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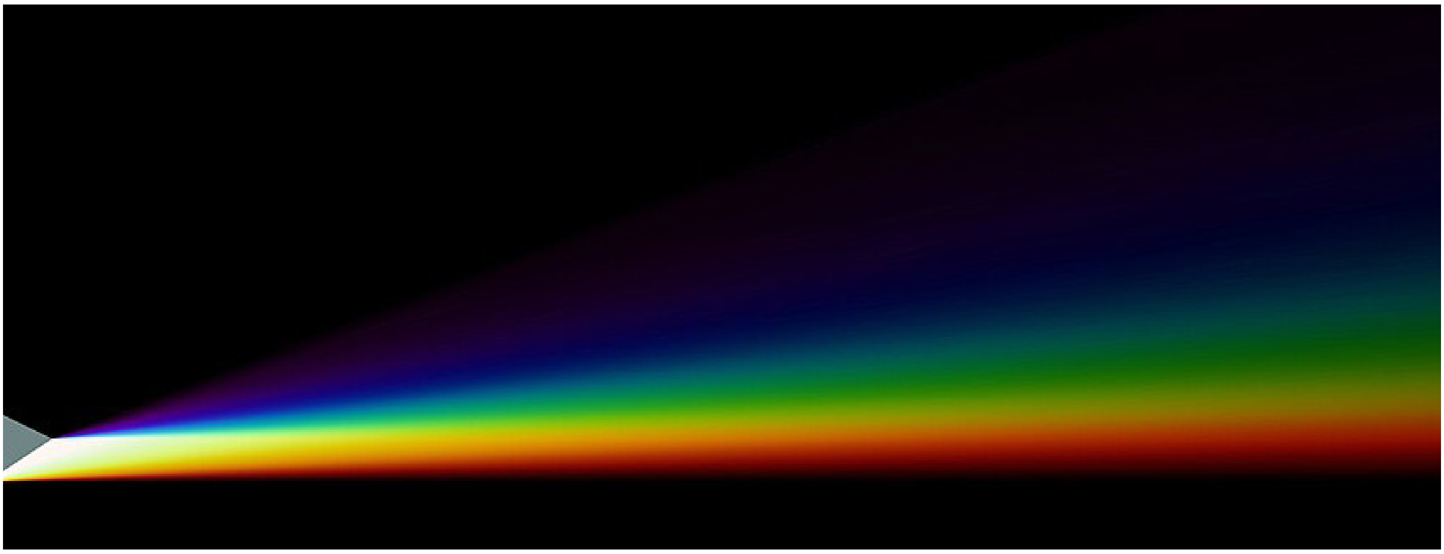

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# Shedding light on a Picasso

**Kelly Giannakoudaki and George Chatzisavvas**

Explore how researchers investigate artworks without damaging them and reveal hidden information in paintings by using different wavelengths of light!

In 2014, scientists and art conservators from the Phillips Collection, the National Gallery of Art, Cornell University, and the Winterthur Museum discovered the form of a man under the main painting of a Picasso artwork by using infrared (IR) technology. More specifically, a bearded man wearing a bow tie and supporting his head with his hand appeared beneath the famous Picasso painting The Blue Room.[1] However, this is not the first time that a hidden image has been revealed beneath a painter's artwork.[2]

Technology and modern imaging techniques are constantly revealing new elements and hidden details of artworks, and thus, the way we perceive art is constantly changing. The main idea behind the use of the technique multispectral imaging (MSI) is as follows: the degree that radiation penetrates into the artwork depends on the wavelength of radiation. So, you can study different layers of an artwork by simply using different wavelengths of light.

### Three main concepts underpin this technique.

The first is that light penetrates into the materials of the artwork to different degrees, depending on its wavelength (figure 1). The top layer (light blue) corresponds to the varnish, the next layer (green) corresponds to the colours of the artwork, the third layer (grey) corresponds to the draft, and the final layers are the canvas (white) and the wooden support (brown). Light (arrows) of different wavelengths reaches different depths into these layers: ultraviolet (UV) rays only up to the varnish, visible-light rays down to the main pigment, and IR rays down to the draft.

