In the Eye of the Beholder: The Process of Eye Development

Breona McNeil, 2019 CTI Fellow
Martin Luther King Jr. Middle School

This curriculum unit is recommended for Middle school students exploring the concept of waves.

Keywords: waves, light, energy, development

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: The idea of waves is such a phenomena to humans, and definitely young adults. This unit will allow students a deeper look into the development of the eye. This unit allows learners to gain the foundational pieces of what light is before going into the different parts of the eye and their functions. Learners will be able to use their knowledge of light and apply it to how the eye sees light. With learning the different functions of the eye, students will learn about developmental eye disorders. With knowing the developmental portion, students will use that knowledge and apply it to different case studies. These case studies will show students that developmental disorders do occur before an individual is born.

I plan to teach this unit during the coming year to 130 6th grade students during the 2019-2020 year.

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Introduction

Rationale

It is known that as life progresses, many things can go wrong. Although many things that can go wrong, we can catch some illnesses, diseases, etc. while symptoms present themselves. Some people are oblivious to symptoms or illness that could affect them in major ways due to not knowing the effects of the illness. The middle school science standards in the state of North Carolina skims the surface of the development of certain organs. Students will not learn about the development of the body until 7th grade and with that, it is only the anatomy of the body. In 6th grade, students learn about the eye and how light travels through. Eye development is not taught during this year in school. How to Build a Human provides the developmental piece to add on to one of the standards taught in 6th grade, which is how the eye perceives light. The basis of this unit is to relay the process of how the eye perceives light.

Demographics

I am a 6th grade science teacher at Martin Luther King Jr. Middle School. Most of our students are transient, so we receive new students quite frequently. In addition to this, our school is about 23% proficient. Over the past year, I have taught children whose reading level is below the current grade level they are in. I have worked with students who are performing above grade level and students who are performing below grade level. Along with our large Hispanic population, good amounts of our children are English learners. .Martin Luther King Jr. middle school serves about 930 students. The demographics of this school consists of 60.3 % Hispanic students, 34.0% African American students, 2.2% Asian students, 1.9% White students, 0.4% Pacific Islanders, 0.2% American Indians. As the years went on, the school's demographics have changed with Hispanic and white students are the majority of the population.

Due to Martin Luther King Jr. serving as a title 1 school, we see a host of students with different needs and struggles. We have 6 students that are McKinney-Vento. These students are classified as students who lack a stable residence. These students often move from place to place. Many times when see these students, they often miss days of school due to lack of stability. We are also a transient school. We have a wide range of students. Many of our students are English Learners. Our population of English Learners range from different levels. Some of these children are newcomers. The newcomers enter into the EL program at a beginner's level and matriculate their way through the program. Our hope is to have our English Learners fluent or have at least moved through the program. Our goal as a school is to teach and to provide our English Learners

with the same opportunity and education the rest of our students receive, despite the language barrier. It is important that our EL students receive the same education as well as building on the students learning English.

Unit Goals

The goal of this unit is to take the scholars on a journey of life towards how the eye sees light, starting in the beginning. The intention is of taking the scholars through the journey of the formation of the body, and especially the eyes. Students will be able to learn this information while going throughout their everyday life as well as taking this information into future science courses. The goal is to extend the knowledge of the students beyond the eye.

Students will begin by learning the process of eye formation. Students will learn that due to cell signaling, we have different organs. Students will go through this journey then will apply it to real life situations. Students will then work with different case studies to determine what went wrong through that specific stage of development. During this unit, the plan is also incorporate different strategies to differentiate and scaffold this unit to the English learners. Along with incorporating differentiation, this unit is intended to reach a middle school student with them being able to grasp the concept of how the eye is formed, the different functions of light, and also developmental abnormalities that could affect the eye. This unit is intended for middle school students who are exploring how the eye sees and processes light from the sun in the form of electromagnetic waves.

Content objectives for this unit are contingent on the North Carolina essential science standards for the 6th grade. Upon completion of the unit, students will understand the process of how the eye sees light and the developmental process of eye formation along with its specific parts.

