Activity 5. Reflection of Pepper's Ghost

Learning Intentions
To understand reflection, the angles of incidence and reflection and how these concepts are applied in the real world.
Learning outcomes include:

- Light travels in straight lines
- How light reflecting off object to our eyes allows us to see
- Different materials will reflect or absorb light differently
- Angle of incidence (i) = Angle of reflection (r).

Before the activity:
The simple physics of reflection is used to create virtual and ghostly images that have depth and appear from nowhere. It is the same principle used to create ghosts in haunted houses and was thought to be first described in the mid-16th century by Neapolitan scientist Giambattista della Porta. It became known as Pepper's Ghost in the 1860s after John Henry Pepper employed it in the theatre to cast his ghostly characters on stage. It is still used for this purpose today and for bringing back from the grave famous performers such as Michael Jackson.

See also https://youtu.be/1pjZ98p9k3c

Your hypothesis
Students should start with the premise that the angle of incidence is equal to the angle of reflection. Get students to consider how angles of reflection and incidence can create a virtual image. What is the role of the inverted pyramid in enabling the illusion of the floating images?

Materials

- Plastic sheet of reasonable rigour. For the two versions I made, I used lids from plastic takeaway containers for one and clear CD covers for the other. The latter is hard to cut, but works well.
- Paper (or graph paper if you have it)
- Stanley knife or scissors
- Ruler
- Marker pen
- Sticky tape
- Mobile phone or tablet to access the holographic images (even though this is not really a hologram).

Teacher Notes	Teaching Notes: Running the activity
What is happening? Light travels in straight lines at least until it hits some form of matter such as dust particles, objects, or other mediums such as water. When it hits the matter, light will reflect (bounce off), be absorbed or, if it passes through a transparent medium, refract – see teachers' resource, *Reflection, absorption, Refraction, Diffraction – the basics*. In this instance we only need to consider reflection.	**Method** On the paper or graph paper, use your ruler and marker pen to draw the trapezoid shape of the following dimensions: 1cm × 3.5cm × 6cm. See Figure 1. below These dimensions will build a pyramid to fit a mobile phone. Depending on the size of your tablet screen, you will need to at least double the size of your pyramid for a tablet.

When light is reflected, the angle it hits the object at (angle of incidence) is the same as the angle it reflects off the object (angle of reflection). It is the reflected light that enters our eyes and our brain uses to process and form images.

What is happening in Pepper's Ghost
While not a true hologram, Pepper's Ghost is a good exploration of light and reflection.

Real holograms were invented in the 1940s and are 3D images created by interference of light beams. A holographic image can be viewed from any angle and you can see all sides of the object that is being projected, for example the front back and sides of a human. You don't need any special props such as the inverted trapezoid in this activity to see a 3D image.

What we have instead with Pepper's Ghost is four symmetrically opposite versions of the same image that are projected onto each side of the pyramid causing all four images to meet in the middle to create what appears to be a 3D image in the centre of the inverted pyramid. Viewers see a reflected virtual image that seems to have depth and appear out of nowhere. See Figures 3 and 4.

Go and look at yourself in a mirror. Your reflected image appears somewhere behind the mirror. The further you step away from the mirror, the further back behind the mirror your image appears. The same concept is happening in the projection pyramid. The reflected image appears to be behind the angled plastic coming off the base of your phone or tablet. See Figure 4. The reflected image of the rabbit off the surface of the pyramid is projected back into the middle of the prism at a distance equal to the distance the image from the video footage is from the base of the pyramid. See Figure 4.

In more sophisticated versions of this classroom or home science model, the concept has a range of practical uses, for example in medicine, marketing and product exhibition, and art. For instance, a

Use this template trapezoid to mark and cut out four trapezoids from your clear plastic.

Use the sticky tape to tape the four trapezoids together as shown in Figures 2a. and 2b.

Use your device to access holographic images. There are lots of different sites, but this one has some cool images.