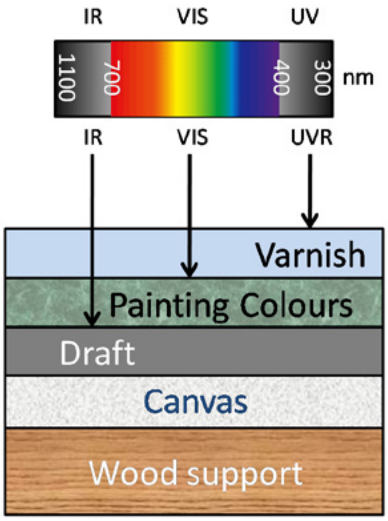



Figure 1: A diagram showing the layers of a painting and the penetration depths of different types of radiation.
*Image courtesy of the authors*

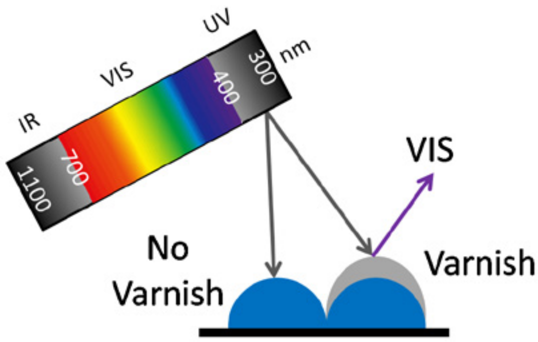



Figure 3. A schematic representation of the fluorescence phenomenon. When UV light (grey arrow) hits the paint (blue bump), nothing happens, but when it hits a layer of varnish (grey bump), it is absorbed and visible-light fluorescence (purple arrow) is emitted.
*Image courtesy of the authors*

The second is the function of filters (figure 2). Filters only let certain colours or wavelengths of light pass through while blocking others. For example, a blue filter (left part) allows blue light to pass through but absorbs or reflects other colours like red and green. As a result, we can see only the blue paint colours because they are reflected. The other paint colours absorb the light, so we see black spots in those areas.

The third is fluorescence (figure 3). Some varnishes contain special molecules that absorb invisible UV light and then almost instantly (a few nanoseconds) release part of that energy as visible light. This is called fluorescence, and it makes the varnish glow in the dark when it is exposed to UV light.

By exploring different imaging techniques, students understand the interaction of light with matter, get familiar with applications of basic principles of physics in practice, and finally realize the interdisciplinary nature of scientific knowledge. This STEAM project aims to combine students' love for both art and science, and it is suitable for students aged 14–18.

## Activity 1: Multispectral imaging using UV radiation

This activity is related to UV fluorescence imaging, and takes advantage of the fact that varnishes used on paintings often

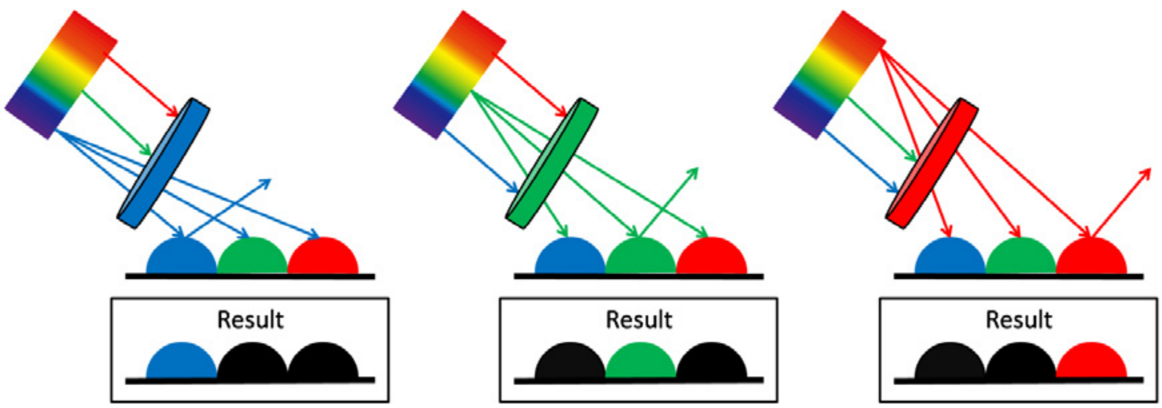


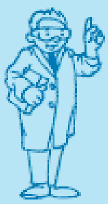

Figure 2: A schematic representation of how filters function
*Image courtesy of the authors*

fluoresce under UV light. Therefore, with this particular technique, it is possible to examine and diagnose the state of conservation of the painted surface of an artwork.[3]

Time required: 40 minutes.

