Experiments in Optics and Photonics Engineering Education at Penn State

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ABSTRACT

During the fall semester of 2022 an experimental first-year seminar on applied optics was taught for the first time at The Pennsylvania State University. The ongoing goals of the course are to recruit students to electrical engineering and to retain them while steering students towards a specialization in optics and photonics. This was attempted through hands-on experiments demonstrating basic concepts in optics, and tours of laboratories on campus that demonstrate the wide range of applications of electrical and optical engineering. Experiments included aligning fiber optics, building telescopes, building pinhole cameras, experiments with fluorescence spectroscopy, transmission spectroscopy, and demonstrations of polarization. In addition to the first year seminar, the following semester a senior level experiment-based course on applied spectroscopy was offered as well. In addition to experiments, the senior level course includes peer instruction. While the audience for the two courses differ, the goals are much the same to recruit and retain students in optics and photonics. The effectiveness of course presentation in each case is evaluated based on student response and feedback. The two courses' materials will be compared and improvements will be discussed.

Keywords: education, student lab experience, hands on education

1. INTRODUCTION

At The Pennsylvania State University, hereto after referred to as Penn State, optics and photonics education could be more cohesive inter- and intra- department. Currently photonics educations is spread between many programs with little coordination between them. This results in many courses covering the same material, without consistent quality. To that end, two courses are in active development within the electrical engineering department to increase student involvement in the field. Both a first year seminar and senior level course are part of the program and dually utilize experiential learning and peer instruction to facilitate greater student involvement and retention. Both course are in active development during the semester. This arrangement allows modifications to be made during the class that better suit the educational goals of the students. In addition to better education the course is designed to help address the need for optics and photonics technicians across industry as addressed in *Wanted: Optics and Photonics Technicians*.[1]

2. METHODS

Both courses use a combination of the *Lab-Based Studio* and *Mini-Lecture Studio* classroom paradigms as defined by DeLyser and Thompson *et al.*[2] The lab-based studio paradigm is built around the presentation of a new topic, practicing and simulating the material, and the presentation of the result. The mini-lecture studio paradigm is based on short lectures with the majority and remainder of the class period devoted to active and cooperative learning. The goal in the application of these teaching paradigms is to inspire students to continue learning and improve student motivation. Student-subjects in the work reported greater motivation. In development of the labs there was not a conscious effort to use any particular pedagogical framework. That being said, ultimately a behavioralist framework was used with the instructor using a "facilitator" teaching style.[3]

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First Year Seminar Methods

All first year students at Penn State are required to take a first year seminar course. As stated by the Engineering Design and Innovation department at Penn State, first year seminars for students in engineering have the following objectives:[4]

1. To introduce them to university study
2. To introduce them to Penn State as an academic community, including fields of study and areas of interest available to students
3. To acquaint them with the learning tools and resources available at Penn State
4. To provide an opportunity for them to develop relationships with full-time faculty and other students in an academic area of interest to you
5. To introduce them to their responsibilities as part of the University community

The first year seminar in this study, aptly titled *Laser Laser!*, focuses on optics and photonics from a hands on standpoint. Laser Laser! is one of many first year seminars taught at Penn State, but the only one to the authors' knowledge specifically on optics. Students are given enough information to facilitate individual experimentation within the parameters of the class. This course builds on the work of Kane and Venkatesulu presented at ASEE First Year Engineering Experience 2019.[5] The following experiments and topics, in no particular order, were discussed:

1. Absorption Spectroscopy
2. Fiber Optics
3. Galilean and Keplerian Telescopes
4. Pin Hole Cameras
5. Polarization, Transmission, and Refraction
6. Wireless Optical Communication
7. Fluorescence

Figures 1 and 2 show first year students participating laboratories within the class. In class experiments included absorption spectroscopy, pinhole cameras, fluorescence spectroscopy, building telescopes, and investigating fiber optics. Students were evaluated on class participation and via a worksheet completed during class.

In addition to in-class experimentation students were led on tours of several locations on the Penn State campus including the Breazeale Nuclear Reactor, the Penn State Dairy Complex, Dr. Katia Lamer's, of Brookhaven National Lab, mobile aerosol lidar suite, and Dr. Venkat Gopalan's Ultrafast and Nonlinear Optical Characterization Lab at Penn State. Figure 3 shows students outside at the mobile lidar facility. Each tour facilitates students building familiarity with the campus, as well as introducing students to the scope of electrical engineering in the photonics field as well as giving opportunities to think outside the box.

