an educational pathway for students from secondary school to college and to foster program sustainability by building a support network for educators. The alliance model concept was developed by NEBHE based on the US Department of Education's Tech Prep program, which started in the early 1990s.The Tech Prep program funded secondary and postsecondary schools to develop curricula that were 2 plus 2, meaning that students would take the first two years of a given program during the last two years of high school and would then complete the second two years at a community or four-year college.

NEBHE initiated the alliance model in the NSF/ATE professional development project AQUA (1997-2000). It proved to be very successful. Therefore, the model has been continued in the PHOTON, PHOTON2 and now the new project, PHOTON Problem Based Learning (PBL).

Positive results from implementing this model are that the partner college begins to find ways to reach out to the high school students while the high school begins to develop a relationship with the college. This ultimately leads to educators developing curriculum articulation agreements between the educational institutions. It also acts as an excellent recruitment tool for the college since students begin to develop a relationship with the college while still in high school. The NEBHE projects have also found that having a partner educator nearby creates a support system that helps teachers work together to solve problems and develop new and innovative ideas. Since the high school teachers tend to be more applied in their teaching strategies while the college are often more theoretical, the alliance collaboration has proven to lead to a very complementary synergy.

Lastly, the alliance model included local photonics employers. PHOTON2 found this to be an extremely valuable strategy with regard to generating support for education from industry while building a skilled local workforce for employers. This is further described in the summer internship component of the project.

2. PHOTON2 project activities

Two cohorts (Cohort 1 and Cohort 2) of educators from 38 institutions in twelve states across the US were selected to participate in the PHOTON2 professional development program. Project activities included an introductory two-day workshop, a one-semester web-based “Introduction to Optics and Photonics” course, a two-week summer internship with a local photonics company, extensive hands-on experiential learning, and ongoing technical support with curriculum development and implementation from the project principal investigators and a capstone showcase workshop.

Each institution was provided with a 15-chapter text that contained the optics and photonics course content, a \$4000 custom optics lab kit that includes a field-tested lab manual with over 30 experiments ranging from simple demonstrations of refraction and diffraction to building and aligning a Michelson interferometer, and two CD-ROM videos in which PHOTON2 instructors provide step-by-step instructions for performing each experiment. In addition to the PHOTON2 lab kit, a supplemental lab kit was developed toward the end of the project to allow for greater student access to the lab exercises.

2.1 Introductory workshops

Since the participants were scattered across the country and no face-to-face contact would take place during the distance-learning course, the project principal investigators conducted two-day introductory workshop for each of the project alliances. During the spring 2004, workshops were held for members of Cohort 1 in Massachusetts, Pennsylvania, Texas and Arizona. Participants from these four alliances were prepared to begin the “Introduction to Photonics” course in fall 2004.

During fall 2004 and winter 2005, the PHOTON2 principal investigators traveled across the country from New Hampshire to Hawaii for the second round of introductory workshops. Workshops held in Tennessee, New Hampshire, California and Hawaii brought the project’s Cohort 2 educators together to learn about the course and practice with the WebCT online environment.

Each two-day workshop introduced participants to of photonics technology. On the first day the project team gave a presentation about the history and goals of PHOTON2, and led teachers through a demonstration of the web-based course software. Also, at every workshop the first day concluded with a field trip to a nearby photonics-related company or laboratory, see fig. 2.

Figure 2. Industry site visit in Hawaii

The second day of each workshop was devoted to hands-on work with the PHOTON2 photonics lab kit. Participants learned about laser safety and practiced setting up the equipment, to prepare for the coursework to come.

2.2 "Introduction to Photonics" distance-learning course

The three-credit Introduction to Photonics course was delivered via the WebCT platform through Three Rivers Community College (TRCC), a member of Connecticut's Distance-learning Consortium. The instructional resources developed in the previous PHOTON project—the 15-chapter textbook, lab kit and lab manual as well as some introductory Explorations—were central to the course. Equipment questions that arose during the course were quickly answered by posting photos to the course web site.

In the first offering of the course (Fall 2004) to Cohort 1, the structure was similar to the online introductory optics course taught previously at TRCC to traditional college students. Photonics topics were introduced through text readings, web-based interactive applets, and hands-on lab activities using the PHOTON2 lab kit. Participants worked both individually and collaboratively with alliance members to complete assignments. Threaded discussion and real-time online chats were used to allow participants to work with their alliance members and to ask questions or make comments to the instructor. Participants were given specific assignments that included self-tests, quizzes, and several reflective journal entries spaced throughout the semester. A final curriculum project was required of each participant, outlining the planned implementation of the course material in the instructor's own classroom.

It quickly became apparent that participants were conversing mostly with the instructor, if at all, and efforts to encourage communication among participants were not particularly successful. Therefore, in the semester break between the Cohort 1 and Cohort 2 courses, with the assistance of University of Connecticut education specialists, the course structure was completely redesigned to foster a more collaborative learning environment to encourage increased student engagement.

The introductory workshops for the Cohort 2 alliances were also changed to more clearly delineate expectations for the course. Although the members of the alliances had met in person at the regional introductory workshops, teachers in alliances from different geographical areas had never met. To allow participants to introduce themselves to the larger group and engage in a period of informal socialization, the course web site was opened for one week before the start date for the course. Teachers had the opportunity to log onto the site and were encouraged to post to the threaded discussion including where they were from, why they were participating in the project, their educational background and any other information they wanted to share such as hobbies or family information.