## Materials

- 1 piece of watercolour paper
- Watercolours (or any water-based paint)
- Acrylic varnish
- UV lamp/torch light
- Student worksheet



### Safety note

Caution is needed when using UV light. In addition to ensuring that students do not look directly into the light source, please check for any local guidance or requirements.

## Procedure

1. Start with engagement task 1, as described in the worksheet, by asking students to make their own hypotheses about how scientists managed to 'see' under the main painting.
2. Continue with task 2 and ask students to categorize radiation into visible or invisible to the human eye.
3. Go to task 3 and discuss with students what type of radiation they would use to study the varnish of an artwork.
4. Ask students to paint a picture using the paper and watercolours.
5. Cover part of the picture with the varnish.
6. Let the varnish dry for several minutes.
7. Illuminate the drawing with the UV lamp/torch and observe the fluorescence.
8. Ask students to alter their paintings by drawing over a small area of the varnish. Encourage them to work out how they could check if an original painting had been altered. Check their solutions on their paintings.

## Results and discussion

In figure 4, one cloud is covered with varnish, while the other is not. If the painting is illuminated with normal lighting, then we see it as it is shown on the left. If painting is illuminated with a UV lamp, then areas that are covered with varnish appear brighter.


Figure 4: The left cloud is covered with varnish, while the right one is not. The left image shows the painting under visible light. When the painting is illuminated with UV light (right), the varnish absorbs the UV light and releases part of the energy as visible light, making it appear brighter, while the right one is barely visible.
*Image courtesy of the authors*

This happens due to the property of certain pigments of fluorescing in the visible region of the spectrum after excitation with UV radiation with a wavelength between 300 nm and 400 nm.

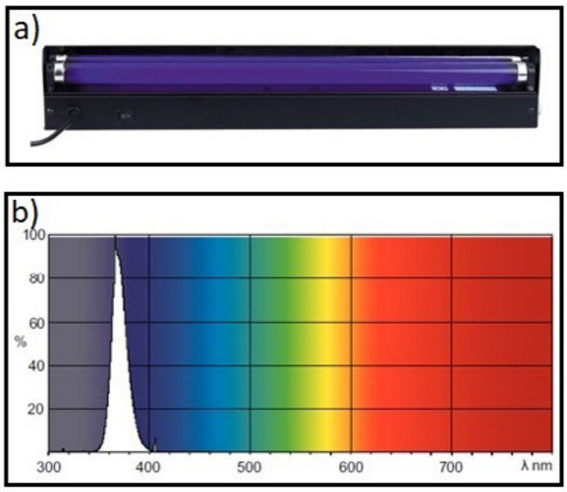



Figure 5: An example of a UV lamp (a) with its electromagnetic spectrum (b)
*Image courtesy of the authors*

Varnishes, used on the surface of artworks, whether older or more modern, show this fluorescent property, in contrast to any later interventions or surface damage, which appear as dark spots without any fluorescent property.

# Activity 2: Multispectral imaging using visible radiation

Imaging using radiation in the visible region of the spectrum can give us information about the artist's work itself, since visible radiation penetrates the varnish and reaches a level below it. The use of different filters can allow the selective passage of light. Images of the painting are captured by a typical camera and can be converted into black and white (greyscale) for easy identification of areas that absorb radiation (black areas) and areas that reflect radiation (white areas), as shown in figure 6.

This activity can be implemented in two ways, depending on the age level of the students. In the first case, the filters are held in front of the camera. In the second case, a rotating platform is constructed and controlled by an Arduino microcontroller.

Time required: 40 minutes.

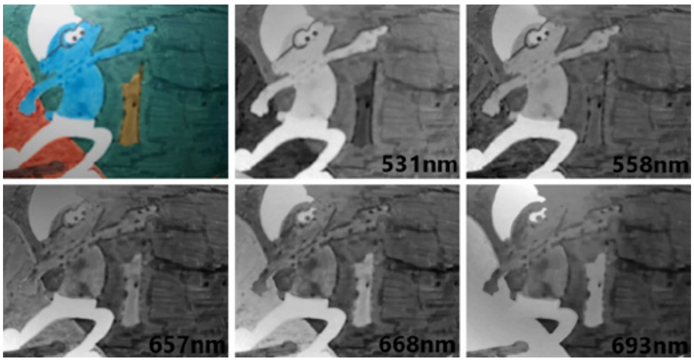


Figure 6: Different representations of the same painting according to wavelength
*Image courtesy of the authors*

