Student Learning through Independent Projects in Introductory Optics

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Abstract: During a semester-long introductory optics course, each student is required to develop an experimental optics-related project from proposal to completion. We present outcomes on student learning from this multi-week, student-driven course component.

1. Introduction

1.1. Course Description

The Optics course, offered in the Physics Department at Spelman College, is laboratory-based and covers introductory optics. It is a required course for Physics majors and the first lab where only majors are enrolled. There are between 2 - 6 students enrolled in each offering, which meets once weekly. Course topics include reflection, refraction, diffraction, interference, and polarization of light. Students investigate some basic applications of geometric optics by building a simple refracting telescope and measuring optical fiber transmission. All students must develop an independent project related to some area of optics; which they propose, develop and carry out towards the end of the semester.

1.2. Independent Project Assignments

The independent project requires four assignments: proposal, revised proposal, oral presentation to the class, and a final summary paper. Although these experiments are not the focus of the lab meetings until the last 3 – 4 weeks, students are asked to begin planning early in the semester. A first draft of a proposal is typically due in week 4 of the semester, and students must have a list of needed supplies, in addition to the topic area and the question they plan to investigate. After receiving instructor feedback, students submit a revised proposal at mid-semester. They carry out their experiments during last 3 – 4 weeks, followed by presentations on the projects during the last lab session. After the presentation, students complete a summary paper on their work, having the option to incorporate any feedback from their peers or the instructor given during the presentations.

2. Examples of Past Projects

Table 1 gives the descriptions of past student projects. Many projects have looked at various materials and their refractive indices (n) as functions of other variables, such as temperature or solute concentration. In fall 2020, the College exclusively offered courses online due to the COVID-19 pandemic. These experimental projects were completed at the students' homes [1]. Figure 1 shows data from a student project on index of refraction of sugar solution as a function of concentration.

Table 1. Past project descriptions (*Fall 2020 semester online only)

Year	Project description
2020*	n of sugar in water as a function of sugar concentration
	Determining red and blue light intensity from electronic devices
	n of glass versus wavelength of laser light
	n of sugar water solution as a function of temperature
2018	Determining if n is proportional to density (using different liquids)

Sixteenth Conference on Education and Training in Optics and Photonics: ETOP 2021,
edited by A. Danner, A. Poulin-Girard, N. Wong, Proc. of SPIE Vol. 12297, 122972F
© 2022 SPIE · 0277-786X · doi: 10.1117/12.2635589

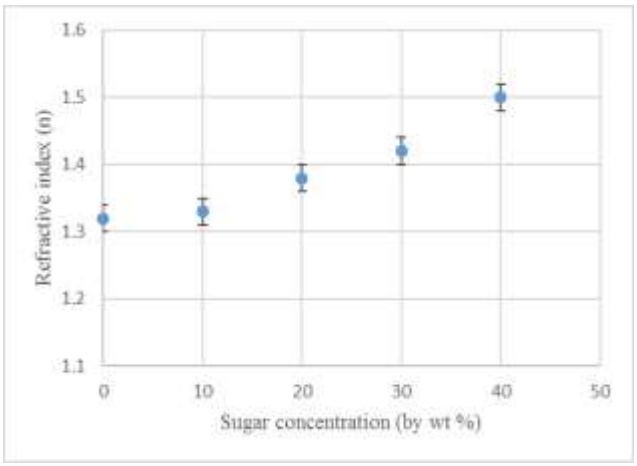

Fig. 1. Refractive index of sugar-water solution.

3. Outcomes

Students used what they learned during the semester and applied it to their independent projects. Although several recent projects used basic measurements of incident and refracted angles to study refraction in liquids or solids, this activity does reinforce the earlier content on refraction. One purpose of this course is to build student skills as they move from the introductory physics sequence to upper level physics courses. The initial proposal assignment forces students to think in advance about any safety procedures (ex. laser or chemical) that they will need to implement. The overall project helps with this bridging to the upper level by requiring each student to become actively involved in a project. An example of maturation as a physics major can be deduced from the errors bars on refractive index in Figure 1. The student included calculations and discussed the uncertainty values in the initial presentation. In introductory level labs, an instructor would have to prompt a student to discuss quantitative uncertainty.

In our introductory physics labs, students work in groups (usually 2 or 3). At times, groups divide certain tasks among themselves. Example tasks are setting up sensors properly, using software to collect data, circuit building, etc. Although each group may have experience with the different laboratory tasks, individual students may not have the experience needed to be proficient. In the Optics lab however, students often work individually. Though they may rely on each other for support when getting started, tips, and suggestions, they must accomplish all required tasks in order to complete their individual lab work successfully.

The activities in the independent project contribute to the maturation of a lab student and physics major, by reinforcing earlier content and developing scientific skills. This type of student directed project has characteristics that lead to "student ownership" [2], which are important for developing persistence in the sciences. Future offerings of this course will use a survey tool such as the Persistence in the Sciences (PITS) survey to determine any growth in students' project ownership and self-efficacy. These factors are important for the retention of women in science, technology, engineering, and mathematics (STEM) majors [3].

4. References

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