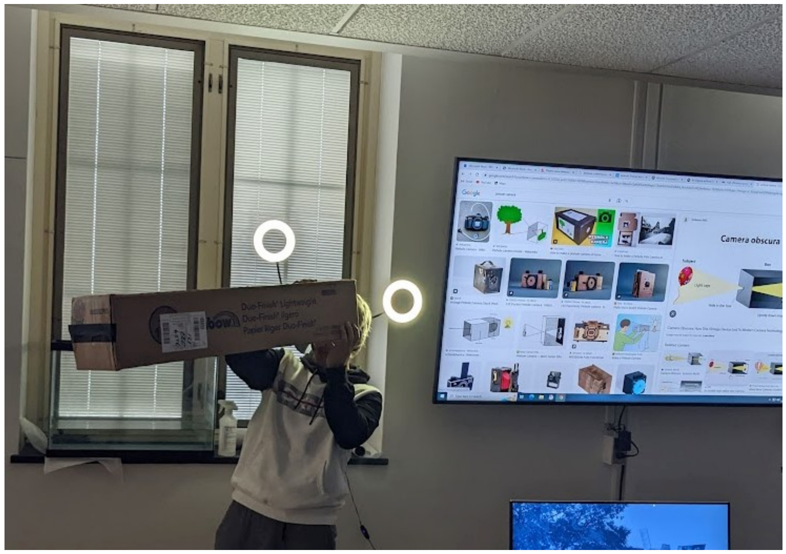

Figure 1. A student observes a ring light projected through a pinhole camera they made

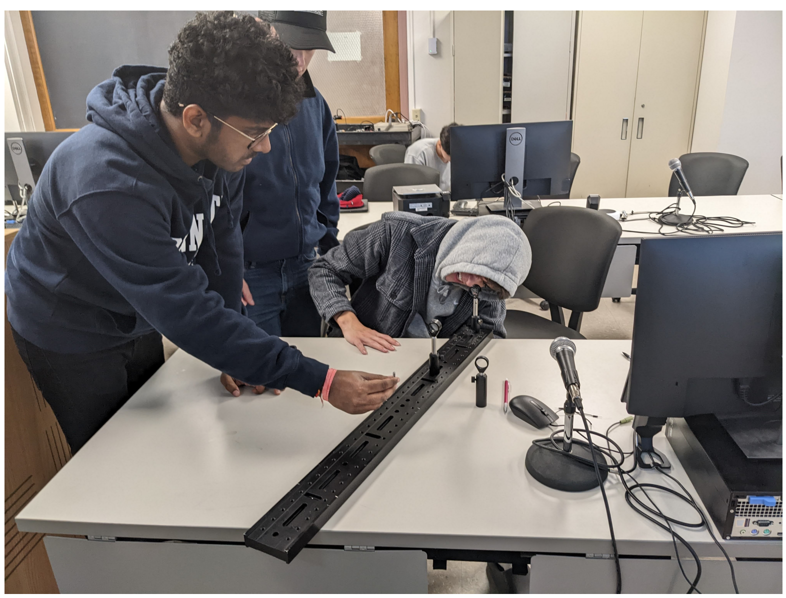

Figure 2. Students assemble a Galilean telescope on an optics rail

Figure 3. Students observe the operation of Dr. Katia Lamer's, Brookhaven National Laboratory, mobile lidar

Figure 4. Students aligning the optics of a spectrometer utilizing off-axis parabolic mirrors

Senior Level Methods

The newly developed senior level course *Applied Optics and Spectroscopy* utilizes the mini-lecture paradigm similar to the project based learning photonics course at the University of Pittsburgh by Clark *et al.*[6] A topic is presented to students during the first twenty minutes of class, and students then experiment with the topic and utilize it to make spectroscopic measurements. For many students this is their first experience in an optical engineering lab and serves as an introduction to the field on the whole. Figure 4 shows students aligning the optics of a spectrometer previously analyzed in the lecture portion of the class.

Topics discussed in the class include the following:

1. Geometric Optics
2. Light Matter Interactions
3. Lasers and Other Light Sources
4. Absorption and Transmission Spectroscopy
5. Fourier Transform Infrared Spectroscopy
6. Raman Spectroscopy
7. Atomic Emission Spectroscopy
8. Cavity Ringdown Spectroscopy

In addition to the experimental portion of the class, students give biweekly presentations on papers that they have read. This facilitates students participating and taking an active part in the education of their classmates. Lastly, guest lectures are delivered by other faculty and experts in the field. This helps establish the breadth of the field of spectroscopy. Figure 5 and figure 6 respectively show students presenting and listening to a guest lecture. Students in the senior level course are graded on their biweekly presentations, class participation, one midterm, a final project, and problem sets administered throughout the semester.

