The Science Behind Art and Literature: How We Process What We See and Hear

Amanda Bridgeford
High School of the Future

Overview:

Far too often in education, core subjects are taught are stand-alone courses. Students are rarely shown how interrelated theses subjects really are. Students should be aware of how related their courses are; they should realize – or be taught to understand – that a historical perspective can explain why a scientist theorized the way he did, for example. Since I am a science teacher, I would like to focus on the science of art and literature. How do we process these two? I would like to incorporate art when we study the eye: how do we process the colors? How is the experience (viewing works of art) different for those who are colorblind? Also, to utilize the literature aspect, how do we process the words we see on the page? How do those who have disabilities (such as dyslexia) process the words and letters differently, and why? When we study the ear, I would like to use literature of various types, especially poems. We could listen to poems and then discover how our ear (and then the brain) processes the information. This could possibly involve working with the English teacher to bring in writers my students may be learning about at the time – like Emily Dickenson and Langston Hughes. I would also like to bring in works by scientists such as Darwin, A.R. Wallace, S.J. Gould, and Carl Sagan.

Rational:

In ninth-grade Physical Science in the Philadelphia School District, students are expected to learn the parts of the ear and eye as part of the Physics unit. The way this information is presented can be very boring. We use our eyes and ears for everything we do; yet in Philadelphia teachers are given but a day to teach them about these two vital parts of our bodies. The eye and ear are part of a unit on waves, focusing on sound and light. This is very useful, but I would like to bring in more real-life applications for their learning. Additionally, I could team with the English and art teachers in innovative and creative ways. This unit can also be modified to be taught to Physics classes as well.

Background:

In the Philadelphia School District, the Physical Science curriculum is a confused hodge-podge mixture of several scientific disciplines: Chemistry, Physics, Earth Science, and Astronomy. Unfortunately, the curriculum is not terribly clear about this fact. The Physics portion is broken into several units: Force and Motion; Work, Power, and Energy; Waves; and Electricity and Magnetism. These units are supposed to be taught near the beginning of the year; it involves a great deal of math, word problems, and algebraic formulas. Those who have taught ninth graders in Philadelphia realize what a struggle this can be.

This year, my second year of teaching Physical Science, I decided to rearrange the curriculum a bit. I noticed that students who had been disengaged the entire year were suddenly captivated when we started learning about the sun, moon, planets, and stars. So I started the year off with Astronomy, instead of pushing it off until the last few weeks of June. I decided to start off with the big picture, and then zoom in, little by little, to the small things. So I am ending the year with Physics, which is actually somewhat convenient: I will have taken my learners full circle. We will learn about the laws of Physics that work on Earth and then apply them to what we learned in the fall to worlds outside our own.

One of the most interesting aspects of the Physics portion of the Physical Science curriculum, for me, is being able to talk about human anatomy – the eye and ear. As a teacher, Biology is my first love; I find life far more interesting than rocks. Even though I am technically only allowed one day per structure, if that, I've decided that if I can teach Astronomy first instead of last, then why not stretch something I love out into a week or more? Furthermore, I've discovered that memorizing a million facts for a test is not necessarily helpful for students. I want my students to be able to *think* like scientists, to appreciate the world around them, to *want* to learn about anything and everything.

So I must, for this unit, learn more about the eye and ear. Specifically, as these two structures relate to waves. Waves can be very difficult for students to visualize. It is quite easy for them to think about the waves hitting the beach but sound waves? Light waves? What on earth?

Waves have several key features. A ***crest*** is the very top of the wave; a ***trough*** is the very bottom. A ***wavelength*** measures the distance from one crest to the next, or from one trough to the next. Wavelength is represented by the Greek letter λ (lambda, extremely confusing for students but "w" and "W" have been used multiple times already in previous cases, namely for weight, work, and watts). The height of the wave is the ***amplitude***.

Now the fun part: formulas! ***Frequency*** (abbreviated ***f***) must be calculated using the ***period*** (abbreviated ***T***, not t for time as it has been previously). The period is the time it takes a wave to complete one wavelength. Unless we want to pull our hair out with more conversions, period should be measured in seconds. Frequency is measure in hertz, abbreviated ***Hz***.

