Communicating Science with the Arts

Chris Chiaverina
New Trier High School
Winnetka, IL 60093
fizzforfun@aol.com

For over a decade, I, along with my colleagues at New Trier High School in Winnetka, Illinois and Tom Rossing at Northern Illinois University, have been incorporating elements of the visual and performing arts in our physics teaching. We've found that the arts serve as very effective vehicles for teaching a variety of topics in physics, especially optics. Thus far we've examined connections between the visual arts and the following optical phenomena: shadows, reflection, color mixing, diffraction and polarization. We have also brought students from the science and performing arts departments together to study theater lighting and acoustics.

While there are many ways to incorporate the arts in physics instruction, we have essentially used three approaches. These are: 1) the inclusion of art-related material in the physics curriculum; 2) interdisciplinary collaborations; and 3) gallery exhibitions. I will now elaborate on these efforts.

Art in the Physics Classroom

Shadows

We begin our study of geometric optics with an exploratory activity on shadows. After students become familiar with the rudiments of shadow formation and rectilinear propagation, we delve into the importance of shadows in visual perception and art.

Historically, shadows are important for they provided early evidence that light travels in straight lines. Shadows also provide us with information regarding the shape of objects…and more.

Artists employ numerous visual cues to produce the illusion of depth and three-dimensionality. Shadows are one of the most potent of these visual devices. Renaissance artists are attributed with initiating the use of shadows in drawings and paintings. This use of light and shadow in painting is known as chiaroscuro ("light and dark"). We introduce our students to chiaroscuro by showing them a number of paintings by artists from various periods that illustrate this technique. By examining this artwork, our students learn how artists take advantage of our perception of shadows to produce the illusion of depth and establish mood.

Anamorphosis

Anamorphosis, from the Greek words meaning "formed again," is a process that stretches and distorts images beyond recognition through the sophisticated application of the laws of perspective. When viewed from the proper angel or, in some instances, with the aid of a reflector, the distorted images appear quite normal. Anamorphic art, which flourished during the seventieth and eighteenth centuries, is now regarded as somewhat of an artistic curiosity.

Anamorphic art appears to have originated in China and brought to Italy in the 16th century, about the time Renaissance artists like Leonardo da Vinci were mastering the use of linear perspective. The ancient Chinese employed mirrors to restore normal perspective to their distorted drawings and paintings. Leonardo and his contemporaries took a different approach. They developed and refined perspective anamorphosis, a form of intentional image distortion that is eliminated when the image is viewed from the proper angle. This technique was later used by Hans Holbein to conceal a skull in his famous painting *The Ambassadors*.

Although the popularity of this rather arcane art form waned after the Renaissance, practitioners of anamorphosis may still be found today. Contemporary artist William Cochran has created a delightful anamorphic mural of a young woman on the side of a bridge in Frederick, Maryland. Like Holbein's Ambassadors. Cochran's painting is best viewed from a particular vantage point.

We attempt to keep anamorphosis alive by introducing it to our physics students during our unit on mirrors. While studying curved reflectors, our students create their own "catoptric" or mirror anamorphic art by first drawing an image on a rectangular grid. Then, point by point, they transfer the image to a cylindrical grid. This deforms their drawing (Fig. 1). To see their drawings in its undistorted form, they view them in a cylindrical reflector (Fig. 2)

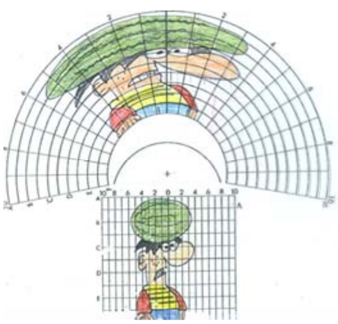


Figure 1

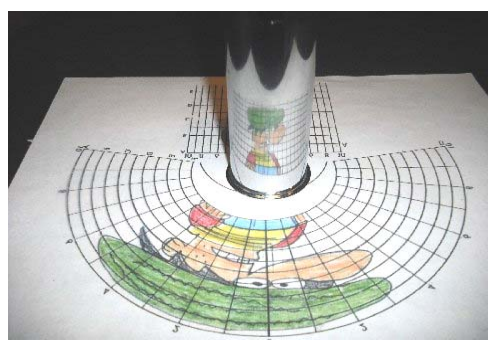


Figure 2

Color Mixing

Color is one of the most obvious and striking aspects of art. Students often have difficulty understanding the difference between the mixing of light (additive mixing) and the mixing of pigment (subtractive mixing). We provide them with several hands-on experiences and demonstrations to help them understand the two processes.