Results

Results and findings based on student response and engagement in both courses are discussed:

First Year Seminar Results

Student experience was gauged through the use of a focus group administered by a facilitator from the Leonhard Center for Enhancement of Engineering Education at Penn State. The report for the focus group stated that students found the tours of labs and hands-on experiences to be of significant value. After the course students were more enlightened on what a degree or career in electrical engineering can consist of, and how it is related to other fields such as chemistry. Consensus among students was that prior to the course they were unsure what "optics" meant as a field, but now feel well-informed about the field. The focus group included all students in the class, given its small size, and as such was representative of the demographics of this course. Unfortunately course demographics skewed strongly towards young white males, and as such this cannot be extrapolated to other more diverse programs within the university.

When asked for feedback on the course one student said:

> "[The instructor] provided engaging projects that helped introduce me to possibilities in the field of electrical engineering. One thing I really appreciated was the friendly and open environment [the instructor] curated in the class. I felt more than safe to be inquisitive and explore. They allowed conversations to flow which was not only informative but fun too."

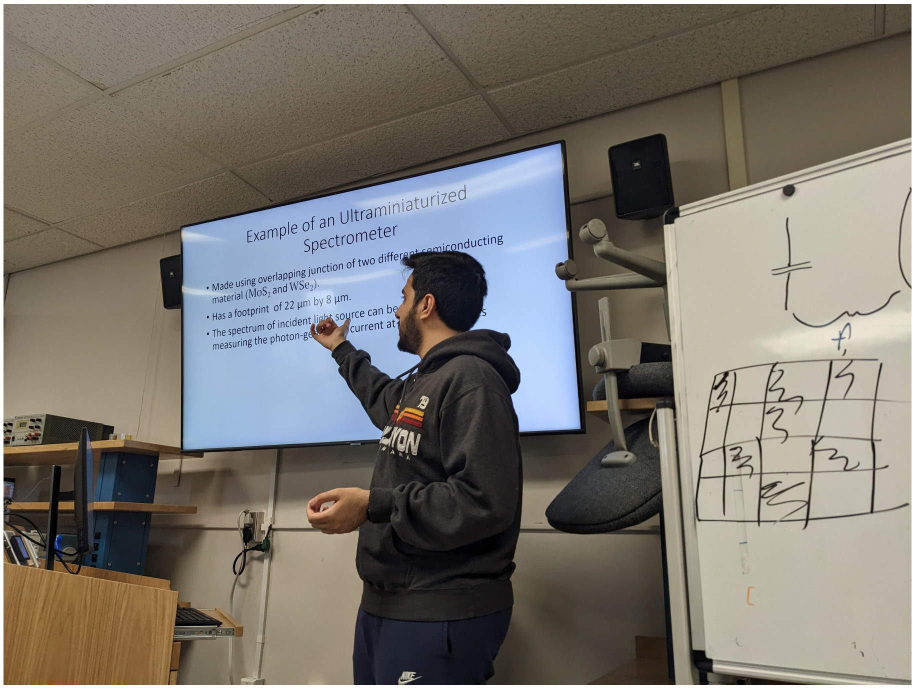

Figure 5. A student presents on the paper that they read the previous week

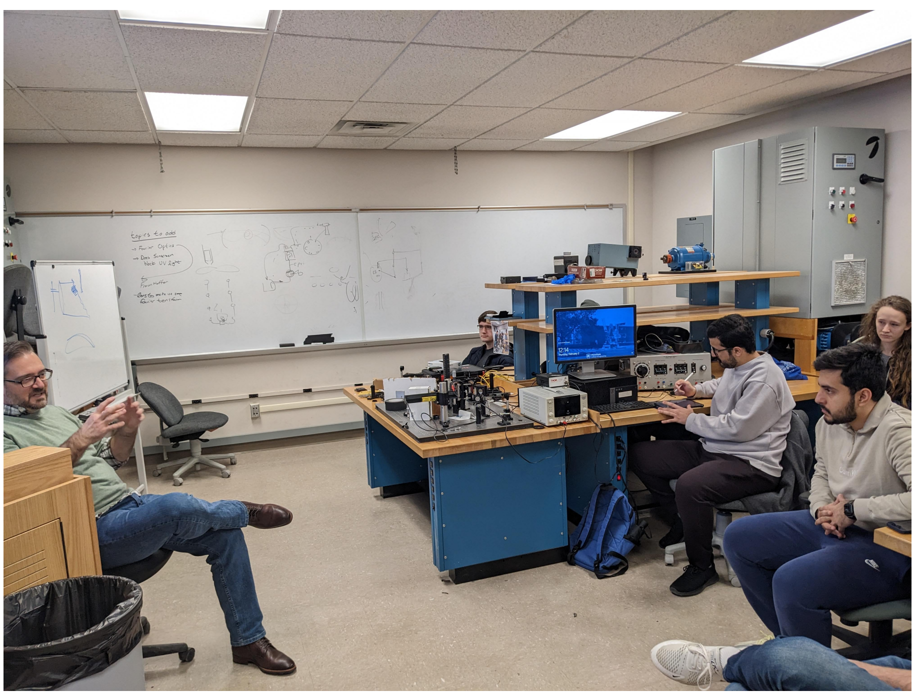

Figure 6. Students listen intently to a guest lecture given by a representative of the Penn State Electro Optics Center

Senior Level Results

The most notable result of *Applied Optics and Spectroscopy* is that students have gained a much more thorough understanding of the process for aligning optics. During the first day they needed to align a laser to a distant target; it took them approximately half an hour to ensure that the laser was parallel to the table. Approximately three weeks later they were able to align the optics for an absorption spectroscopy experiment, a more complex setup, within 10 minutes.

As students continued to present on papers they read they have gotten better at identifying what papers to present on as well as synthesizing the information into a format that their classmates can digest.

When asked for comments on the course one student had the following to say:

> "The student-led research reports expand the scope of the course dramatically. Virtually every student found a different niche for the applications of spectroscopy. Almost every class has some sort of hands-on activity where we could see the day's topic in action."

It is worth noting that when the semester began, the student quoted above chose to drop another course in favor of this one for the "unique educational opportunity" it provides. In addition to that, students have been observed instructing each other on topics and addressing questions on their own. Each class they develop a plan together to assemble the experiment of the day.