Content Research

Over the years, scientists have contemplated where human life truly begins. Many scientists have claimed that at the instance of conception is where life begins, or even when the organs start to develop. While the beginning processes of how life begins is very important during the overall process, the different developmental stages are also important. Later on in the process is the birth of different organs. Within these organs, the eye is developed.

The focus is to take the students on an exploration of how the eye works. Before we dive into the function of the eye, the students need to know how the eye became to be what it is, through cell development. As adults, we know that there are separate parts of the eye, but each of the parts of the eye come from different tissues. The life cycle consists of four parts: fertilization, cleavage, gastrulation, and organogenesis.

Fertilization

As the sperm cell makes its way to the egg, the sperm receives support in order to make it there. The uterus contracts in order to pull the sperm closer to the egg. Sperm will also receive directions from fluid flow and temperature signals. Many sperm are lost along the way while only a few hundred sperm will make it to the egg. Once the sperm has a clear direction as to where it is going, it will then start to coordinate to get to the egg. The tail will move with purpose. Once the sperm encounters the egg, it will enter into the egg sideways.[1] Once the sperm reaches the egg, it will then try to burrow itself in the egg realizing that it has to go through different layers.

During fertilization, male and female gametes combine to form one fertilized egg. Only one sperm will make it through to the egg. Once the egg and sperm fuses, genetic material fuses. This process also activates the egg's metabolism. Cleavage is the process where the embryo stays the same size but many cells are created through cell division. During gastrulation, germ layers are formed and body axes are set up. In order for these things to happen successfully, the movements of the cells are crucial.[2] It takes two gametes to make an offspring.

Gastrulation

Cell movements help determine the different organs for the body. During gastrulation, it allows cells to move through the blastopore into the inside of the embryo. As a result of this, three layers are formed: ectoderm, mesoderm, and endoderm. The ectoderm means outside, mesoderm is in the middle, and endoderm are cells from the vegetal hemisphere. The ectoderm is the outer layer of the embryo. It is responsible for making the epidermis, the brain, and the

nervous system[3]. The endoderm makes the epithelium for the digestive system and other organs. The mesoderm is responsible for the blood, kidney, heart, and gonads.

Gametes

Commonly known, a female will produce an egg and a male will produce sperm. There are some cases of an individual having both gametes. These correct term for individuals as such are called hermaphrodites. Differences occur which bring about variation. Variation is a difference in individual organisms caused by genetic differences or by environmental differences. The greater the amount of variation in a species, the more chance there is that an individual will exist that can survive in a particular situation.[4]

Sex Determination

Sex determination is determined by the rise of reproductive organs due to the Mullerian and Wolfian duct. Mullerian ducts develop while the Wolfian duct degenerates if a female phenotype is present. In a male, the Wolfian duct will remain while the Mullerian duct degenerates. If the Mullerian duct is present, organs that will form include the fallopian tubes, uterus, and part of the vagina. If the Wolfian duct is present, organs present consists of the epididymis, vas deferens, ejaculatory duct, and seminal vesicle.[5]

Sex determination varies amongst different species. According to the *National Center for Biotechnology Information*, in humans, each of the females, eggs carry an "X". Half of the male sperm carry an "X" and half carry the "Y". [6] Secondary sex determination comes from the different body parts. If an individual is a male, there are different body parts that consists of penis, scrotum, seminal vesicle, and prostate gland. If an individual were a female, there would be a vagina, clitoris, labia, cervix, uterus, oviducts, and mammary glands. We use these different body parts to determine the sex of an individual.[7]

Organogenesis

Organogenesis is the production and development of the organs of an animal or plant. During organogenesis, of course different organs are developed. During organogenesis, this is when the different cells will begin to move and become organs. Cell signaling is at the forefront of the major development of the body. Cells can send signals; receive them, as well as reciprocating them. [8]

Cell signaling allows the cells to make the executive decision on what actions they will take to get the task completed. Forming the eye as an example. We know that the eye has different parts with different functions. Depending on which cells decide to go where through cell signaling, all of the functions are handled. The formation of the eye is through induction.