Frequency formula: $f = 1/T$

The speed (***v***) of waves can also be calculated. Hooray! To do this, we must know the wavelength and period.

Wave speed formula: $v = \lambda /T$

We can further torture our students by pointing out that frequency and period are related, so we can use the following formula for wave speed:

Wave speed formula #2: $v = \lambda f$

It's really important to point out to students that wave speed will depend on the medium that the wave travels through – a wave will travel more quickly through air than through water, for example. Also, the conditions of the media are important: pressure, temperature, and/or density variations will cause a variation in wave speed.

Something important to mention: there are two types of waves. ***Transverse waves*** are the ones everyone is familiar with. With this type of wave, the motion of the medium is perpendicular to the motion of the wave. Some examples include a wave on a string, waves in the ocean, and doing "the wave" at a sporting event. ***Longitudinal waves*** are just the opposite – the motion of the medium is in the same direction as that of the wave. Sound waves are an excellent example of these waves, the most difficult for learners to understand.

Waves don't just wander around; they interact. ***Interference*** occurs when two waves take up the same physical space. What happens as a result of that interference depends on when and where they intersect. ***Constructive interference*** occurs when two waves meet and their amplitude combines so that the amplitude of the resulting wave is larger than either original wave. This will happen if they both have positive amplitudes (or are in the "crest" phase). ***Destructive interference*** occurs when two interfering waves meet and the resulting wave has a smaller amplitude than either original wave. This happens when one wave has a negative amplitude (or is in the "trough" phase). ***Reflection*** occurs when a wave hits a boundary and bounces back in the opposite direction. ***Refraction*** occurs when a wave bends because it is passing through a different medium, like from air to water. ***Diffraction*** occurs when waves bend around an object instead of bouncing back.

Sound waves are, for obvious reasons, of extreme importance for my unit. Sound waves are longitudinal waves. They require a medium – such as air or water – to move through. (This is an excellent opportunity to connect back to Astronomy – do sound waves travel in space? Why or why not?) Remember that frequency formula that looked like nonsense? It's actually really important for sound. The frequency is directly related to the pitch – the higher the number of the frequency, the higher the pitch sounds to us (as in, higher notes on a piano). Also, animals have different sensitivities to frequency ranges. Human ears can generally hear from 20 Hz to 20,000 Hz. Dogs (and most other animals) can hear at higher frequencies. The speed of sound, like other waves, depends on the properties of the medium. The speed of sound in air can be calculated with the below formula:

$$v = (331+0.6T)\ m/s$$

*Note that in this formula, ***T*** represent temperature in Celsius (not the period)

When the pitch of an object passing you changes from high to low, you have experienced the ***Doppler Effect***. Students will be most familiar with this effect from the passing of an ambulance, fire truck, or police car.

Sound ***intensity***, known to students as *volume* or how loud something is, is measured in ***decibels*** (***dB***). Intensity is measured on a logarithmic scale. For example, a whisper that is 10 dB is 10 times as loud as something that measures 0 dB; the average home, at 20 dB, is 10 times louder than that whisper but 100 times louder than 0 dB. The human ear can be damaged when sound intensity reaches a mere 85 dB (a concert can be well over 100 dB).

The ear is responsible for collecting and processing sound waves. The human ear is divided into three parts: the outer ear, the middle ear, and the inner ear. The outer ear is comprised of three structures: the pinna (also called auricle; the visible portion), the ear canal, and the tympanic membrane (commonly called the eardrum). The outer ear collects sound and tunnels it toward the middle ear. The middle ear starts with the eardrum and contains three ossicles, or ear bones. The inner ear contains the cochlea, vestibule, and semi-circular canals. The cochlea is the organ of hearing, and contains several structures important for this function. The vestibule and semi-circular canals are important for detecting motion.

Light is also critical to understand for this unit. Like the waves mentioned previously, light can also refract and reflect. Unlike other waves, however, light does not need a medium to travel in. The speed of light, *c*, is always a constant 183,310 mi/s or 299,776 km/s in a vacuum. The value for *c* varies according to the medium, such as water or air, causing refraction. This characteristic of light waves allows microscopes, eyeglasses, and other optical equipment possible. Light can be measured according to its brightness or intensity. Light is obviously necessary for sight.