On the last day of the semester an anonymous survey was given to the class. This survey allowed students to voice their thoughts on the class's operation, their experience, and how material was presented. Questions were constructed using Likert scales, and whenever possible, phrase completion scales. As suggested in Hodge *et al* phrase completion scales can lead to higher quality data.[7] The majority of students found that the freedom provided by the class structure and,built on labs and lectures, allowed them to learn better. Students were asked to rate on a five point Likert scale how much they agreed with the following statement: "I feel confident that with access to references and equipment I could set up a spectroscopy experiment in the lab or at work". Three of eight students strongly agreed, four agreed, and two were neutral. Despite the small number of participants, this indicates that the root of the course is good, but still needs further refinement. Ideally, future students would all rate the prior statement with "strongly agree."

Discussion

Student feedback about both courses and their hands-on experimental nature has been positive. Given the positive feedback, more courses across educational levels will be developed using this model. The takeaway being that hands on experimentation is a compelling way to teach optics fundamentals. It is worth recognizing that the two courses were both limited in scope and number of student participants. Further studies on these classes is warranted. In the future, courses like this will be part of an optical engineering certificate program in development within the electrical engineering curriculum. The program in development offers an opportunity to build many courses utilizing the paradigms used in both the first year seminar and senior level course. Going forward, greater industry integration and feedback will also be included in the courses.

REFERENCES

[1] Wills, S., "Optics & Photonics News - Wanted: Optics and Photonics Technicians."

[2] DeLyser, R. R., Thompson, S. S., Edelstein, J., Lengsfeld, C., Rosa, A. J., Rullkoetter, P., Whitman, R., and Whitt, M., "Creating a Student Centered Learning Environment at the University of Denver," *Journal of Engineering Education* **92**, 269–273 (jul 2003).

[3] Bouchrika, I., "Pedagogy in Education: Guide To Frameworks & Teaching Methods — Research.com."

[4] "First-year Engagement — Penn State Engineering."

[5] Kane, T. and Venkatesulu, E., [*ASEE First Year Engineering Experience*], American Society of Engineering Education.

[6] Clark, R., Wang, M., Zaghloul, M., Sullivan, S., and Chen, K., "Project-Based Learning of Optics and Photonics: How to Teach a Stand-Alone Technical Elective "Niche" Course? American Society for Engineering Education," in [*2019 ASEE Annual Conference & Exposition*], (2019).

[7] Hodge, D. R. and Gillespie, D. F., "Phrase Completion Scales," *Encyclopedia of Social Measurement* (April 2017), 53–62 (2004).