One of the most commonly used methods of demonstrating additive color mixing in space is based on the projection of red, blue and green lights on a screen. In Figure 3, red, green and blue compact fluorescent lamps are used to illuminate a white screen. An object placed between the light sources and the screen produce vibrant colored shadows.

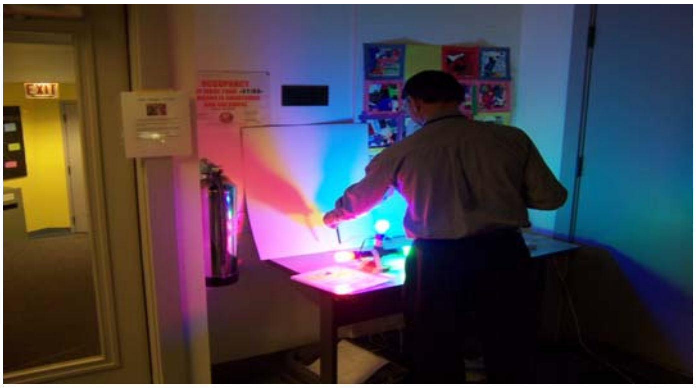


Figure 3

A rather novel way to demonstrate additive color mixing in time is to mount three light sticks on an electric drill. Persistence of vision melds the colors together. (Fig. 4)

Figure 4

To investigate subtractive color mixing, students receive a “lab in a bag” consisting of six filters and a pair of diffraction glasses. Through guided inquiry, students use the filters and glasses to “discover” the rules of subtractive mixing.

Using an activity created by colleague Diane Riendeau, students then investigate subtractive mixing using India inks (Fig. 5). India inks are used because they are inexpensive, essentially water soluble and obtainable in cyan, magenta and yellow.

Figure 5

A “paint by numbers” approach is used to color an abstract design (Fig. 6). Each of the numbered areas that make up the design corresponds to a statement on a worksheet such as “this color absorbs red light.” Students must first identify the color and then use a single ink or a mixture of inks to produce the desired color. A completed colored design is shown in Figure 7.

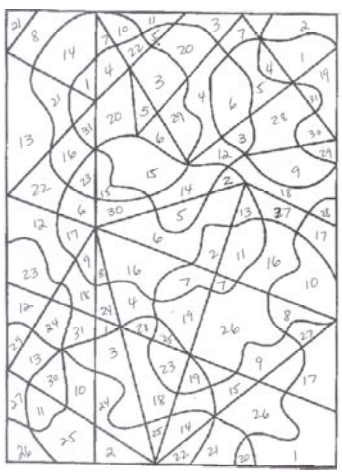


Figure 6

Figure 7

Resolution and Pointillism

The wave nature of light puts a limit on our ability to see fine detail. When light passes through a small circular opening, such as a lens or the pupil, it diffracts. As a result, the image of a point source appears as a set of circular fringes centered about the geometrical-optics image of the source.

One consequence of diffraction is the limit it places on the eye’s ability to resolve the images of two closely spaced sources of light. If the overlap of the individual diffraction patterns is too great, the images will no longer appear distinct.

While diffraction often makes for fuzzy images, our inability to separate closely spaced objects is a good thing when it comes to viewing pointillist art, television screens and outdoor LED displays. With distance, arrays of thousands of tiny, closely spaced dots are seen as continuous images.

To demonstrate the eye's limited resolving power, students produce pixilated images from paper dominoes. Using templates available at no charge from DominoArtwork.com, students assemble images of Abraham Lincoln, Martin Luther King, the Mona Lisa and the Statue of Liberty, and our current president (Fig. 8). These plans are created by Oberlin College professor Robert Bosch using a mathematical technique called integer programming.

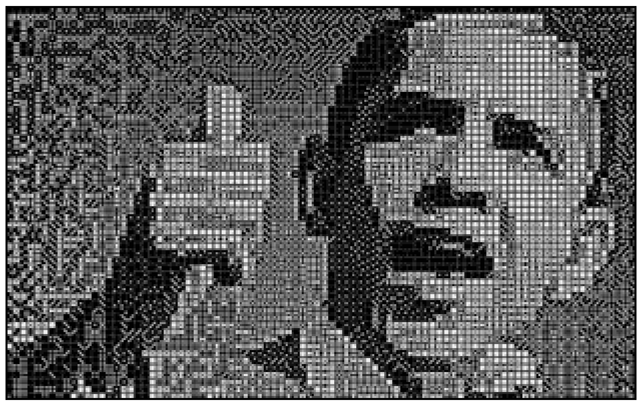


Figure 8

According to the Rayleigh resolution criterion for a circular aperture, the eye can just resolve images if the angular separation between objects is of the order of 10^{-4} radians. After producing their domino art, students apply this standard to predict the appropriate viewing distance.

