

# **Integrating Undergraduate Research into the Electro-Optics and Laser Engineering Technology Program at Indiana University of Pennsylvania**

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## **ABSTRACT**

Bringing research into an undergraduate curriculum is a proven and powerful practice with many educational benefits to students and the professional rewards to faculty mentors. In recent years, undergraduate research has gained national prominence as an effective problem-based learning strategy. Developing and sustaining a vibrant undergraduate research program of high quality and productivity is an outstanding example of the problem-based learning. To foster student understanding of the content learned in the classroom and nurture enduring problem-solving and critical-thinking abilities, we have created a collaborative learning environment by building research into the Electro-Optics curriculum for the first- and second-year students. The teaching methodology is described and examples of the research projects are given. Such a research-integrated curriculum effectively enhances student learning and critical thinking skills, and strengthens the research culture for the first- and second-year students.

**Keywords:** Electro-optics education, undergraduate research, problem based learning

## **1. INTRODUCTION**

Since the Electro-Optics and Laser Engineering Technology (EOLET) Program was launched in 2002 at Indiana University of Pennsylvania (IUP) [1-3], the undergraduate research has been integrated as an important part of the curriculum. The mission of the undergraduate research is to extend the opportunity to participate in research activities to all the first- and second-year students in the program, to stimulate student engagement through collaborative undergraduate research, to make an original intellectual or creative contribution to the discipline, and to encourage and promote university-industry collaboration. In this paper, the collaborative research based learning environment created for the first- and second-year students is described. In addition, the teaching methodology to implement the research projects is discussed and research project examples are given.

## **2. THE UNDERGRADUATE RESEARCH**

Several definitions of undergraduate research have been used throughout academe. A generally accepted definition developed by the Council on Undergraduate Research is that the undergraduate research is [4]

*“an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline.”*

This definition includes all kinds of research from both disciplinary and interdisciplinary fields, utilizes a “teacher-scholar model” for participating faculty members, and ensures that both students and faculty mentors have a vested interest in the research experience.

In recent years, it has become a part of the educational strategies in many research-intensive universities in the United States to incorporate undergraduate research for the most able students. Undergraduate research programs, such as Summer Undergraduate Research Experiences (SURE) and Research Experiences for Undergraduates (REU), offer research opportunities for a small number of the most able undergraduate students in their 3<sup>rd</sup> or 4<sup>th</sup> year at selected institutions through research projects supported by funding agencies such as the National Science Foundation (NSF). For the first- and second-year students, they have not traditionally been involved in undergraduate research, because the

expectation for undergraduate research at “research-centered universities” is to produce “original” perhaps “cutting edge” knowledge, suitable for publication in refereed professional journals.

### 3. STUDENT RESEARCH INTEGRATED CURRICULUM

The EOLET program at IUP is designed to educate a wide range of students for entry into the rapidly-evolving optics and photonics workforce. The student has a choice of either going directly to work after graduating from the Associate in Science – Electro-Optics and Laser Engineering Technology (A.S. EOLET) Program, or to matriculate and earn a B.S. degree in the Electro-Optics track in Applied Physics (B.S. EOLET). The EOLET students must develop the hands-on, problem-solving skills necessary to become successful EOLET technicians and engineers. In terms of curriculum design, the undergraduate student research concentrates on students’ learning process which is designed to be as close as possible to the research process in the discipline. In this case, what is learned/produced may not be new knowledge *per se*; but it is new to the student and, perhaps more significantly, transforms their understanding of knowledge.

In the past, we have been actively bringing research opportunities to the A.S. EOLET students. To develop suitable research topics with the limited resources and equipment is difficult. We have to balance enduring fundamental problem-solving skills with vocational marketplace realities in this rapidly evolving field. The research project offered should be sufficiently challenging, interesting and informative. By the end, students will have a positive attitude toward research, and appreciate that most of the phenomenal applications they study are the results of genuine engineering and technology. The interest developed would lead to greater willingness to become involved and to apply the concepts they have learned. The summative outcomes of the completed research projects are presented and evaluated on the “Industry Day” event. This practice helps undergraduate students in the program to better understand the process of scientific research. It increases the retention of photonic principles and concepts; it will enable them to advance to higher level of education, and enhances their employability.

