

Cooperative Learning Environments for Engineering Courses.

Alexander N. Cartwright
Department of Electrical and Computer Engineering
State University of New York at Buffalo

Abstract

Undergraduate students have a strong desire to participate in hands-on “real-world” projects. Moreover, undergraduate students included in the author's research in optics and materials showed much excitement and interest in these research areas. The success of these undergraduate projects encouraged the author to convert two of the photonics courses at the State University of New York at Buffalo (UB) to have a similar environment to that of research. Specifically, a cost effective (only requires changing teaching style) collaborative active-learning environment to stimulate student interest was implemented. This learning environment incorporates the recently developed pedagogical techniques that have resulted from the engineering and science curriculum reform being pursued throughout the country: cooperative learning, experience-based hands-on learning, and the application of information technologies. Moreover, these techniques are especially well suited for engineers entering industry since they emphasize group efforts, active learning, and gender and race friendly learning styles. Here, the results of the first semester of using a collaborative active-learning environment in a senior level course and the plan for using this technique in a sophomore level computer programming course (with a larger numbers of students and two different sections for better assessment) will be presented.

Introduction

Student interest in the physics related courses in Electrical and Computer Engineering, like photonics, materials, and fabrication, continues to decline. In this work, the author will focus on deficiencies in educating photonic engineers. The loss of interest in these areas is mostly due to the demand, from industry, for computer engineers and sciences and the promise of high paying careers. However, the author feels that this decline is also due to the inability to involve the students in physics related courses in an exciting manner. It has been proposed (and implemented to some degree) to include multimedia technologies to enhance the student learning environment by providing virtual laboratories and lectures using computer technology. Although these technologies can potentially provide an enhanced learning environment, they are expensive to establish and maintain, and, therefore, are not readily available. In addition, as pointed out by Wallace and Mutooni¹, merely presenting the material using WEB based learning may not

guarantee students will use it effectively. Therefore, the use of WEB based learning must be carefully planned before implementation.

In addition, the physics related courses are, traditionally, taught as theory based lecture style courses. These courses are viewed as boring by the majority of the undergraduate students. In contrast, students in computer engineering can be successful and actively participating in their education from the very beginning, e.g., when learning to program they write a program and immediately see the results of their work. Furthermore, a parallel can be drawn between the current state of photonic engineering (including photonic materials, optics and lasers) and the early years of computer science (CS). In the early years, CS demanded primarily graduate degrees for beginning positions. However, after a few years of expansion, CS demanded mostly bachelor degrees for entry-level positions. As a similar high technology area, in its infancy, photonic engineering should undergo a similar maturation and soon be requiring mostly bachelor degrees. Unfortunately, the current training level of undergraduate students does not adequately prepare them for entrance into this exciting market (The growth of photonics continues to be at a terrific rate (16% in 1995 - 1996) and is expected to be as high as 18% this year²). To date, the majority of the training in lasers and photonics is conducted at the graduate level. With the continued advances in photonics, the need for earlier training becomes essential. Undergraduate students must be able to compete for and contribute directly to jobs in this industry. *This is a problem with the educational method, not the abilities of the students.*

Undergraduate Research: Independent Study Projects

As a further deterrent to undergraduate students pursuing photonics at the State University of New York at Buffalo (UB), as at many comparable schools, the undergraduate curriculum in Electrical and Computer Engineering leaves little room for students to investigate photonics. Therefore, in the spring of 1996 the author recruited his first undergraduate Independent Study students to work in the Laboratory for Advanced Spectroscopic Evaluation (LASE). It was hoped that this experience would encourage them to pursue jobs in the optics area and to provide essential hands-on experience. In the 1996-1997 school year the author was fortunate enough to have six undergraduates working on various independent study projects. Furthermore, these have been some of the best students at UB. These include a number of undergraduate students: four NASA Fellowship winners, three SUNYAB Presidential Fellowship winners, and one NSF Graduate Research Fellowship and Department of Defense Graduate Research Fellowship winner. Working with these students has been extremely rewarding, and only encourages continued involvement of undergraduate students in research. Topics of their work have included and will include (title of work, (fellowship), name, and graduation class):