Interdisciplinary Collaborations

Physics and the Theater

Each year we schedule a day of interdisciplinary activities with the performing arts department. The collaboration affords physics and performing arts students an opportunity to examine the art and science of stage lighting as well as auditorium acoustics.

We invite students to join us on the stage to observe how the color of objects is affected by color of the incident light. Students first observe the color of their clothing under white light. The while light is then turned off and each primary color is used in turn to illuminate the stage and its occupants. Students are amazed by the dramatic changes in the perceived color of their clothing that accompanies changes in lighting (Fig. 9).

Figure 9

Students then experience acoustical interference produced by two loudspeakers. Moving around the auditorium, students locate and remain at points where the sound level is low. An easily discernable nodal pattern emerges when a large number of students participate.

The Art and Science of Birefringence

A weeklong program introduces art and physics students to color theory, polarization and artistic composition. The week begins with an exploratory activity on color and color mixing. Following this experience, students hear about color from both a physicist's and artist's point of view. Students then return to the lab to investigate polarization. During the course of this activity they encounter birefringence. A discussion of polarization is followed by a lesson on composition. Students are then ready to produce their tape art.

The birefringent tape used in this activity reveals beautiful colors when viewed between crossed polarizers. Students layer tape on microscope slides to determine how color depends on tape thickness. Once they have created their color key, they produce polarization tape art by placing carefully cut pieces of tape on a plastic substrate. The figure below shows a color key surrounded by several examples of student tape art (Figure 10).

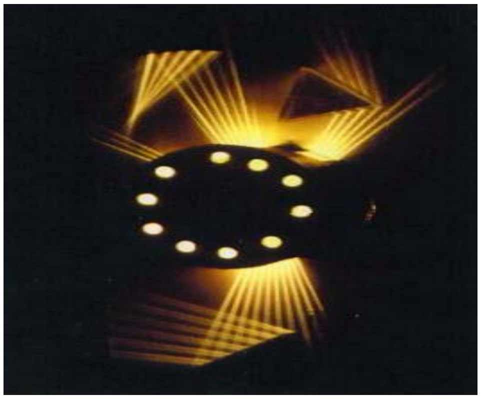
Figure 10

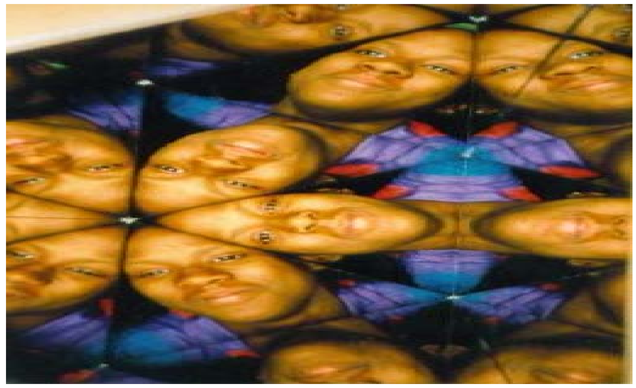
Gallery Exhibitions

The Connections Project
Teachers and students from three departments at New Trier High School have produced over 100 engaging, hands-on exhibits that allow people of all ages to discover elements common to the arts, mathematics, and science. Supported by New Trier High School and Toyota TAPESTRY and GTE GIFT grants, the Connections Project has developed cross-curricular displays that have been used in elementary, secondary and college classrooms and laboratories, learning centers, art galleries, and other public venues.

Emulating San Francisco's Exploratorium, our traveling hands-on museum's focus is the connections among science, art and human perception. Like the Exploratorium, the museum's mission is to allow students of all ages to explore, discover and see the linkages between seemingly disparate disciplines. Over the years, we've had thematic shows on visual perception and the arts, light and color, reflection and symmetry.

Shown in Figure 11 below, starting from the upper left corner in a clockwise direction, are four examples of Connection Project exhibits. They are: a light table, multiple images of a young man produced by a giant kaleidoscope, an impossible triangle, and an interactive anamorphic art display.





Final Thoughts

The possibilities for incorporating elements of the visual and performing arts in physics instruction seem endless. Bringing these disciplines together also addresses the compartmentalization of knowledge that is so prevalent in our schools. This is a good thing, for in the words of Exploratorium artist, scientist, educator and one of the founders of the museum Bob Miller: “There is no graver threat to the process of discovery than that dread disease, ‘hardening of the categories.”