## Materials

- 1 piece of paper
- Markers/watercolours (any type)
- 1 set of optical filters (e.g., a blue, a green, a yellow, an orange, and a red one)
- A camera that can be connected directly to a PC or an internet protocol (IP) camera that can be connected to a smartphone or to a PC via an IP network
- Smartphone (or router and PC)
- Student worksheet


Figure 7: Various filters
*Image courtesy of the authors*

## Procedure

1. Go to task 4 of the worksheet and experiment with students using visible radiation.
2. Connect a typical IP camera to the smartphone, following the camera manufacturer's directions, to see what the camera captures. Alternatively, the camera can be connected to a laptop/PC through a router. The drawing is placed in front of the camera, while various filters are inserted between the camera and the painting; these filters allow the selective passage of light through the camera lens.
3. Activate greyscale on the smartphone[4] to easily identify the areas that absorb radiation (black areas) and the areas that reflect radiation (white areas).
4. Ask students to draw a picture with various colours.
5. Place the picture in front of the camera.
6. Hold one filter in front of the camera and ask students why some areas of the painting have black areas and others white areas.
7. Place all the filters one by one and observe how the brightness of a certain area (e.g., the blue colour of the Smurf) changes.

## Extension activities

A nice extension activity is to build a rotation platform and program it to cycle through the filters. Rotation could be achieved with a servo motor that is controlled by an Arduino microcontroller.[5] Also, PC software could be used to send commands to the Arduino controller to rotate the platform for specific angles. The Arduino sketch and the software that we made (source code and executable) can be found in the supporting material, along with full instructions for the construction of the rotating platform.

Older students can also get the intensity normalization of the captured images, and they can also construct a graph of intensity of the pixels of a specific area of the drawing versus the wavelength. This way, we get the 'fingerprints' of our pigments! Full instructions are given in the supporting material.

## Results and discussion

This activity enables students to observe that, as we change the filter, different areas of the image appear brighter. For example, if we have a blue filter ($\lambda_{mean}$ = 531 nm), the blue areas of the project appear brighter, while the red areas appear darker. Conversely, for the red filter ($\lambda_{mean}$ = 693 nm), the roof of the house appears bright, while the blue areas appear dark. This is very useful from a teaching point of view for students, as they can understand the reflection and absorption of radiation, but also the fact that colour is not an objective property of matter.

In the art world, the study of different colours through the use of different optical filters enables art conservators to study the pigments the painter has used and check the authenticity of a painting.

## Activity 3: Multispectral imaging using infrared radiation

Imaging using IR radiation uses the near-IR region (750 nm to 2500 nm). The radiation penetrates the first layer, which is usually the varnish, but can be the entire colour layer, and thus, reaches the artist's draft (figure 8).[6] Graphite, mainly used in an artist's draft, strongly absorbs IR radiation.

Time required: 40 minutes.

### Materials

- 1 piece of paper
- 1 pencil
- Markers/watercolours
- A camera that can be connected directly to a PC or an IP camera that can be connected to a smartphone or to a PC via an IP network. This camera must have a night-mode option
- Smartphone (or router and PC)
- Student worksheet

### Procedure

1. Ask students to draw a sketch with a pencil.
2. Ask students to cover the sketch with markers or other paint, such as watercolours or oil paint. Avoid using the colour black.
3. Place the painting in front of the camera and set the camera to night mode (either by turning off the lights or by covering the light sensor of the camera).
4. Go to task 5 of the worksheet and ask students to answer the initial question: how did they manage to see under Picasso's main painting?
5. For more fun, you can divide students into groups and ask each group to make their own drawing. Then, have the students guess what is under the others' paintings.

### Results and discussion

This noninvasive technique is often used by art conservators to discover hidden details or hidden images beneath a painter's artwork. And this is exactly the case with many of Picasso's paintings. In earlier times, many artists, mainly for economic reasons, painted on already-painted canvases, with the result that today we discover many hidden paintings under the main artwork. So, this constant revealing of hidden details in artworks is very important, as it changes the way we perceive art.