- 1) *Time-resolved Frequency Upconversion* (NASA, NSF, DOD, Presidential) Christopher Striemer, '97.
- 2) *Fourier Optics and Imaging*, (NASA, Presidential) Matthew Blaszczak, BS '97, MS '98.
- 3) *Data Acquisition and Control Software*, (NASA, Presidential), Michael Albright, '97.
- 4) *Java Educational Applet Programming*, (NASA), Menq Pan, '97.
- 5) *Optical Non-destructive Testing*, (NASA), Nathan Merkel, '98.
- 6) *C++ and Java Programming*, Matthew Matteo '96, Ross Padak, Jon Drury, Keith Nowicki '97.

The rewarding experience of working with these students reinforced the authors belief that students are interested in learning but want to learn in an environment that is challenging and enjoyable. A few things were obvious when working with these students: 1) The independent study students worked as team members and tried to help each other as much as possible. 2) Because their projects were distinct, they knew that their grade depended on their individual performance (and not the lack of performance of classmates). 3) This cooperative environment encouraged them to perform at a very high level. Unfortunately, this type of environment is not available in many classes in college. After attending teaching workshops, a curriculum reform institute, and the 1997 American Society for Engineering Education Annual Meeting, the author realized that this style of teaching was called a collaborative (or cooperative) active learning environment^{3,4}.

Extension of Ideas to Teaching

As mentioned earlier, physics related courses have typically been taught using lecture style classrooms. Professors present the theory in the classroom and assign homework problems designed to teach the concepts of interest. This teaching style is largely ineffective in motivating students and stimulating student interest because it does not provide the essential experience that one gains with experience-based (hands-on) cooperative learning. Moreover, this teaching style tends to make students work in a more competitive or individualist environment that does not promote learning. Students focus more on how to get a good grade, rather than understanding, and helping each other to understand, the material.

Any changes in the photonics curricula should address the general trends throughout the country. The photonics industry is now providing turnkey laser sources that make it possible to make state-of-the-art technologies available at the undergraduate level. Therefore, students at the undergraduate level can and should contribute to the photonic industry as photonic engineers. The author feels that an understanding of lasers and photonics can be taught without enormous amounts of math and physics because qualitative understanding can *precede* quantitative understanding. In addition, many companies are converting to a team-oriented work environment. Consequently, any teaching environment should teach interpersonal skills through classroom discussions and group projects.

With this in mind, the author has converted the photonics courses at UB, traditionally taught as lectures, to laboratory courses with high design content which include cooperative (collaborative) learning, experience-based learning, and the application of information technologies. Specifically, RAQ (reading to answer questions)⁵ and LAB (Launch, Activity, Build understanding)⁶ learning techniques are being followed. These experience-based techniques have been successfully used in calculus and computer courses at the University of Wisconsin Eau Claire^{6,7}. Furthermore, the photonics courses have home pages on the WWW, encourage the use of email, and require the use of technical professional software. Taken together, these changes provide an excellent discovery-oriented environment to enhance student learning. More importantly, these undergraduate laboratory courses with high design content stimulate interest in materials, lasers, and physics (areas with declining student populations and student interest).

This teaching style has a number of advantages over using traditional lecture style teaching for teaching photonics:

- a) Incorporates experience-based learning (active vs. passive learning) by teaching students the basics and relying on laboratory/computer experience to stimulate an interest in theory.
- b) Incorporates cooperative learning groups.
- c) Instills the theoretical ideas more concretely by allowing students to design systems.
- d) Prepares students for jobs in the photonics industry and for advanced courses in photonics.
- e) Laboratory experiments show the multidisciplinary aspects of lasers and photonics - computers, optics, controls, software, physics, and chemistry.
- f) Teaches the use of information technologies (software, WWW) to enhance learning.
- g) Requires written and oral communication of design concepts and procedures.

All of these advantages help to prepare the undergraduate students for either industry or advanced graduate work.