Induction

Induction occurs when one cell type has the ability to change neighboring cells. The cell receiving the signal has to have a receptor. The inducer produces a signal. The responder will have a receptor, which makes it able to respond.

We know that eye development is not solely a mammal capability, but an insect capability as well. Experiments were conducted in the past to watch the actual process of eye development. Regulator Ey in flies perform the same functions as Pax-6 in vertebrates[9]. This regulator is crucial for eye development. Ey can signal the formation of an entire organ, not just a single cell type. In a *Drosphila* , the common fruit fly, the Ey gene is expressed earlier during development on the leg. The Ey gene expression has caused an eye to develop in the middle of the leg. The Ey gene binds to DNA sequences in the regulatory regions.[10] In some cases, the regulators will respond to the Ey gene to create a positive feedback loop that ensures that the protein will continuously form. This does not normally happen, this was an experiment to see if eye formation could manifest in a new location.

Eye Development

The eye forms through the interactions of the epidermis and neural tube. It is important that there is communication between the two tissues. The lens, for example, must form over the retina. If there is no communication between the two, the cells designated for these specific functions could work overtime and not work together. The optic vesicle extends from the neural tube. The optic vesicle will then bend to become the optic cup.[11] The optic vesicle plays a major role as it triggers lens formation. The lens will then send a signal to the optic cup and the wall to differentiate and become two separate layers. Those layers are the pigmented retina and the neural retina. Once the lens forms, the ectoderm above it becomes the cornea. Proteins are then secreted which allows for the differentiation.[12] The thyroxine hormone allows drains the tissue, which allows the cornea to become transparent.

Different tissues from embryonic development are responsible for eye development. The lens and cornea derives from the surface ectoderm; however, the retina and epithelial layers of the iris are from the anterior neural plate. The overall process is very complex, but the process is successful if transcription factors and well as signals are at the forefront for ensuring that that the formation of the different components of the eye are correct.[13] In the beginning processes of development a single eye field forms in the middle of the head, inside the anterior of the neural plate during gastrulation. Once the eye field forms, it separates into two separate entities, the optic vesicle and later optic cup. The lens develops from the ectoderm due to the optic vesicle. Once the lens develops, Pax6 acts as a control gene. Pax6 plays a critical role in the formation of tissues and organs during embryonic development.[14] Pax6 is a transcription factor and is seen

throughout eye development. The cornea forms from the surface ectoderm and the iris forms from the optic cup.[15] The outer layer of the optic cup becomes the retinal-pigmented epithelium. The main part of the inner layer of the optic cup forms neural retina with different cells. Among the different cells that form, photoreceptors are one of the cells. Retinal ganglion cells grow towards the optic stalk forming the optic nerve. Once the eye develops, each part of the eye takes on its individual functions.

The Eye

After the development of the different parts of the eye, we know that each part has a very crucial role. The sclera is the white part of the eye and it gives the eye its spherical shape. The cornea is the transparent portion of the eye with the function of providing the eye with focusing power. The anterior chamber is the space in between the cornea and iris. The sole function of the anterior chamber is remained filled with aqueous humor.[16] The iris is the colored part of the eye and the function is to control how much light enters the eye. The iris hosts a small portion called the pupil. The lens contributes to bending the light before the retina receives it to be processed. The focus is to refract light from the outside and into the retina.

The function of the retina is taking the images that are projected and converting them to electrical impulses. Two of the photoreceptors located in the retina are rods and cones. Rods, which focuses in dim light times, such as evening or nighttime; while Cones are used in well-lit situations, such as daytime. After the cones and rods perform their duties, the retina translates what it sees and sends the electrical impulses to the brain via the optic nerve. The optic nerve connects the eye to the brain. Its main purpose is to transport information to the brain.[17]

How the Eye Sees Light

The synopsis of how the eye sees light rays reflect off an object and enters the eye through the cornea. The cornea will refract the light coming through the pupil while the iris regulates the amount of light passing through. Light rays will continue to pass through the lens and bend to focus on the retina. The cells in the retina converts light energy into electrical impulses. The optic nerve sends impulses to the brain, which produces an image.[18]