Place your trapezoid on the video device in the middle of the four images displayed. The narrow end of the trapezoid is on the bottom touching the video device screen.

Results
What can students see? Get them to describe what they see as they turn the device around to view the image from all sides.

Can they describe how the physics of reflection is creating the 3D illusion?

Get students to draw ray diagrams on how the reflection of light is working to generate the illusion. Compare this to Figure 4.

3D animation of blood flow through the human heart could help doctors explain to their patients what is happening in their body and how they can treat it. Companies can use such 3D models to provides potential customers a view of their product from all angles rather than the normal 2D version. Today the principle is used in teleprompters and the 'heads-up' displays in fighter jets, some cars and various museum exhibits. See FLEET's version of this illusion here. For more a deeper dive into the concept of reflection, check the main teacher resource, Reflection, absorption, refraction, diffraction. **Concepts for students to understand** • Light travels in straight lines. • We see objects when light reflects off the objects back to our eyes. • Some materials reflect light better than others. Cardboard tends to absorb light. Mirrors reflect light well. • Angle of incidence (i) = Angle of reflection (r)	

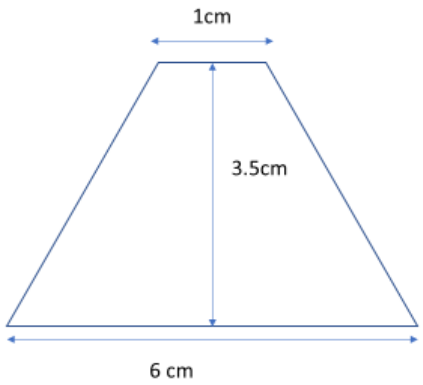

Figure 1. The dimensions of the trapezoid (pyramid) suitable for a mobile phone

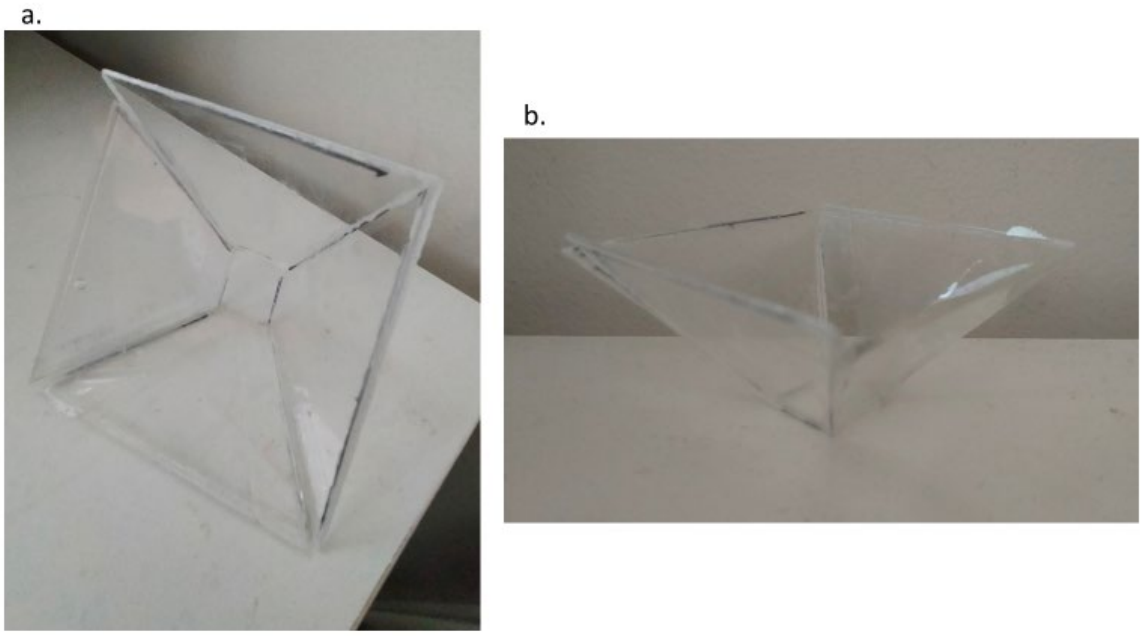

Figure 2. Trapezoid (pyramid) taped together? Figure b. shows which way the pyramids sits on the video source