Implementation: ECE492 - Laser Electronics, Fall 1997

In this course the students designed a laser resonator based on a given gain medium's specifications. In-class discussions used formal cooperative learning groups to address various aspects of the design process. Moreover, students were responsible for researching the literature, monthly reports (two page written and ten-minute oral), and a final thirty-minute oral and a ten-page report. In conjunction with the design of the laser and in-class discussions, students performed experiments in the LASE at UB. These experiments investigate various laser phenomena. Significant use of computer resources was required. Moreover, Java™ Applets are being developed to be used as some of the activities and laboratories. These applets are interactive, readily accessible on the WWW, and serve to prepare the students for laboratory experiments and to introduce and enforce theoretical concepts. To this end, we have developed a few educational applets that cover topics of interest: Photon Lifetime, Fabry-Perot Resonators, Cavity Stability, and Polarization of Light are available at <http://www.ece.buffalo.edu/~faculty/cartwright/javaprogram.html>. These applets enhance the educational experience. Taken together, these experiments and discussions provided the necessary experience and tools to design the laser. Additionally, students learned to make tradeoffs and to justify their decisions. More importantly, students were encouraged to take more responsibility for their education.

Ideal Class Sessions

A typical discussion session for this course require the students to actively participate in the lecture. It is important to emphasize that the students must participate in these discussions. The professor's role is to make sure that the class stays on track to achieve their design goal. In addition, the professor serves as a starting point for finding the necessary information/reading to answer the questions that arise in class. The cycle of discussions is as follows:

- a) The professor launches the discussion, e.g. design a laser.
- b) Class discusses the launch, in cooperative learning groups, and the professor suggest reading.

- c) Assign laboratory experiments consisting of real experiments (in a laser lab) or virtual experiments on a computer. Upon completion of these experiments, discuss the topics again to see if the experiments spurred more questions.
- d) If the questions are related to previous readings, return to those topics. If not, postpone the discussions and incorporate recently acquired knowledge into the design.
- e) Once included in the design process, see if more information is necessary. If so, go back to (a).

Notice that in a design course, the discussion is re-launched each time a topic is changed. These launches consist simply of discussions of what is necessary to proceed with the design.

Observations and Assessment

There were only a small number of students in this course (fourteen) and a complete quantitative assessment was not possible. However, the author did notice some excellent results of the change in teaching style. The students found the course more appealing and the class attendance was excellent (generally twelve or more of the fourteen students attended the lectures). In addition, the lecture/discussion periods were fun for both the teacher and students. In addition, the author tried to lead some class discussions of learning styles and techniques, group interactions and self-development using the book by Landis⁸. This allowed students to be more accepting and forgiving of each other in group activities.

At the beginning of the course, students were reluctant to talk and participate in the discussions. As the semester continued, the students became more comfortable with this style. The biggest challenge for the professor is to act as a facilitator and try to steer any discussions toward the topic of interest. Of course, these discussion sessions did not proceed in the same manner as the ideal class session discussed above. The author had to resort to formal lectures in order to cover some specific details. However, in those cases the author tried to limit the amount of time of sustained lecturing. Students were encouraged to answer questions, state the necessary steps or give an expected answer to the questions based on previous experience. This allowed the lecture to be broken into shorter time periods. Furthermore, students were allowed to deliver some of the lecture material.

Before the beginning of the semester, the author had decided to sacrifice the amount of material studied in the course for a better understanding of less material. Surprisingly, the students not only had a good grasp of the concepts, but more material was covered this semester (albeit not including all the minute details) than in a previous semester of a lecture based course. In addition, on the first quiz of the class, twelve of the fourteen students received 90% or higher. On the final quiz, the majority of the students performed extremely well.

Finally, the author must admit to making a big mistake by allowing the students to choose their own groups. This resulted in one group containing the best students in the course (based on GPA). For future implementations, the author will use the techniques for choosing effective groups discussed by Hunkeller and Sharp⁹.

Future Implementation: ECE494 - Optoelectronics, Spring 1998

This course will be a more open-ended photonic design course. The students, working in groups, will design new products using photonic devices as building blocks. Specifically, the groups will be asked to design photonic products to replace current electronic versions. The learning

environment will be the same as Laser Electronics (cooperative learning environment). However, the course size will not allow complete assessment of the teaching style.