Defects in Eye Development

In the body, there are things that can go wrong developmentally which can hinder the formation of organs and even body parts. The same thing can occur during eye development as well. Even though there are different conditions that occur after the eyes development, there are conditions that present themselves due to a defect in development. Astigmatism, muscular degeneration, retinoblastoma, retinopathy of prematurity, and cataracts are a few conditions that occur due to a breakdown in eye development.[19] Astigmatism is a defect in the eye or in a lens

caused by a deviation from spherical curvature. Distorted images occur because of the different shape of the eye.[20] Retinopathy of prematurity occurs in premature infants and is the results from abnormal development of blood vessels in the retina. As infants are born, ROP (retinopathy of prematurity) can improve or there could be complications of this specific defect.

Abnormalities of the Eye

As anything else in the body, there are different things that can go wrong in the body. Abnormalities in the human body can occur at any point in time. We have seen that if there is a mutation in any hormone or gene, there is a chance that the genes expression is through a phenotype. Phenotypes are the set of observable due to an organism's genotype.

Amblyopia is a condition where there is limited vision in one eye. The lazy eye wanders inward and outward. The cause of this is due to an abnormal visual experience that occurs earlier in development. The weaker eye will receive fewer signals. The most common cause is a muscle imbalance[21]. Amblyopia is caused by refractive errors, nearsightedness (having trouble seeing things far away) or farsightedness (having trouble seeing things close up), and astigmatism (which can cause blurry vision). Strabismus is the result of both of the eyes move together but within kids, their eyes do not align. On eye my wander and drift into different directions. Cataracts cause cloudiness in the eye's lens. Individuals who are up in age tend to experience cataracts more frequently.

Defects in eye development can lead to major issues such as Microphthalmia, Anophthalmia, and Coloboma just to name a few. In the case of Microphthalmia is when a small eyeball is the result. Anophthalmia is a disorder that occurs from a disruption of the SOX2 gene[22]. SOX2 makes an important protein that is critical for the formation of tissues and organs. The protein produced by SOX2 is a transcription factor. This protein regulates the activity of other genes, especially those that are important for development. If the SOX2 gene is absent, there is a disruption of the other genes. These genes are essential for the development of the eyes as well as other organs.

Coloboma is the result in which a piece of tissue in any part of the eye is missing. During development, a seam known as the optic fissure will close to form the structure of the eye. The result of an optic fissure not forming completely is a Coloboma. During development, there is a change in genes or a chromosomal abnormality. Environmental factors can also affect early development.[23]

Microphthalmia is a condition where one or both eyes are abnormally small. The cause of Microphthalmia could be from chromosomal abnormalities or from environmental factors during development. Some of these factors can include but are not limited to vitamin deficiency, infections, or exposure to substances that can cause birth defects.[24]

Instructional Implementation

Teaching Strategies

Teaching strategies that will be used in this unit are will focus on direct instruction, discovery, and inquiry. Students will have the foundation of the types of waves before entering into light and the developmental portion of the eye. Students will participate in direct instruction through Cornell note style. The importance of vocabulary will be enforced during this unit due to the nature of the content. Students will explore the parts of the eye through a simulation. Simulation will take place on a website where the students will be able to click on different parts of the eye and will be able to discover the different functions of the eye. Students will also learn through hands on discovery.

A model of an eye will be used so that the students can take out the different parts of the eye as well as placing them back together. Students will be placed in groups to do the hands on discovery of the eye. After students learn about the eye and functions, case studies will be introduced. After the foundation of the eye and the different parts of the eye, students will learn about developmental issues that could go wrong. With the knowledge that students will learn throughout the unit, students will be able to work on case studies to determine what happened during development, which caused that specific developmental issue. After, students will be able to research to find possible solutions for the developmental problems acquired during development.

All observations will be written inside of the students' interactive notebooks. Before diving deep into each substandard (6.P.2.1 and 6.P.2.2), students will write down the standard as well as the essential question. By writing down the essential questions, students are made aware of the learning objectives before the beginning of the unit.

