Motivational and didactic efficacy of an interdisciplinary learning path on IR Reflectography and False Colour imaging of artworks

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Abstract. We present an interdisciplinary didactic module at the high-school level about Infrared Reflectography and Infrared False Colour imaging of artworks jointly conducted by physicists with an art historian expert in heritage science. The teaching sequence includes use of do-it-yourself materials as well as professional instrumentation. It is shown that this interdisciplinary and practical didactic path succeeds in fostering students’ (particularly female students') attitude towards learning physics and represents an effective way for introducing advanced topics in the field of radiation-matter interaction, while opening the way to untying some important conceptual knots related to colour image formation.

Introduction

We describe and discuss the efficacy of a module focused on the Near Infrared (NIR) range and on the application of NIR optical techniques to non-invasive diagnostics of paintings. Knowledge of human eye colour vision, colour additive synthesis and RGB-colour decomposition are prerequisites for this didactic path. The teaching sequence was jointly conducted by physicists together with an art historian expert in heritage science and is centred on Infrared Reflectography (IRR) and Infrared False Colour (IRFC) imaging, two widespread investigation techniques that allow identifying the original underlying drawings (i.e., IRR) and differentiating the artist's palette (i.e., IRFC) [1]. The proposed practical activities include the preparation of multilayer painting mock-ups with low-cost materials, the modification of webcams into NIR cameras (CCD sensor) [2] and the use of a digital image manipulation software. Their efficacy was investigated through students' final reports and worksheets. The complete teaching sequence including both IRR and IRFC was proposed to two groups of students, while two other groups followed the IRR-module alone. One group of students also explored the use of a professional scanning camera (InGaAs sensor) for IRR. All the students (a total of 49 between 17 and 18 years old), together with their physics and art schoolteachers, came from the fourth and fifth year of different high schools with either scientific or humanistic curricula. In any case, students were let free to choose whether to take part to the formative module on a volunteer basis. The percentage of female students who participated to the course was indeed very high (32/49).

The didactic path

The learning path consists of interactive guided lectures about IRR and IRFC as related to the layer structure of paintings, followed by the corresponding experimental activities. The properties of NIR radiation and of its interaction with the painting layers are addressed pointing out the high NIR transparency and low reflectivity of the pigments of the visible pictorial layers in contrast to the high NIR reflectivity of the chalk-based preparatory ground and the high NIR absorbance of the carbon-based drawings. It is explained that the IRFC set-up requires an additional imaging device sensitive to the visible range together with the use of an imaging manipulation software that allows associating the infrared image to the red channel while the red and green images are associated respectively to the green and blue channels and the blue image is discarded. Comparison of the RGB image with the IRFC one allows identifying different materials of the same colour that have different responses in the NIR range. The core of the practical activities is the construction of a do-it-yourself (DIY) NIR camera. "Artworks" to be analysed are also prepared by the students themselves as multi-layer targets made with low-cost materials. Using their DIY webcams students collect NIR images of their artworks and obtain IRFC images using open access software on their computer. With one group of 18 students we were also able to propose the use of the professional NIR-camera "Apollo" (by Opus Instruments).

Results and discussion

Learning outcomes were investigated through worksheets that included questions about IRR and IRFC (answered by 11 students) and a total of 36 final reports. Since students were left free to choose the formative module, the high percentage of female students (2/3) who took part to the learning path is a strong indication that an interdisciplinary approach based on the connection between Physics and Art can arise the interest of female students in physics and can, more generally, be a possible route to face gender issues. Analysis of worksheets and reports shows that optics applied to cultural heritage indeed represents an effective and strongly motivating approach to optical physics. Students recognized that DIY materials helped them in understanding physical principles but considered particularly exciting exploring the use of professional instrumentation. Aims and advantages of infrared imaging techniques applied to the diagnostics of paintings are well understood, while the activities about false colour imaging highlight the need and offer the opportunity for untying some conceptual knots related to *associating colours to an image*: each one of the three groups of receptors (the cones) present in the eye retina is sensitive to “the light intensity in a specific range of frequencies present in the light beam” and not to “*a colour* present in the light beam”, giving rise to "bidimensional patterns of light intensity specific for each group of receptors"; these, in turn, are separately perceived as red, green and blue images by the brain that creates the one-to-one *association* of each range-of-frequency to the three primary colours, giving rise to the final overlapped colour image. Only a deep comprehension of these critical points allows understanding that in the IRFC technique the bidimensional pattern of light intensity in the NIR range acquired by the infrared camera is an additional intensity pattern (a fourth "grey-scale" image) that can be mapped into the red-channel for the final visualization.

References

[1] J. K. Delaney, M. Thoury, J. G. Zeibel, et al. Visible and infrared imaging spectroscopy of paintings and improved reflectography, *Heritage Science* **4**(6) (2016).
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