For the Cohort 2 version of Introduction to Photonics, the scope of photonics topics to be covered during the semester was reduced to allow more time for reflection on teaching and learning. The topics that were retained were those judged "most likely to be taught in my classroom" by the participants in Cohort 1. Reducing the number of technical topics allowed teachers to spend more time on the remaining core concepts, leading to deeper understanding, which in turn would increase the likelihood that the material would be taught in their own classrooms.

The most important change in the course was the shift from an "instructor centered" course to a "learner centered" course, with the instructors acting as facilitators rather than leaders. Each of the photonics instructional modules was rewritten to begin with an open-ended application problem, to be answered through the activities of the module. After a few days of individual study, including readings, computational problems, web-applets and tutorials, and hands on experiments participants entered into discussions with their regional alliance partners to collaboratively solve the application problem. The module ended with a report out to the entire class. During the module, the content expert instructor acted as "coach", reading the discussions, answering questions when asked, prodding reluctant participants, and holding online office hours, but not leading the class in any particular direction.

In order to disseminate the PHOTON2 "Introduction to Photonics" distance-learning course to a wider group of educators, a third offering was held in spring 2007. Cohort 3 included a high school science teacher from Romania who will give a presentation at this conference of what she learned from the distance-learning course.

2.3 Summer Internships

The PHOTON2 project provided educators with internship experiences in photonics companies and in college/university laboratories. In summer 2005, 24 of the 36 PHOTON2 teachers/faculty who completed the distance-learning course participated in one-to two-week paid internships. Eighteen employers, including photonics companies as well as universities that conduct research in optics/photonics provided internship sites for the PHOTON2 educators. Nine participants also did a one-to two-week internship with either the same or a new internship host during summer 2006, see fig. 3.

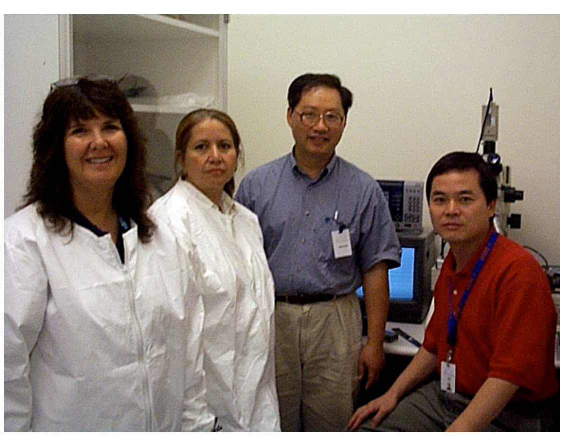

Figure 3. Three PHOTON interns (left) with host (far right)

The purpose of the internships was to establish collaborations between educators and employers. Each PHOTON2 participant was encouraged to do a paid one- to two-week summer internship at a local company or college/university. Because of the short duration of the internship, in most cases, the internship consisted of a job shadowing experience rather than actually working on a project. In collaboration with the optical professional societies and other sources of industry information, the PHOTON2 project manager provided assistance in locating internships for the participants. In some cases, the participants had already established relationships with local employers.

The internships catalyzed relationships between the educational participants and industry that resulted in donations of equipment from industry; cash donations to the participating schools; guest speakers from industry; industry tours; and numerous opportunities for students including internships, scholarships and future employment. The benefit for the employers was that they now have the opportunity to hire skilled workers that can help them grow their businesses.

2.4 Mentoring and listserv

The PHOTON2 listserv was started during Project PHOTON that preceded PHOTON2. At this point the listserv includes more than 100 participants. The listserv has a dozen mentors from industry and education who monitor and participate on the listserv. Mentors' responses to questions posed by PHOTON2 teachers and faculty and project PIs add a very current and state-of-the-art dimension to the discussion.

2.4 Showcase Workshop

PHOTON2's capstone activity was hosting a showcase workshop. The workshop was modeled after the successful NSF/ATE Annual Meeting held in Washington, DC. This meeting, attended by the principal investigators and partners of all of the 300+ ATE funded projects and centers, includes guest speakers, breakout sessions and the showcase where each project/center displays a booth that describes its activities and products, see fig 4.

Figure 4. PHOTON participants at San Diego Showcase workshop

A collaboration with SPIE provided a perfect meeting venue for the PHOTON2 showcase workshop, held from August 14 – 17, 2006 in San Diego, California. Twenty PHOTON2 educators from across the country came together to share with each other and the attendees of the SPIE annual meeting how they have implemented what they learned during Project PHOTON2 and the "Introduction to Photonics" web-based professional development course.

Each PHOTON2 Showcase participant presented a poster session that described his/her work. Co-Principal Investigator Nick Massa recorded interviews with each of the participants. To view videos of the interviews please visit www.nebhe.org/photon2, go to the "Showcase Workshop" link and click on the name of the school and PHOTON2 participant. Participants met in breakout sessions to discuss implementation issues and offer solutions to shared challenges and made a field trip to the Palomar Observatory, see fig.5.

Figure 5. Visit to the world-class Palomar Observatory

3. Conclusion

Since 1995, the New England Board of Higher Education has successfully administered several National Science Foundation Advanced Technology Education grants for teacher professional development, laboratory improvement, and curriculum development in optics/photonics. A comprehensive set of instructional materials, including a textbook and an industry quality lab kit with supporting materials, have been developed and field-tested and are available from commercial vendors. More important, a community of optics/photonics educators and industry representatives has been created that stretches from Maine to Hawaii to Romania. A goal of NEBHE's participation in the CSET "Science Education in School" international workshop is to disseminate this work to an international audience that may lead to future collaborations.

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