There are many sources of light in today's society, from the sun to fluorescent lamps to LEDs (light-emitting diodes). The brightness of a light source is measured as *luminous intensity*, which is measured with a unit known as candela, abbreviated as cd. The rate of energy flow carried by light is luminous flux. This is measured with a unit called *lumen*. The amount of area illuminated by a light source is know as *illumination*.

Only a small portion of the electromagnetic spectrum is visible to humans. The wavelengths of the visible spectrum range from about 380 to 730 nm. At the lower end of the visible spectrum are the purples and blues; these colors have short wavelengths and high frequencies. At the high end are the oranges and reds; these colors have long wavelengths and low frequencies. (Remember the formula for frequency if this doesn't make sense!) Bright colors have greater amplitudes than dull colors, which have small amplitudes.

Refraction and reflection are slightly different with light waves. Because light travels in a straight line, light waves are referred to as *rays*. Reflection involves light waves bouncing off a surface. There are many types of reflection; only two are necessary for the purposes of this unit. *Specular reflection* occurs when light rays hit and bounce off a smooth surface, such as a mirror; the light waves are reflected in the same direction. *Diffuse reflection* occurs when hit and bounce off a rough surface; the light waves are reflected in many directions. There are several key terms necessary when discussing reflection and light waves. The *plane surface* is the object that the light waves strike. The *incident ray* is the initial light ray. The *reflected ray* is the resulting light ray. The *normal* is a line perpendicular to the plane surface. The *angle of incidence* is measured from the incident ray to the normal. The *angle of reflection* is measured from the reflected ray to the normal. According to the *law of reflection*, the angle of reflection is always equal to the angle of incidence. This is important in determining the type of image reflected by various types of mirrors.

There are several types of mirrors; each produces a different type of reflected image. A flat mirror will form a virtual image, which is the same size and shape as the object in front of the mirror but in reverse. Curved mirrors distort the image; this is explained by the law of reflection. Concave mirrors create can create a real image, which can be focused. Concave mirrors are used in telescopes.

Refraction refers to the light not reflected, or the light that does not bounce off a surface. It is the change of the direction of light due to the change of medium, such as when light passes from air to liquid, and therefore change of speed. Snell's law describes what happens when light is refracted. The angle of incidence, θ_1, is related to the angle of reflection, θ_2, by the equation below. The wave velocities of each type of medium is represented by *v*; the refractive index of each type of medium is represented by *n*.

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

The refractive index, also known as the index of refraction (n_s), can be found using the speed of light in a vacuum, *c*, and the speed of light in the medium, v_s, as shown by the formula below:

$$n_s = c/v_s$$

When light passes from air, which is not very dense, to a medium that is denser, such as a liquid or glass, the ray will bend toward the normal. If the light ray passes from a dense medium to a less dense medium, the ray will bend away from the normal. This explains the broken appearance of straws in a glass of water, for example, or the difference between the apparent position and actual position of fish in a pond.

The human eye is very similar to a camera. The eyeball is made up of several key parts, among them the pupil, iris, cornea, lens, retina, and optic nerve. Light enters the eye through the cornea. The iris controls the amount of light entering the pupil. The light then travels to the lens, which focuses the image on the retina. The light travels to the retina in the back of the eye, which contains numerous photosensitive cells known as rods and cones. The image on the retina is real, inverted, reduced – and upside down. The brain is, however, able to process the image in the proper orientation.

With normal vision, the lens is shaped by muscles attached to it. These muscles are able to change the curvature of the lens so that an object seen is focused on the retina. In nearsightedness, the image is focused in front of the retina. In farsightedness, the light rays strike the retina before they are focused. These conditions are fixed with diverging lenses for nearsightedness, and converging lenses for farsightedness.

Objectives:

This unit is intended for students in Grades 9 or 10. They have a 48 to 57 minute period of science and English. They may not have art and thus an outlet for their creativity.