## Conclusion

The specific experimental process is an opportunity for secondary school students to connect theoretical concepts found in school textbooks, such as the electromagnetic spectrum, photons, wavelength, and reflection, with the observation of suitable optical phenomena, which often exceed the limits of our own senses. Research at an international level shows that phenomena related to light and its properties are very difficult for students of all age levels;[7–9] this is also confirmed by our own daily experience in the classroom. The aim of this project is, on one hand, to help students face

Figure 8: Artwork in the visible spectrum (left) and the same painting illuminated with IR radiation (right).
*Image courtesy of the authors*

their personal preconceptions about visible light and its properties, especially with respect to light transmission, and to remove any misconceptions regarding invisible radiation, such as the origin of UV and IR radiation or the dangers and usefulness of each radiation. On the other hand, this project could be an alternative teaching proposal for teachers themselves. In the activities, materials found in school laboratories and free software have been used, while the cost of any additional component is low.

Finally, the project cultivates the students' STEM skills because, during the implementation and execution of the activities, the students are confronted with various challenges at a mathematical, technological, and engineering level. At the same time, however, this specific project also encompasses the students' love for the arts and the creation of their own 'works of art', because an interdisciplinary approach is followed to achieve the final goal. «

## Cutting-edge science: related EIROforum research

### CERN

Did you know that physics can help uncover hidden paintings? At CERN, scientists use special technology to look beneath layers of paint without damaging the artwork. A small particle accelerator called MACHINA can scan paintings and artefacts to reveal hidden. Along the same lines, CERN's Timepix particle detectors helped prove that a lost painting was actually made by the great Renaissance master, Raphael.

Just like in "Shedding Light on a Picasso", where students explore how light interacts with art, CERN's technology helps experts study paintings in new ways. Science isn't just for labs—it can also save history!

**www.cern.ch**

## References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[5] Instructions for the construction of the rotating platform: https://sites.google.com/view/scienceonstage2024/rotating-platform-construction-guide

[6] Fontana R et al. (2018) Multispectral IR reflectography for painting analysis. In Bastidas D, Cano E (eds) *Advanced Characterization Techniques, Diagnostic Tools and Evaluation Methods* pp 33–47. Springer. ISBN: 9783319753157

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[9] Karrqvist C, Andersson B (1983) How Swedish pupils, age 12–15, understand light and its properties. In Helm H, Novak JD (eds) *Proceedings of the International Seminar: Misconceptions in Science and Mathematics* pp 380–392. Cornell University, Ithaca.


## Resources

- Access a digital repository with the necessary theoretical background, worksheets, photos, etc.
- Watch a video demonstrating this project.
- Discover how new ILL research can help prevent the destruction of precious artwork during restoration.
- Read about how some studies have helped to reveal a hidden portrait by Rembrandt.

- Try some simple experiments to illustrate temporal additive colour mixing: Anta A, Goiri E (2024) Colour magic: additive mixing and coloured shadows. *Science in School* **70**.
- Explore the science behind anamorphosis: Liang Y (2024) Exploring anamorphosis: revealing hidden images with mirrors. *Science in School* **68**.
- Explore how colours arise through reflection, absorption, and transmission: Félix RC, Paleček D, Correia TM (2024) Colour science with lasers, gummy bears, and rainbows. *Science in School* **66**.
- Explore structure–function relationships with this photomicroscopy art project: Varga JP (2023) It's a small world: using microscopy to link science, technology, and art. *Science in School* **61**.
- Build a simple stroboscope and create beautiful optical illusions with water: Chatzisavvas G, Giannakoudaki K (2022) 'Defying' gravity with a simple stroboscope. *Science in School* **60.**
- Read about the colour blue in nature and the chemistry behind it: Bettucci O (2022) Colour in nature: true blue. *Science in School* **60**.
- Learn how to distinguish between real and fake astronomical images: Muñoz Mateos JC (2024) CSI Astronomy: learn how to spot fake astrophotography images. *Science in School* **69**.
- Read about the colour pink in nature and the chemistry behind it: Bettucci O (2022) Colour in nature: think pink. *Science in School* **57**.
- Discover how X-ray techniques have revealed chemical changes in the pigments of van Gogh's paintings: Brown A (2011) Van Gogh's darkening legacy. *Science in School* **19**: 19–25.

## AUTHOR BIOGRAPHY

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Together, they participated in the 2022 Science on Stage – Europe festival in Prague, Czech Republic, where they received an award within the theme 'Technologies in STEM education' for their project 'Defying gravity!', and in the 2024 Science on Stage – Europe festival in Turku, Finland.

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