A research-based module on optical spectroscopy for freshmen in biotechnology

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Abstract. A research-based innovation started three years ago in physics course for biotechnology freshmen in Udine University (IT) in order to revise contents and methods. The focus is on topics promoting the building of a phenomenological-based didactics focused on the developed of methodological competencies. Optical spectroscopy has been chosen as a topic characterizing the professionalism of a biotechnologist, and an intervention module has been experimented in the a.y. 2017/18 with 60 students. Written pre and post test inspired by PER literature monitor student learning outcomes and innovative lab activities have been included.

1 Introduction and goals

Teaching introductory physics at university level in bio-technology degree is a challenge involving the need of revising contents, contexts in which topics are addressed, methods and educational activity, according to recent research literature [1]. Students should become able to apply physics concepts in the different contexts required by the specific professionalizing degree. It is necessary to improve methodological elements, interpretative instruments and technical competences characterizing the specific field of study, producing an active participation of students in learning physics.

In the last three years we have been experimenting several innovations in introductory physics courses for life-science area students in Udine University (IT) in which single design-based research [2] formative intervention modules on specific topics are integrated in the curricula.

One relevant topic for the professionalism of a biotechnologist is optical spectroscopy, but very often this topic is not included in introductory physics courses. It represents a context in which to address the role of energy in physical analysis, a validation instrument of interpretative models through indirect measures and a way to interpret a code in order to get information on the changes and the states of a physical system, offering an important disciplinary contribution on the epistemological and methodological plan of physics.

In the a.y. 2017/18 an intervention module on optical spectroscopy has been experimented with freshmen in biotechnology with design-based research methodologies. The characteristics of the intervention module on optical spectroscopy are here described .

2 The module on optical spectroscopy

In the a.y. 2015/16 an intervention module on optical spectroscopy has been introduced for 60 freshmen in biotechnology at Udine University, as the first stage of the design-based research we are carrying out. In the academic year 2017/18, introductory physics for biotechnology was a 4-CTS course (out of a total of 180 CTS during 3 years) offered during the first semester of the first year. 26 hours out of a total of 52 were devoted to lab activities, 20 hours were devoted to frontal lessons and 6 hours were devoted to tutoring and exercises. The module on optical spectroscopy covered 10+2 hours (5 hours pre-test + lecturing part, 4 hours laboratory, 1 hour problem solving activity, 2 hours final exam). The sample consisted of 60 freshmen, selected at the beginning of the academic year by means of a selection test with the same criteria at national level out of 200 applicants.

Research questions are:

1. How does lab activity contribute in students awareness of the emission process?
2. How do students relate spectral lines and atomic energy levels and vice-versa?
3. How to build a module on optical spectroscopy for biotechnology freshmen taking into account their needs?

The lecturing part of the module of optical spectroscopy is part of the one of optics: light sources, propagation of light and light/matter interactions have been addressed. Diffraction is explored from a phenomenological point of view, deriving the laws governing the phenomenon. Diffraction grating dispersion principle is then addressed and spectra emerge as identity card of elements. The phenomenological laws of Kirchhoff, Wien and Stefan-Boltzmann introduce the Planck interpretation of emission. No role is attributed to the Bohr atomic model, in favor of a more general energy level model by means of the idea of photon introduced as interpretation of the photoelectric effect. The interpretative role of energy levels assume relevance in examples on how to bridge between spectra and energy levels through an analysis of the Balmer and Rydberg's empirical formulae.

4 hours were devoted to the laboratory activity, carried out in 3-students group sessions, based on the analysis of a single-slit diffraction pattern with a light sensor connected to the PC, the analysis of LED and gas-discharge lamps spectra and the analysis of absorption spectra using a digital spectroscope.

The same pre and post test have been submitted to students before the intervention module and after it, concurrently with their final exam. The tests consisted in 7 open-ended questions addressing the main learning knots emerged in the literature [3, 4], as for example the ability to sketch an energy level diagram knowing the energy values and the ability to predict the expected discrete spectrum. Qualitative research criteria is used to analyze collected data.

3 Conclusion

Lab activities on optical diffraction are essential in order to understand diffraction grating's role in the detection of optical spectra. The explicit request of paying attention to grating and slit's roles, that previous works showed to be critical concerning lines' shape, turned out to be sufficient to gain more awareness (RQ1).

Several alternative models accounting for the formation of spectral lines are initially present, and the module allows to obtain a correct interpretation of optical spectra (RQ2).

After 3 years of experimentations students' needs in order to have a coherent frame which contents are integrated in an introductory physics course emerged. The importance of theoretical, experimental and problem solving activities turned out to be essential. Two approaches (through a wave model or through a photon model for light) ending with an analysis of Balmer and Rydberg's works from an historical point of view are possible, allowing the analysis of important methodological elements in the foundation of students' physical knowledge (RQ3).

References

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