Research perspectives on teaching and learning about spectra in high schools

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Abstract. Spectra of mechanical and electromagnetic waves are increasingly gaining attention in the physics education community due to their role in classical and modern physics. In the symposium, different perspectives about the teaching and learning of spectra will be discussed.

1 Introduction and aims

Spectra of mechanical and electromagnetic waves have often been proposed as a relevant topic in introductory physics since they are an emblematic example of how physics makes use of indirect measurements to obtain information on otherwise inaccessible systems [1]. Moreover, spectra played a relevant role in the transition between classical to modern physics [2]. However, research has shown that students' understanding of this topic is often limited [3-4]. Therefore, how to improve the teaching of and to assess students' learning about spectra are important goals for research in physics education. The aim of the symposium is to address the above issues by exploring the following key aspects of teaching and learning about spectra in high schools: 1) design of teaching/learning sequences (TLSs) about the role of spectra and spectral analysis in classical and modern physics; 2) design of innovative experiments to teach about spectra; 3) design of suitable tools to assess students' understanding of spectra. Each of the four papers in the symposium takes a different perspective to address the aforementioned issues, providing meaningful insights for research in the field. In the following, we briefly resume the papers that will contribute to the symposium according to the chosen key aspects.

2 Overview of the papers in the symposium

2.1 Design of TLSs about spectra

The first two papers address issues in the design of TLSs about spectra. Paper *1* (*A problem-based teaching and learning sequence aiming at interpreting spectra in quantum physics introductory courses*) describes the implementation of a TLS that aims at building a quantum model of emission and absorption of radiation that allows high school students to explain the frequencies and intensities of the spectral lines in emission and absorption spectra. Using a pre-post, control-treatment research design, the authors show that the TLS activities had a statistically significant impact on students' understanding and interpreting atomic spectra. Paper *2 (Research-Based Proposals on Optical Spectroscopy and Secondary Students' Learning Outcomes)* describes the design of an educational path on optical spectroscopy using the Model of Educational Reconstruction. The proposed activities aim to help students understand the relationships between the energy-levels model of atoms and observed light emission with simple, low-cost spectroscopes. In such a way, they can build a bridge between classical and modern physics. Using a design-based research approach, the authors refined the educational path in six different implementations.

2.2 Design of experimental activities about spectra

The third paper (*Colours in your pocket: smartphone-based spectrometers to investigate the quantum world*) concerns issues in the design of innovtive experiments about spectra. The paper describes the use of two low-cost spectrometers to study light transmission with two different aims: (i) to investigate the additive and subtractive models of colour formation; (ii) to study the selective absorption of a material and explain it from a microscopic point of view. The spectrometers allow to perform wavelength and light intensity measurements with a good accuracy. A qualitative examination of spectra emitted by different light sources helps students understand the different physical mechanisms underlying production of light. A quantitative analysis of the spectra allows students to measure: (i) the typical features of the blackbody emission; (ii) the spectral lines due to de-excitation of gaseous atoms (*Hg, H*), which allows to estimate the Rydberg constant (iii) fluorescent emission (typical wavelengths and lifetimes). Spectroscopy measurements have been also employed to evaluate the Planck constant *h* by measuring the wavelength of the light emitted by LEDs of different colours and the corresponding threshold voltage. The topic addressed in Paper 3 will be discussed in two separate presentations at the symposium.

2.3 Design of assessment tools about spectra

The fourth and final paper *(Developing and validating a conceptual survey to assess students understanding of mechanical and electromagnetic waves spectra)* deals with the issue of measuring students' understanding about spectra. The authors discuss the development and validation of an open questionnaire. First, a pilot version was developed, building on available literature [5]. Then, it was revised according to students' responses collected during a trial phase. Preliminary data shows that the revised questionnaire can be a useful tool to identify students' difficulties when dealing with spectra.

3 Implications

Together, the four papers show that, despite unavoidable differences, a reliable body of knowledge and an effective set of educational resources to improve the teaching and learning of spectra at high school level is being developed. Further implications will be discussed at the conference.

References

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