In order to integrate the research into the EOLET curriculum, we use authentic research projects to replace some of the standard lab experiments in one of the core EO courses - EOPT 260 *Industrial Applications of Lasers*, because the objectives of this course for the second year students are to familiarize students with basic concepts of laser technology, and to develop logical and analytical thinking and problem solving skills in laser applications. The process-centered research experience is open to and required for all the second year students who take this course. However, the research project is open to the first year student to participate as well. He or she could work on a project or team up with a second year student. Hence every student in the EOLET program will have at least one research project done before they are graduated from the two-year A.S. EOLET Program.

During the early stages of the project, mentors provide guidance in project selecting and planning. To help them to get started, a list of new research projects in photonics is provided every year for them to choose based on their interests. Students are also encouraged to initiate and design their own research projects of their own interest with the guidance from the faculty mentor. After the possible research projects are presented to students with detailed background and expectations, mentors need to guide the student into deeper intellectual engagement by suggesting technical solutions that are appropriate and recognized by the discipline to a project.

During the second stage, students need to complete a short written report to outline the project, the objectives, the technical solution and material/equipment needed. Once the project topics are finalized and the goals are set, all the materials and equipment needed for each project are secured. The necessary materials are purchased through funding such as SPIE as well as the financial support from the Department and University. In addition, the well-equipped laboratories, the electronics lab and the optics lab, are made accessible to the students whenever a faculty member or lab technician is present. During this stage, mentors need to work alongside students in the lab, teach students how to use equipment and allow students to observe good lab techniques and approaches to problem solving. The supervision is provided in details to each student who needs helps, and the progress of each project is closely monitored. The supervising attention is focused on both the student’s development and the results of a project.

The final stage includes the project demonstration/presentation, which are evaluated by peer-students. Finally these projects are displayed and demonstrated on the annual “Industry Day” event. The local industry leaders, EOLET program advisory board members, state and local representatives, and secondary school partners are invited to IUP Campus for a demonstration and poster session presented by the students. The students provide an overview of their projects and are

available for questions and suggestions. The tangible result or deliverable product of each project is peer-reviewed, critiqued, and judged in a manner consistent with disciplinary standards. The event is also intended to provide the opportunity for industry leaders to meet and to discuss any job openings with the students.

#### 4. RESEARCH PROJECTS IMPLEMENTATION

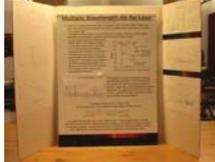
Every second-year EOLET student has to do a research project independently or teamed up with a first-year student in the program. However, a joint project can not to have more than two members. The timeline for a project is listed below (see Table 1). The project will be presented to the whole class and peer-evaluated by your classmates.

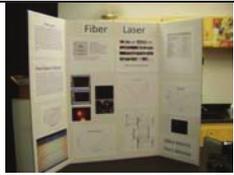
Table 1. EOLET Student Research Project Milestones.

Week	Project Milestones
3	Research project presentation – background, problem area, and objectives (10% of the total project score)
7	Research proposal report - the material/equipment list, technical solution, deliverables (10% of the total project score)
14	Poster submission, project demonstration and peer-evaluation (40% of the total project score)
15	Project final report (40% of the total project score)

In general, most students put significant time and effort into these projects and seem to enjoy working on them, as indicated by their enthusiasm and the high quality of the end results. Some of the projects have been presented outside the EOLET program such as IUP Undergraduate Scholars Forum, national and international conferences [5-11]. On average, there are about 10 projects completed every year. Table 2 lists some of the projects finished by the EOLET students in recent years.