Future Implementation: EAS230 - Higher Level Programming, Spring 1998

This course will be a sophomore-level programming course that contains approximately 150 students. The course is arranged in two different sections, taught by two different faculty members. To fully assess the effectiveness of this teaching style, the author, in conjunction with the other faculty member will have identical course content except for the teaching style. This should allow the complete quantitative assessment by providing a control group.

Assessment

The assessment of this technique for engineering courses will be conducted following some of the same procedures presented by Demetry and Groccia¹⁰. This includes surveys of the students' opinions of computer programming, working in groups, and participating in in-class discussions at the beginning of the semester and again at the end of the semester for both sections. Furthermore, both sections will have the same exams and projects. However, because the section based on collaborative learning will have students working in groups, this section will have additional requirements on assignments (mostly in reporting on the groups activities and effectiveness). To avoid dysfunctional groups, the author will assign groups for the projects and in-class activities. Finally, both sections will have unannounced quizzes designed to test the students qualitative understanding of concepts related to computer programming. Finally, to avoid any bias of the assessment of the teaching styles, the exams, quizzes and projects will be graded by either graduate students or student assistants who will be unaware of the students sections. (Students will be given identification numbers for assessment quizzes).

Summary and Conclusions

The use of undergraduate students in research pointed to some flaws in the education of electrical and computer engineers for photonics. The success of using these students prompted the author to revise the curriculum of his courses. Specifically, the pedagogy used in classrooms for more physics oriented courses in electrical and computer engineering was changed. Based on the first semester of teaching Laser Electronics, the technique was successful at stimulating student interest in photonics and materials. The students were more capable of answering conceptual questions of lasers and photonics. However, this course was too small to base any significance to the perceived differences in the learning and understanding of the concepts. In addition, the author may have been biased by his desire for the technique to be successful. Therefore, the author will use the technique in a sophomore level course in computer programming. By comparing the authors section to a second control section, the author hopes to quantify the improvement of student understanding using collaborative active learning.

Finally, based on the enjoyable experience of using this technique for one semester, the author hopes that others will try this teaching style.

1. David R. Wallace, Philip Mutooni, "A Comparative Evaluation of World Wide Web-Based and Classroom Teaching," *Journal of Engineering Education*, vol. 86, no. 3, 1997, pp. 211-219.
 2. Laser Focus World, pg. 72, January 1997.
 3. Johnson, D. W., & R.. Johnson, *Active Learning: Cooperation in the College Classroom*. Edina, MN: Interaction Book Company, 1991.
 4. Johnson, D. W., & R. Johnson *Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning*. (4th Edition). Englewood Cliffs, NJ: Prentice-Hall, 1994.
 5. Bansenauer, B. , "Reading to Answer Questions: Using Student Questions in the Classroom," *Selected Papers from the Seventh National Conference on College Teaching and Learning*, July, 1996.
 6. Goulet, M., "LAB: Launch, Activity and Building understanding," *NSF Curriculum Reform Institute*, Oshkosh, WI (1997).
 7. Bansenauer, B., "From Listeners to Questioners: A Classroom Practice Built on Students Asking Questions Within A Learning Community," *NSF Curriculum Reform Institute*, Oshkosh, WI (1997).
- TM Java and all Java-based trademarks and logos are trademarks or registered trademarks of Sun Microsystems, Inc. in the U.S. and other countries.
8. Landis, Raymond B. (1995). **Studying Engineering A Road Map to a Rewarding Career**. Burbank, CA: Discovery Press.
 9. David Hunkeller, Julie E. Sharp, "Assigning Functional Groups: The Influence of Group Size, Academic Record, Practical Experience, and Learning Style," *Journal of Engineering Education*, vol. 86, no. 4, 1997, pp. 321-332.
 10. Chrysanthe Demetry and James E. Groccia, "A Comparative Assessment of Students' Experiences in Two Instructional Formats of an Introductory Materials Science Course," *Journal of Engineering Education*, vol. 86, no. 3, 1997, pp. 203-210.

ALEXANDER N. CARTWRIGHT: Alexander N. Cartwright received his Ph.D. from the University of Iowa in 1995 and has been an Assistant Professor at the State University of New York at Buffalo since August 1995. He is active in curriculum reform within his department and devoted to the use of undergraduate students in research. His research interests include semiconductor optoelectronic devices and optical non-destructive testing.