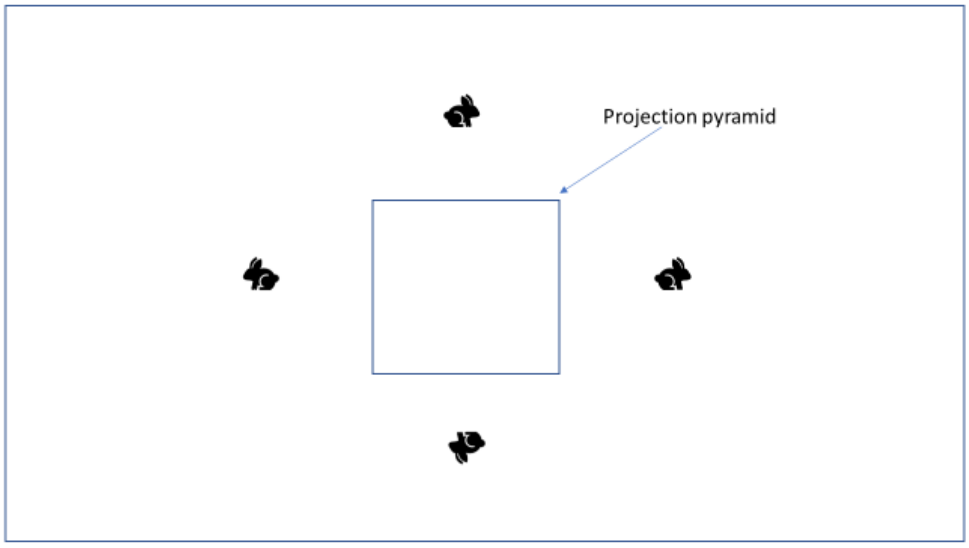

Figure 3 The video source showing the four symmetrically opposed rabbits with the pyramids in the middle.

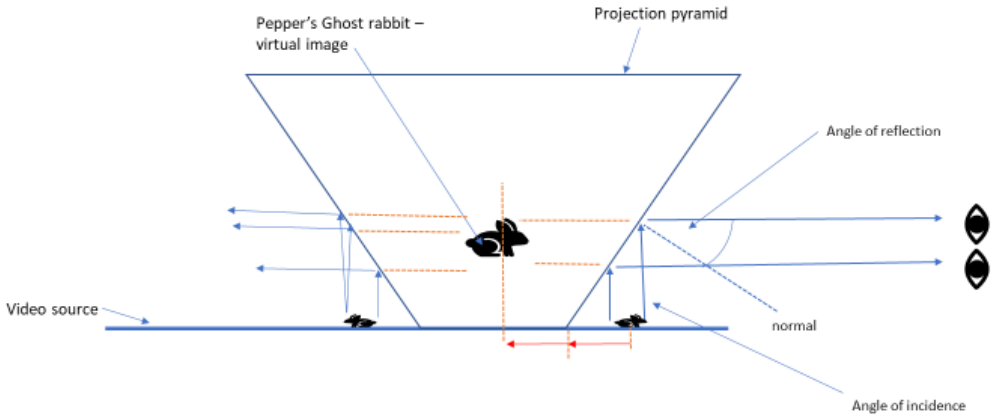

Figure 4. The smaller base of the pyramid sits on the video source that projects the four symmetrically opposed rabbits onto each side of the prism and projects them back into the centre of the pyramid the same way your image in a mirror appears a similar distance behind the mirror as your actual distance from the mirror.

Acknowledgement: The idea for this activity is adapted from Science World - https://www.scienceworld.ca/resource/peppers-ghost-hologram-illusion/