Waves: Direct Instruction and Discovery

At the middle school level, students will learn about light through the lens of learning about waves. Students will learn about the different types of waves: transverse and longitudinal. Students will learn the different parts of the waves and will learn how energy moves through the different types of waves. After the students explore the different types of waves, they will move into light waves and how the eye perceives light. Students will use differentiation glasses and will look at a source of light. By doing this, the students should elicit the idea that they see different colors by using the diffraction glasses. Students will brain dump question in their notebook for a set amount of time. This will give students the idea that the eye sees light in a completely different way and will open their minds to the process of how it happens.

Using this strategy will elicit students to name the colors that they see. This will also allow the students who are newcomers to gain additional support to foundational vocabulary that is needed. The remainder of the students should be able to name the colors that they see through the diffraction glasses. Some students start saying the phrase "ROYGBIV", which will give them a push into introducing the electromagnetic spectrum, but more importantly the visible light portion. Students will have questions that they will answer according to their observations.

Teacher will then begin to give direct instruction on light waves through Cornell notes from AVID practices. During direct instruction, students will take notes on light waves and what type of wave it is. Students will take guided notes on light waves and solidifying the concept that they are mechanical waves. In their guided notes. Students will learn that light is a transverse wave that can be emitted from the sun or any light producing objects. Students will solidify the concept that light is energy and not matter. Students will also take notes on light moving through mediums**.** While taking notes, students will learn that light waves are the only waves that can travel through a vacuum. After taking notes, students will see a picture of the electromagnetic spectrum. Students will make observations in their notebooks on which wavelength goes with what specific color of ROYGBIV. Students will then participate in a sorting activity. The sorting activity will serve as a check for understanding for the teacher, then the electromagnetic spectrum will then be introduced. Students will draw this in their notebook and label the wavelengths of the visible light portion of the EMS.

Eye: Direct Instruction and Discovery

It is difficult for students to see the different parts of the eye. After direct instruction, students will participate in discovery of the eye through the interactive website. Students will use this website to go through the different parts and functions of the eye. Throughout the website, students will copy down the functions of the eye in their interactive notebooks. Apart of the website is taking a check for understanding. This check for understanding will be used to solidify the parts of the eye and its functions.

After discovery and exploration, the idea of optical illusion will be introduced through a picture of a dress. In the past, this specific dress is seen to be either be white and gold or black and blue depending on the light. Students will observe on what they see in their interactive notebooks. The dress will lead the students to a TED talk on optical illusion. This will give students insight to the concept of what we perceive is different in reality. After the TED talk, students will revisit their observation of the controversial dress. After the TED talk, a class discussion along with a survey to gauge the students' concept of optical illusion. Optical illusion will introduce students into eye development. Students will learn about the development of the eye. Students will learn which parts of the eye develops during certain periods of development.

This time will be allotted for direct instruction with Cornell note taking. During direct instruction, students will learn about the structural developments up until birth.

Once students take notes on the development of the eye, specifically the different parts, developmental issues will be introduced. Before direct instruction and Cornell note style taking, students will learn about developmental problems through whole class instruction. During instruction, students will take notes in a graphic organizer detailing what happened during development and the effects of such developmental things. Students will then use this graphic organizer to help with the upcoming case studies. The case studies will elicit the students to dive deeper into the content and will provide the students with the opportunity to problem solve.

Students will then explore the Children's University of Manchester website to explore the different parts of the eye. This website is an interactive, which will provide students an experience of seeing the different parts and functions of the eye.

Disorders due to Development

There are a host of things that could go wrong during development. Visual impairments are common, but not many people know about them. Visual impairment limits the ability to see. Some of these disorders can be corrected and some of them cannot. According to the American Optometric Association, the most common cause of visual impairment in non- Hispanic, African Americans, and Hispanics is cataracts.[25] The idea is that students are exposed to these different visual impairments through case studies. Many of the students wear glasses, but are not sure why. Students will receive case studies that will display different disorders.