The objectives for the unit include:

- Identify and label the parts of the eye and ear
- Explain the functions of the parts of the eye and ear
- Analyze the ways the brain processes information from the eye and ear.
- Identify several pathologies related to hearing and vision and analyze how these pathologies affect the enjoyment of art and literature.
- Create a work of art, poem, or short story that reflects upon the concepts of this unit.

Strategies:

In this unit, students will have access to multiple resources to assist their learning. There will be pictures of the eye and ear, with and without labels, for their perusal and study. We will also use various websites with different views of the eye and ear so they become accustomed to seeing these objects in different way but can still identify the important parts. Experience has taught me that students are not always proficient at recognizing structures on a diagram different from one they labeled in class and studied at home. Repetition will be of vital importance for students to learn the parts of the eye and ear, as I have learned from teaching the anatomy of the cell.

The ability to solve word problems is of extreme importance for the entire Physics unit. I spend a lot of time in class modeling this ability for my students. They have to be able to identify the givens in the word problem. They have to know what they need to solve for, or find. They have to know how to use and rearrange the formulas we've gone over in our notes. I've found it helpful not to mention the phrase "word problem" when I am modeling and assigning these problems in class. I've noticed that some students have an aversion to the phrase and this may be a hindrance to their ability to do as well as they are actually capable. I've also been in constant contact with our Algebra I teacher, who has been wonderful in helping out with teaching – and re-teaching, several times – the students how to rearrange formulas. It is really important to assess what your students are and are not able to do. Making assumptions may lead to many headaches!

For the final portion of the unit, in which the student produces a product that reflects their understanding of the unit's concepts, it is vitally important that a rubric is used to evaluate the work produced. It may be important to insist on several poems, instead of just one, for instance.

<u>Classroom Activities</u>

Day 1

Objective: The learner will be able to identify the parts of the ear. The learner will be able to identify the physical processes involved in processing hearing.

Part I

Students will be given information about the parts of the ear. This is available in the Physical Science textbook and on numerous websites found in the Bibliography. I would recommend having students label several different diagrams of the ear, as I have noticed that they seem to have some difficulty identifying the structures if a picture different from the one they learned is presented on a quiz or other assessment. Students should also realize that the ear is split into three parts: the outer ear, middle ear, and inner ear.

Part II

Students will learn the functions of each part of the ear. Depending on the resources available, this can be done through a website available online or in a note-taking format.

Part III

In the form of an exit slip or quick quiz, test what they students learned in class. Examples can include: "Identify the function of 3 parts of the ear (your choice!)" or having them fill out as many parts of the ear on a pre-copied half-sheet of paper as they can in 3-5 minutes.

Day 2

Objective: The learner will be able to analyze the brain processes involved in processing auditory information.

Part I

It is vitally important that students remember the structures found in the ear in order to fully understand the concepts of today's lesson. The day could begin with a Do Now or other class starter that asks a question similar to the previous day's Exit Slip/Quiz.

Part II

Sound waves cause the eardrum (tympanic membrane) to vibrate according to their frequencies. This begins the process of hearing; the next step involves the three bones of the ear. The malleus, incus, and stapes (commonly known as the hammer, anvil, and stirrup, respectively) then vibrate, passing the sound waves to the next step: the cochlea. The cochlea is spiral-shaped, often referred to as resembling a snail, and contains another smaller structure: the organ of Corti. The cochlea's main function is to transform sound waves into electrical impulses which are then processed by the brain. This is done chiefly by small hairs moving in a fluid found inside the organ of Corti. When the hairs move, they transmit an electrical impulse to the brain via the cochlear nerve, the eighth cranial nerve. Sound is processed in the cerebral cortex. The pitch of the sound is determined by the position of the hairs. Louder sounds move more cells than softer sounds.

This information can be relayed to students in a variety of ways. Several websites (see the bibliography) contain animations that are extremely useful. But beware: not all animations are created equally! Be sure to preview the animation before showing it to your class to evaluate it for accuracy and appropriateness for your classes.

Part III

In order to assess for understanding, the students could fill out or draw a flow chart showing the process of hearing, starting with a sound wave. They should also label *where* each step occurs in the ear.