Table 2. Some Undergraduate Research Projects Completed in Recent years.

<p><b>Research Title:</b> A Computer Interfaced Grating Spectrometer</p> <p>A grating spectrometer is interfaced with a computer. The performance of the spectrometer is optimized. The spectrometer is then used for the spectral characterization and measurement of various optical filters.</p>	
<p><b>Research Title:</b> Multiple Wavelength He-Ne Laser</p> <p>This project demonstrates a He-Ne laser operating at both green and red wavelengths by using a carefully designed laser resonator. The laser output spectral property is characterized with an optical spectrum analyzer.</p>	
<p><b>Research Title:</b> 3D Imaging with a Laser Scanning System</p> <p>A laser 3D scanner is used to construct and analyze the 3D image of the Northpointe Campus building. Such a system offers a useful tool in building design, inspection, and documentation of cultural artifacts.</p>	
<p><b>Research Title:</b> Supercontinuum Generation in Photonic Crystal Fiber</p> <p>By using a femtosecond laser, supercontinuum is generated in a photonic crystal fiber (PCF). The experimental setup and results are reported, as well as the supercontinuum evolutions when pumped at normal dispersion and zero dispersion wavelengths.</p>	
<p><b>Research Title:</b> Holographic Diffraction Gratings</p> <p>By making use of the holographic method, the produced interference fringes are used to generate the diffraction gratings. The obtained gratings are tested to give a high contrast ratio first-order diffraction pattern, as expected.</p>	

<p><b>Research Title:</b> High power diode pumped fiber laser</p> <p>A diode pumped Yb doped double cladding fiber laser operating at 1084 nm was built. An output power of 3W was obtained from the fiber laser when pumped at 910 nm.</p>	
<p><b>Research Title:</b> When Should We Change the Car Oil?</p> <p>The purpose of this project is to analyze the accumulation of contaminants in engine oil over a broad range miles, using a laser, a sensitive detector and a powermeter. The system could be implemented in a car for a real-time monitoring.</p>	
<p><b>Research Title:</b> Solar Powered LED House Number Display Project</p> <p>In our project, we set out to improve night visibility of residential or commercial building's street number using green photovoltaic and high efficiency solid-state lighting technology. The LED display will be a beacon for visitors, delivery service drivers, as well as, emergency responders in the dark, which was charging up and powered by the sun light.</p>	
<p><b>Research Title:</b> Growing Under Ground</p> <p>This project demonstrate how to grow different types of plants underground, where abandoned limestone mines provide a steady temperature of 65F at which many plants could thrive all year round. We also demonstrate that light color/intensity, moisture level, and temperature in the soil are monitored and controlled at real-time using PLC/LabView interfaced with a PC.</p>	
<p><b>Research Title:</b> Optical Hydrophone</p> <p>This project builds an optical fiber sensor to detect underwater vibrations.</p>	

## 5. CONCLUSIONS

An effective and efficient undergraduate research program has been built into the EOLET curriculum for the first- and second-year students. Although a successful undergraduate research project requires a significant investment of time and energy from the mentor, the research experience can be extremely valuable for the student. Such a vibrant undergraduate research program of high quality and productivity is an outstanding example of the problem-based learning. By creating an active learning environment that fosters inquiry and discovery, the research-integrated curriculum effectively enhances student learning and critical thinking, and strengthens the research culture for the first- and second-year students and their employability. In addition, it also provides an excellent opportunity to outreach and engage with the local community and EO companies.

Students participating in undergraduate research experience cognitive and intellectual growth. Measured by performance on traditional evaluations (exams, quizzes, papers, reports, etc.) and on the jobs after graduation, benefits include greater gains in mastering both content and contextual knowledge, enhanced ability to put classroom knowledge into practice, increased creativity and critical thinking, enhanced problem-solving skills, higher retention and graduation rates, and higher articulation rate from the A.S. degree to the B.S. program in EOLET.

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