Project-Based Learning Case in Photonics Engineering Course: Implementation of a Spectrophotometer

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Abstract: A project-based teaching course for postgraduate students in the field of Photonics Engineering is based on the implementation of a Spectrophotometer. Hard and soft skills are evaluated in the implementation with an auto-evaluation criteria.

1. Introduction

The ability of students to formulate and deal with complex problems, both theoretically and practically, is a key point in the education of professionals in the field of sciences and engineering [1]–[3]. The usual way to give lessons is to split theory and practice. However, after this formative period, students will have to face complex multidisciplinary problems in their future career. They will have to apply all the set of competences and skills acquired during their training period, as well as their previous experience in the field of research, development or management [1]–[4]. To approach this kind of problems, new teaching techniques based on learning through the resolution of complex problems have been developed [4]. In this new paradigm, students must look for the practical solution of a specific problem, for which they must use their skills both in their theoretical knowledge and in finding technological solutions to the specific application they face. The fundamental idea of this paradigm is to endow the student with a certain autonomy when it comes to focusing on the solution of the problem, fostering both his/her technical/technological ability and critical thinking in the interpretation of the obtained results [5], [6].

When addressing a practical problem, different issues must be considered, mainly regarding the scope of the problem as well as the practical limitations that usually occur in the field of higher education. In the specific case of photonics, these constraints are usually associated with the high cost of the equipment and its availability, i.e. the temporary restrictions on access to such equipment and the closed nature of the photonics instrumentation, which reduces the improvement options and the number of tests that can be carried out by students [7].

In this work, a teaching proposal consisting of the realization of a photonics engineering project based on the design, manufacturing, control and data extraction of a low-cost spectrophotometer as an end-product is described. The aim of this problem is primarily, but not exclusively, to complete the abilities associated with the Interuniversity Master's program in Photonics Engineering in the subject of Experimental Projects I [8]. It is also an objective to reinforce and integrate the theoretical and practical knowledge acquired in the whole program of the Master.

The proposal is to design the layout and build the whole instrument from scratch, after receiving: information on the specifications to achieve, a series of 3-D PLA printed pieces, a photodiode and its conditioning circuit, a white LED on its printed circuit board, a linear stepper motor, its driving circuit, threads and an Arduino microcontroller (Fig. 1, Left). The teaching design is as dynamic as to be undertaken in pairs of students or individually. This has been demonstrated as very practical under supervening situations as the ones produced in the last season, where the Covid-19 pandemics joined to a snowstorm made very hard to get a fully in-the-lab season, and the students could complement their work at home.

The goal is that the students manage the hands-on problem to achieve a fully operative spectrophotometer with the materials that have been listed (Fig. 1, Right). Moreover, we take advantage of the facilities in the Universities where this Master is taught: the dispersive element is created using nanoimprint techniques into a class 10000 clean room, in a special session after which the students carry their own-manufactured diffraction grating. Once the first prototype is assembled, the students program a control system under LabView's Lynx © and upload it to their Arduinos UNO, connected to the motors driving and photodiode conditioning circuits and receiving a readout of the spectrometer while the grating is rotated. From then on, they must develop their critical thinking and apply scientific method to: calibrate the system in wavelength with their own tools (such as knowing the absorption spectrum of

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, 122970Y
 doi: 10.1117/12.2635535

some substances or filters), to improve the system to expand its specifications, or to explore its performance limits (Fig. 2). Finally, in a collective session taking place under a scientific Conference format, they show their product and defend its performance facing to questions and queries of the rest of mates and teachers.

Fig. 1. Left: all the stuff provided to the students. Right: schematics of a possible rehearsal.

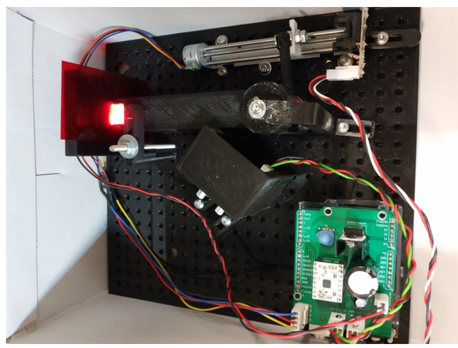

Fig. 2. A final spectrometer as developed by a student individually (Sahar Safarloo). A red filter is placed to measure its transmittance.

2. Acknowledgment

This research was funded by the EU structural funds (FEDER) and the Communidad de Madrid through the "Programa de Actividades de I + D" ("SINFOTON2-CM"—S2018/NMT-4326) and BG20/00136

3. References

[1] T. Scharf, "Optical engineering: Understanding optical system by experiments," in *ETOP 2017 Proceedings (2017), paper 104521F*, May 2017, p. 104521F. Accessed: Jun. 07, 2021. [Online]. Available: https://www.osapublishing.org/abstract.cfm?uri=ETOP-2017-104521F

[2] W. Johnstone, B. Culshaw, D. Walsh, D. G. Moodie, and I. S. Mauchline, "Student laboratory experiments on erbium-doped fiber amplifiers and lasers," in *Sixth International Conference on Education and Training in Optics and Photonics*, Jun. 2000, vol. 3831, pp. 259–267. doi: 10.1117/12.388733.

[3] A. P. Camacho, A. Janowski, A. Konak, and S. Kulturel-Konak, "Creative problem solving builds entrepreneurial mindset," in *2016 IEEE Integrated STEM Education Conference (ISEC)*, Mar. 2016, pp. 65–70. doi: 10.1109/ISECon.2016.7457556.

[4] N. Massa, M. Dischino, J. Donnelly, and F. Hanes, "Problem-based learning in photonics technology education: Assessing student learning," in *Education and Training in Optics and Photonics (2009), paper ETB4*, Jun. 2009, p. ETB4. doi: 10.1364/ETOP.2009.ETB4.

[5] A. F. Zhou, "Integrating Undergraduate Research into the Electro-Optics and Laser Engineering Technology Program at Indiana University of Pennsylvania," in *ETOP 2013 Proceedings (2013), paper EFB1*, Jul. 2013, p. EFB1. Accessed: Jun. 07, 2021. [Online]. Available: https://www.osapublishing.org/abstract.cfm?uri=ETOP-2013-EFB1

[6] J. Savery, "Overview of Problem-based Learning: Definitions and Distinctions," *Interdisciplinary Journal of Problem-Based Learning*, vol. 1, no. 1, May 2006, doi: 10.7771/1541-5015.1002.

[7] F. L. Naranjo, G. Martínez, Á. L. Pérez, and P. J. Pardo, "Design, development, testing and validation of a Photonics Virtual Laboratory for the study of LEDs," in *12th Education and Training in Optics and Photonics Conference*, Jul. 2014, vol. 9289, p. 92891T. doi: 10.1117/12.2070561.

[8] "Course Data." https://aplicaciones.uc3m.es/cpa/generaFicha?est=338&asig=17362&idioma=2 (accessed Jun. 07, 2021).