Day 3

Objective: The learner will be able to design ways to determine the wavelength, wave speed, period, and frequency of sound wave models.

http://phet.colorado.edu/simulations/sims.php?sim=Sound Simulation looking at frequency and amplitude of a single or multiple sound source(s). There are versions of the simulation for multiple languages common to our population of students, and more. Under "Ideas and Activities for the Sim" can be found many contributions from teachers around the country for different grade levels; their difficulty ranges from moderate with step-by-step instructions given, to the more arduous, inquiry-based type of activities. This is an excellent resource for differentiating instruction – the teacher can pick different activities for different students, or direct students to answer certain questions on the activities.

Today's activity could be modeled by the teacher for the entire class if access to individual or shared computers is not feasible. It is vitally important that students make the connections between their knowledge about waves, including frequency, wavelength, and other concepts, and what they have learned about the ear.

Day 4

Objective: The learner will be able to identify the parts of the eye. The learner will be able to identify the physical processes involved in processing sight. The learner will be able to analyze the brain processes involved in processing visual information.

Part I

Students should be introduced to the structures of the eye and their functions. There are eleven basic parts: aqueous humor, choroid, cornea, iris, lens, pupil, retina, rods, cones, sclera, and vitreous humor. Note that rods and cones usually do not appear on diagrams, but students should be aware of them and their functions. As with the ear, students should practice with several different diagrams in order to truly test their mastery of the objective.

Part II

As with the ear, the processing of sight can be summarized in a step-by-step flow chart. Light passes through (in order) the cornea, pupil, and lens. The iris is actually a colored muscle that controls the size of the pupil, thus controlling the amount of light entering the eye. The light wave then hits the retina, which contains receptors called rods and cones. These receptors, like the hairs found in the cochlea of the ear, convert the wave to an electrical impulse that is sent to the brain via the optic nerve (the second cranial nerve). This impulse is processed by the visual cortex, found in the occipital lobe of the brain. The photoreceptors have specific functions: the cones detect color, while the rods are important for motion, peripheral vision, and light sensitivity.

Part III

To test for understanding and mastery of the concepts, students should make a flow-chart demonstrating how light waves are processed by the eye and the brain. Another option is to have students view animations on a variety of websites, available in the bibliography.

Days 5-7

Objective: The learner will analyze the biology behind art and literature.

Students will look at works of art, and instead of thinking about the art, per se, they think about what their eyes and brains are processing what they see. Also, the teacher will play or read aloud selections of literature (which can be scientific in nature or relating to their current English class) and have them analyze what their ears and brains are processing. Also, students could listen to different frequencies and intensities of sound and analyze its effects. It would also be interesting to look at the impact of headphones on our ears!

A decibel meter can be purchased for around $20 at many stores that have a car audio section. Students could measure the decibel levels of various locations around school, their own voices, the sound coming from their headphones, etc. Students could then examine the logarithmic nature of the decibel scale and what that means in terms of increasing intensity of sound.

The actual activities of this portion of the unit will depend on the interest level the students and the materials available.

Days 8-10 (can extend if necessary)

Objective: The learner will choose a project to complete that utilizes either vision or hearing. (This can include artwork, researching a pathology involved with vision/hearing, or others that learners may suggest if educator allows.)

Examples of topics for research:

Vision – colorblindness, myopia ("nearsightedness"), hyperopia ("farsightedness"), presbyopia (usually occurs after age 40), astigmatism, glaucoma, conjunctivitis, etc.

Hearing – hearing loss, such as Otitis Media or Externa, Meniere's Disease, Tinnitus; etc

Students should be encouraged to examine how the pathology affects hearing/vision.

Comments about creating artwork, poems, short stories, etc:

Students should be encouraged to have their products focus on one of two things:

1. What they have learned about the eye or ear

2. The connections between art and literature

   For example, a student could write a poem inspired by a painting, or create a painting inspired by a poem.

Bibliography

Reading List:

De Pree, Christopher G. *Physics Made Simple*. New York: Broadway, 2004. Print.

Holt, *Physical Science*. (Standard School District of Philadelphia Physical Science Textbook). "Hearing and the Ear," pg. 496.

Myers, David G. *Psychology*. Michigan: Worth Publishers. 2010. Print.

Teacher Resources:

The Unofficial Stephen Jay Gould Archive, http://www.stephenjaygould.org/ This is an excellent resource where teachers can access S. J. Gould's biography, short quotations, and entire articles, and pdf files of or links to entire classic and modern science books. (Thus possibly bypassing copyright problems.) For example: several works by Darwin, T. H. Huxley, A. R. Wallace, Richard Dawkins, and Gould himself. Most of these do focus on evolution.

The Carl Sagan Portal, http://www.carlsagan.com/ This site contains some audio clips of Sagan, especially his message to Mars.

The Alfred Russel Wallace Website, http://wallacefund.info/ A. R. Wallace nearly probably would have been credited with "discovering" the theory of evolution had he not written to Darwin about his thoughts while Darwin was debating over whether or not to publish his revolutionary theory. This site contains a biography of Wallace, sound and video recordings about Wallace and related scientists, and pictures of Wallace and his drawings.

Holt, Physical Science. (Standard School District of Philadelphia Physical Science Textbook). "Hearing and the Ear," pg. 496.

Ben Franklin's Armonica, http://www.fi.edu/pieces/dukerich/studentonlineactivities.html This site contains lower-level (middle school) readings about the ear, its parts, music, wavelengths, and sound. These can be used for students with below-level reading skills, or adapted to fit the high school level. There is also an interactive Armonica for students to play online.

Diagram of the Eye, http://www.nei.nih.gov/health/eyediagram/index.asp# On this site, teachers can review their knowledge of the parts of the eye.

Student Resources:

The Unofficial Stephen Jay Gould Archive, http://www.stephenjaygould.org/ The student can be directed to particular links within the website to peruse, read, download, and print the articles or book sections.

Holt, Physical Science. (Standard School District of Philadelphia Physical Science Textbook). "Hearing and the Ear," pg. 496.

Ben Franklin's Armonica, http://www.fi.edu/pieces/dukerich/studentonlineactivities.html This site contains lower-level (middle school) readings about the ear, its parts, music, wavelengths, and sound. There is also an interactive Armonica for students to play online.

Diagram of the Eye, http://www.nei.nih.gov/health/eyediagram/index.asp# On this site, students can interact with the parts of the eye. Using their mouse, they can move a magnifying glass over the images; they can click on terms and a definition will come up. There are several versions of the images, both in color and in black and white.

BBC's Nervous System – Sight, http://www.bbc.co.uk/science/humanbody/body/factfiles/sight/sight.shtml This site goes more in depth about vision, including information – in print and through an interactive animation – about how vision works. Information about how and where your brain processes sight is included. Pay attention to the links on the side of the page – other interesting interactive and tests are included that will challenge students' perceptions.

KidsHealth's Your Eyes, http://kidshealth.org/kid/htbw/eyes.html Included on this site are lower-level readings about the eye, including information about color blindness and other eye problems.

ThinkQuest's Eye Site, http://library.thinkquest.org/J002330/ This site contains pictures of normal vision vs. nearsightedness and farsightedness. Also included: basic anatomy, ailments of the eye, games and interactives.

The Ear: An Interactive Activity, http://www.vtaide.com/png/ear2F.htm Students can drag labels onto the parts of the ear.

Perception of Sound – Human Ear, http://www.epd.gov.hk/epd/noise_education/web/ENG_EPD_HTML/m1/intro_2.html This site includes excellent diagrams and demos of the parts of the ear. Also included: audible range of the human ear (graph with explanation), the Decibel scale, frequency, and mathematical explanations for the formulas for each.

Appendix A

Standards:

English:

1.1.8 C

- Use knowledge of root words as well as context clues and glossaries to understand specialized vocabulary in the content areas during reading. Use these words accurately in speaking and writing.

1.1.8 G

- Demonstrate after reading understanding and interpretation of both fiction and nonfiction text, including public documents.

1.2.8 A

- Read and understand essential content of informational texts and documents in all academic areas.

1.6.8 B

- Listen to selections of literature (fiction and/or nonfiction).

Science:

3.3 B

- Analyze the relationships between structure and function.

3.4.10 C

- Describe sound effects
- Describe light effects
- Describe and measure the motion of sound, light, and other objects.