Students will receive a list of visual impairments: astigmatism, retinoblastoma, cataracts, glaucoma, and retinopathy of prematurity and cortical visual impairment. With this list, the objective is to have students go through the visual impairments and will determine which impairment goes with the case study. After the students determine which impairment goes with the specific case study, students will then dive further and will determine what went wrong during development. During the case studies, students will be able to see that disorders during development are common. Students will also be able to work backwards to find what went wrong in development. Students will be able to use their computers to research the different disorders and the causes of each disorder.

Alternative Activities

The picture book portion of the curriculum will be hands on. This is where students can interact more with the functions of the eye. This will engage the students into learning the different parts of the eye as well as the pathway the eye takes. With this part being hands on, students are able to visually see the pathway and make those connections. The plan is also to

incorporate the different cultures represented in the classroom and to add a social- emotional section in the curriculum. The intent of adding this portion to the curriculum is to provide the opportunity for students to hone in provide the empathy that they will need throughout life.

The picture book can bring life to many things for the English learners. Some of these students have gaps in their education. It is important that what they can connect with, even with certain gaps in education. These students will be able to connect with the basic level of the curriculum. These students are not normally on grade level, so the picture book is a great addition to help students visualize what they are learning.

With technology in the world increasing, there are high hopes for individuals who are struggling with seeing or those having any eye complications. According to *The Medical Futurist,* with the help of technology, "bionic eyes" may be the next step[26]. This is designed for individuals who are indeed blind due to a condition called Retinis Pigmentosa. Retinis Pigmentosa is a condition that causes individuals to lose sight gradually and will affect nearly 1 million people around the world. Visual prosthetics are implanted to restore vision. Students will dive into the world of technology and how it is used to help those who have visual impairments.

Appendix 1

Implementing District Standards

Essential Standard: 6.P.1.1

Compare the properties of waves to the wavelike property of energy in earthquakes, light and sound.

Students will learn about the different types of waves: transverse and longitudinal. Students will also learn about the different parts of waves and the direction of energy and matter in both types of waves.

Substandard: 6.P.1.2

Explain the relationship among visible light, the electromagnetic spectrum, and sight.

Students will learn about the electromagnetic spectrum and the parts of it. Student will dive into the visible light portion of the EMS. Students will then use this to dive into the parts of the eye and its functions. Once students learn the parts of the eye and the functions, students will learn about the development of the eye. Students will use this knowledge to solve case studies.

Appendix 2

Essential Vocabulary for Students

Transverse Wave
Mechanical Wave
Matter
Energy
Electromagnetic Spectrum
Visible Light
ROYGBIV
Cell Signaling
Induction
Optic Cup
Cell Development
Optic Illusion
Sclera
Cornea
Iris/Pupil
Lens
Retina
Optic Nerve
Eye Disorder
Visual Impairment
Microphthalmia
Anophthalmia
Coloboma

Appendix 3

Materials

Model Eye (will be used for the hands on discovery activity)
Diffraction Glasses
Interactive Notebooks
Chromebooks/ Computers

Appendix 4

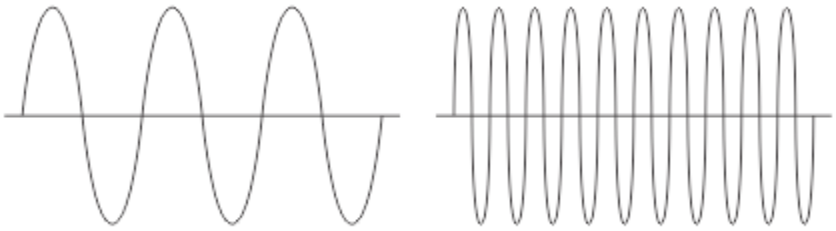
Check for Understanding

CFU for Light Waves

1. The electromagnetic spectrum is the complete range of electromagnetic radiation ranging from radio waves to gamma rays. Which type of radiation in this spectrum is associated with observable colors such as red, green, and blue? (6.P.1.2)
   A. Gamma Rays
   B. X-Rays
   C. Visible Light
   D. Radio Waves

2. Which part of the electromagnetic spectrum can humans sense without using equipment or technology? (6.P.1.2)
   A.Radio Waves
   B. