IMHOTEP'S LEGACY ACADEMY

7.2 The Miracle of Sight: How the Eye Works

Grade 7 Activity Plan

Reviews and Updates

7.2 The Miracle of Sight

Objectives:

1. To understand the structures within the eye, and how it functions.
2. To demonstrate the role of cones in colour vision, and explain why it is difficult to detect colour in the dark.
3. To show that the brain can fill in missing visual information.
4. To calculate the diameter of the blind spot.
5. To observe that the eye can be tricked into seeing colours.
6. To observe and understand that depth perception requires input from both eyes.

Keywords/concepts: pupil, retina, photoreceptor, rod, cone, lens, iris, cornea, optic nerve, blind spot

Take-home product: Styrofoam model of the eye, Benham disks

Segment	Details
African Proverb and Cultural Relevance (10 min.)	"The poorest person in the world is not the one without money but one without vision." **Ghana, West Africa** Dr. Thom Mittag and Kovin Naidoo
Pre-test (5 min.)	Intro to today's topic, brainstorm about how we see.
Background (15 min.)	Activity 1: Eye Structure Discuss the components of the eye, and their functions. Introduce keywords/concepts
Activity 2 (10 min.)	Show students that colour vision is compromised in low light situations. Contrast with animals that can see in the dark ie. Cats, owls
Activity 3 (10 min.)	Demonstrate that the brain explicitly fills in missing visual information
Activity 4 (10 min.)	Demonstrate the blind spot, and why we don't notice we have it. Calculate the diameter of student's blind spot
Activity 5 (10 min.)	Make Benham Discs to demonstrate that the illusion of colour can be created using a black and white image
Activity 6 (15 min.)	Investigate how the contribution from both eyes is needed for depth perception
Post-test (5 min.)	Eye spy trivia game

Suggested Interpretation of the proverb: The absence of money is not an obstacle to someone who has a very strong dream or vision. With great vision comes the ability or drive to fulfill that vision. *Connects to cultural relevance*.

Cultural Relevance:

Dr. Thom Mittag

Mittag is the son of Gerhard Ernst Mittag, the Cape Town architect, who was a "banned person" under the Apartheid government in 1950. Mittag's interest in eye research started as a result of an accidental explosion in the University of Cape Town chemistry laboratory in 1963, in which he lost sight in one of his eyes. In 2002 Dr. Mittag, a South African professor at a New York university won the Balazs Prize for his "outstanding contributions to the field of eye research". Mittag obtained a Ph.D. degree in Organic Chemistry at the University of Cape Town, and is now the Professor of Ophthalmology and Professor of Pharmacology at Mount Sinai School of Medicine in New York.

He is a distinguished glaucoma scientist who has been active for more than thirty years, and published more than 100 papers in scientific journals.

Kovin Naidoo and the African Vision Research Institute

On Tuesday, July 19th**, (find year),** the African Vision Research Institute (AVRI) was founded in Durban, South Africa, thanks to the efforts of Kovin Naidoo. After being invited by the World Health Organisation to an expert technical committee meeting on Global Eye Research in Geneva, Professor Kovin Naidoo realized that public health research in blindness prevention in Africa has been limited. All the research being done was in developed countries, and Kovin felt African research institutions should be more involved. He approached other African Colleagues and raised the idea of an African Vision Research Institute (AVRI), which would conduct blindness prevention research to aid programmes in Africa. Many research institutes in Africa have committed to involvement.

BACKGROUND INFORMATION

Light rays enter the eye through the cornea, the clear front "window" of the eye. The cornea's refractive power bends the light rays in such a way that they pass freely through the pupil, the black size-changing hole in the iris, the colored part of the eye.

The iris works like a shutter in a camera. It has the ability to enlarge and shrink, depending on how much light is entering the eye.

After passing through the iris, the light rays pass through the eye's crystalline lens. This clear, flexible structure works like the lens in a camera, shortening and lengthening its width in order to focus light rays properly.

Light rays pass through a dense, transparent gel-like substance, called the vitreous that fills the globe of the eyeball and helps the eye hold its spherical shape. The light rays come to a sharp focusing point on the retina. The retina functions much like the film in a camera. It is responsible for capturing all of the light rays, processing them into light impulses through millions of tiny nerve endings, and then sending these light impulses through over a million nerve fibers to the optic nerve.

In summary, the cornea is the clear, transparent front covering which admits light and begins the refractive process. The pupil is an adjustable opening that controls the intensity of light permitted to strike the lens. The lens focuses light through the vitreous humor, a clear gel-like substance that fills the back of the eye and supports the retina. The retina receives the image that the cornea focuses on the eye's internal lens and transforms this image into electrical impulses that are carried by the optic nerve to the brain.

Light, refraction and its importance.
Light entering the eye is first bent, or refracted, by the cornea. The cornea provides most of the eye's optical power or light-bending ability. After the light passes through the cornea, it is bent again -- to a more finely adjusted focus -- by the crystalline lens inside the eye. The lens focuses the light on the retina. This is achieved by the ciliary muscles in the eye changing the shape of the lens, bending or flattening it to focus the light rays on the retina. This adjustment in the lens is necessary for bringing near and far objects into focus. The process of bending light to produce a focused image on the retina is called "refraction". Ideally, the light is "refracted," or redirected, in such a manner that the rays are focused into a precise image on the retina.

How do we make sense of light?
Even with the light focused on the retina, the process of seeing is not complete. For one thing, the image is inverted, or upside down. Light from the various "pieces" of the object being observed stimulate nerve endings -- photoreceptors or cells sensitive to light -- in the retina. Two types of receptors -- rods and cones -- are present. Rods are mainly found in the peripheral retina and enable us to see in dim light and to detect peripheral motion. They are primarily responsible for night vision and visual orientation. Cones are principally found in the central retina and provide detailed vision for such tasks as reading or distinguishing distant objects. They also are necessary for color detection. These photoreceptors convert light to electrochemical impulses that are transmitted via the nerves to the brain. Millions of impulses travel along the nerve fibers of the optic nerve at the back of the eye, eventually arriving at the visual cortex of the brain, located at the back of the head. Here, the electrochemical impulses are unscrambled and interpreted. The image is re-inverted so that we see the object the right way up.

Activity 1: Structure of the Eye

Purpose: To understand the structures within the eye, and how it functions

Suggested format: Before going to the school, prepare a model for the students to look at

Item	**Quantity (10 students)**
Styrofoam ball (~10 cm diameter)	10
Pipe cleaner	30
Page Protector Sheets	1
Exacto Knife	1
Markers	12

Procedure:

1) **Draw/Paint** an **iris** and **pupil** onto the Styrofoam ball
2) Use overhead sheet to make a **plastic covering** that can be **taped**/secured over the iris and pupil to demonstrate the cornea
3) **Cut** Styrofoam ball in half with an exacto knife
4) **Paint** or draw a lens directly beneath where the pupil is
5) **Paint** a retina onto the back of the eye. Could also paint the middle to represent the vitreous humour
6) **Twist** three pipe cleaners together and insert them into the back of the eye to show the optic nerve

Additional Resources:
Cross section of eye: https://www.sciencelearn.org.nz/images/2312-cross-section-through-the-human-eye
Rod & Cone Info: http://www.michaelbach.de/ot/col_benham/index.html
Key Concepts: http://hyperphysics.phy-astr.gsu.edu/hbase/vision/visioncon.html#c1

Activity 2: Night Vision

Purpose: To demonstrate the role of cones in colour vision, and explain why it is difficult to detect colour in the dark

Item	Quantity (10 students)
Coloured paper	5 different coloured sheets, cut into 10 rectangles each (50 pieces total)
Scissors	1 pair

Procedure:

1) **TO BE DONE BY MENTOR PRIOR TO ACTIVITY:** Cut five pieces of different coloured construction paper into 10 squares each. Arrange into 10 groups (1 of each colour).
2) **Turn-off** lights. Cover any windows that provide a lot of light.
3) Wait **10 min.** Optional: listen to music, or play a game that does not require seeing.
4) Give each student a square of each colour, and have them **write** which **colour** they think it is on the square.
5) Turn on lights. Determine if colour labels are **correct.**
6) Determine whether certain colours were confused more often than others.

Suggested Discussion Topics:
- How owls see at night
- The tapetum lucidum in cats and dogs and how it helps increase light hitting photoreceptors
- How night vision goggles work: infrared or thermal detectors

Additional online activities:
Night vision stuff: http://www.visualexpert.com/Resources/nightvision.html
Super cool: http://www.nature.com/news/2011/110119/full/469284a.html

Activity 3: Interpret What You See

Source: http://www.exploratorium.edu/brain_explorer/jumping.html

Purpose: To show that the brain can explicitly fill in missing visual information

Item	Quantity (10 students)
Paper	10 pieces
Markers of different colours	10
Ruler	10

Procedure:

1) **TO BE DONE BY MENTOR:** Write the following code on the chalk/white board
   C=G, E=F, H=U, I=J=L, P=P=B, O=Q, X=Y
2) Have students **write** a word on their paper
3) **Replace** all the letters with an analog from the code.
   Ex. ICE CREAM IS GOOD becomes JGF GBFAM JS CQQD
4) Have the students **cover** up the **bottom** half of their coded word with a ruler
5) Have the students get a **neighbour** to read the word
6) Using **original word** (before coding), cover the bottom half, and determine whether neighbour can identify the word
7) Discuss whether it was easier to identify words from top or bottom halves of letters

Activity 4: Blind Spot

Source: http://faculty.washington.edu/chudler/blindspot.html

Purpose: To calculate the diameter of the blind spot

Item	Quantity (10 students)
Paper (8 ½" x 11")	2 sheets
Paper (8 ½" x 14")	3 sheets
Metre stick	1
Markers	1x12 pack

Procedure:

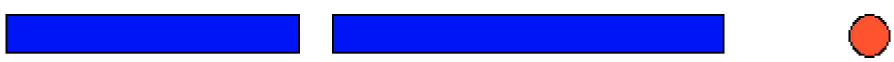
Part 1:

1) Have students pair up
2) Draw the following as far apart on a piece of paper as possible:

3) Have one student **close** their **left** eye.
4) With the right eye, look at the **+**
5) Have second student move the image closer to the student, and ask student to report when the dot **disappears.**
6) Record the distance from paper

Part 2:

7) **TO BE DONE BY MENTOR:** Draw the following on a piece of paper. Place the circle as far away from the bars as possible:



8) Have the student close their right eye.
9) With the right eye, look at the **red circle**
10) Move head closer to image until the blue line no longer looks broken (your brain has filled in missing information).
11) Record the distance

Part 3:

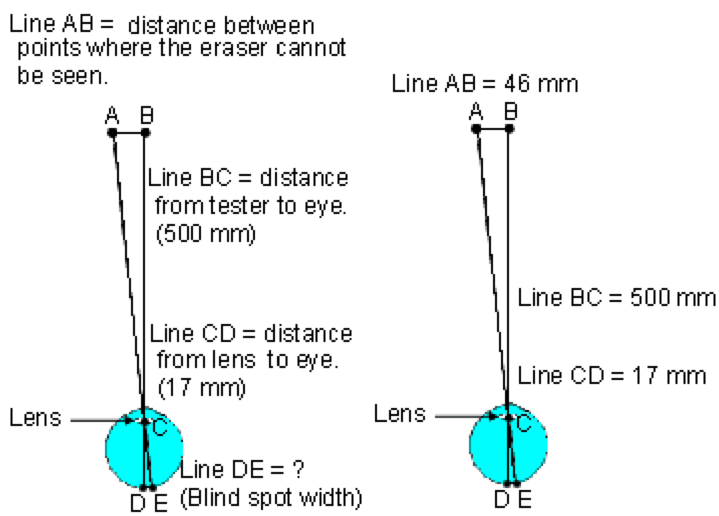
12) **TO BE DONE BY MENTOR:** Draw the following on a piece of paper as far apart as possible:

13) Have the student close their right eye.
14) With the right eye, look at the **+**

15) Move head closer to image until the space in the middle of the vertical lines disappears.
16) Record the distance from paper.

Part 4:

1) **TO BE DONE BY MENTOR:** Make a **tester** by marking + on the far right side of a piece of notebook paper.
2) Have student stand with back to a wall, with their head touching the wall.
3) Hold the tester **500 mm** (0.5 m or 50 cm) in front of their eye. (It may help to have someone help you.)
4) Have student **close** their **right** eye and look at the + with their left eye.
5) Place a pencil **eraser** on the far left side of the tester.
6) Slowly move the pencil eraser to the right.
7) When the eraser **disappears**, mark this location on the tester. Call this point **"A."**
8) Continue moving the eraser to the right until it **reappears.** Mark this location on the tester. Call this point **"B."**
9) **Repeat** the measurements until you are confident that they are accurate.
10) Measure the **distance** between the spots where the eraser disappeared and reappeared.
11) To calculate blind spot width: assume that back of eye is flat, that distance from lens to their retina is 17mm.



Let x represent DE (the blind spot width).

$$\frac{x}{17} = \frac{46}{500}$$

$$500\,x = 782$$

$$x = \frac{782}{500}$$

$$x = 1.564$$

Further optical illusions: http://faculty.washington.edu/chudler/chvision.html

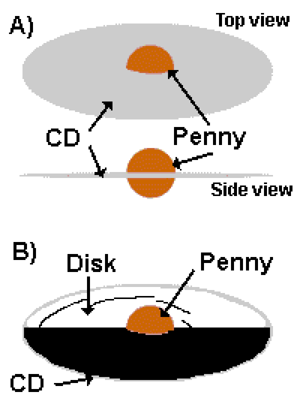
Activity 5: Tricking the Eye

Purpose: To observe that the eye can be tricked into seeing colours using a Benham disk

Item	Quantity (10 students)
Paper patterns	12 cut-outs
Cardboard	12 pieces
Toothpicks	12
Pennie sized Blanks	12
Glue stick	5
Scissors	10 pairs
Drill & Drill bit	1
Blank paper	20 sheets
Black markers	10

Procedure:

1) **TO BE DONE BY MENTOR (prior to activity):** Use the following **website** to print out a mixture of small and large Benham disk **patterns** (12 total): http://faculty.washington.edu/chudler/benham.html.
2) **STUDENTS:** Small patterns should be cut out and glued onto a **cardboard** circle of the same diameter.
3) Large patterns can be glued onto a **CD**.
4) Stick a **toothpick** through the small Benham disks, and a **penny** through the centre of the large Benham disks:



5) When using the tooth pick method, hold to toothpick in one hand and spin the wheel with the index finger of your other hand
6) Rotate disks at a slow speed (3-5 rotations/s). Ask the students to record what colours they observe.

Suggested Variations:

- Change lighting conditions: sunlight, incandescent, fluorescent, etc.
- Change the pattern- have the students make their own using blank paper and a black marker
- Spin clock-wise and counter clockwise
- Change colour of pattern

Additional Resources:
http://www.michaelbach.de/ot/col_benham/index.html

Activity 6: Depth Perception

Source: http://faculty.washington.edu/chudler/chvision.html

Purpose: To observe and understand that depth perception requires input from both eyes

Item	Quantity (10 students)
Pencils	10
Styrofoam cups	5
Penny	5 (have extras)
Laminated target	1
Markers	2
Score sheets	15 pieces of blank paper

Procedure:

Part 1:

1) **To be done in pairs:** Pick up two pencils, one in each hand. Close one eye and attempt to bring the pointed ends of the pencil together.
2) **Repeat** with both eyes open.
3) Have the second student try.

Part 2:

4) **To be done in pairs:** Have students sit across from each other. One student should place a Styrofoam cup 60 cm away from the other (subject).
5) Have the subject **close** one eye.
6) Hold the other student hold a **penny** in the air 50 cm above the table.
7) Have student move the penny around slowly, and ask subject to say **"drop it"** when they believe it will drop into cup.
8) Observe whether it falls into the cup.
9) Repeat with **both** eyes open.
10) Repeat with cup **further** away from subject.
11) Repeat with cup **closer** to subject.
12) **Record and Compare** results of "10 drops" at each distance:

Distance		1	2	3	4	5	6	7	8	9	10	Score
60 cm	One Eye											
	Two Eyes											
90 cm (suggestion)	One Eye											
	Two Eyes											

Part 3:

13) **TO BE DONE BY MENTOR (prior to activity):** Draw a target (circle)on a large sheet of paper.
14) Have one student volunteer to hold an ink marker with tip pointing down above the target.
15) Have another volunteer stand near the target with one eye closed.

16) Ask student with eye closed to direct the student with marker to drop the marker when they think the marker would hit the centre of the target. Try 10 times with one eye closed (different volunteers can be used). Repeat 10 times with both eyes opened. Record results.

Post-test

Eye Spy Trivia

TO BE SET- UP BY MENTOR (prior to activity)

Write each answer on a piece of paper and hide each answer around the classroom. Students should find the correct answer after you read the question.

1) The clear, transparent part of the eye that light waves enter through (hint: front of the eye)

Answer: CORNEA

2) The coloured part of the eye that controls the amount of light entering

Answer: IRIS

3) Structure in the eye that bends light

Answer: LENS

4) An adjustable opening that dilates and constricts

Answer: PUPIL

5) Light sensitive area at the back of the eye

Answer: RETINA

6) Photo-receptors used in dim light conditions

Answer: RODS

7) Photo-receptors used in bright light conditions

Answer: CONES

8) On average, about how many cones are contained in the eye?

Answer: 6 MILLION

9) On average, about how many rods are contained in the eye?

Answer: 120 MILLION

10) What is the nerve that sends visual information to the brain called?

Answer: OPTIC NERVE

11) The region at the back of the eye where there are no photo-receptors is called the _______ ________.

Answer: BLIND SPOT

12) Where did the African proverb presented in today's lesson come from?

Answer: MALI

13) How many passes did the white team make in the gorilla video?

Answer: THIRTEEN (13)

14) What is the condition when a person is unable to distinguish between colours called?

Answer: COLOURBLINDNESS

15) What is perfect vision?

Answer: 20/20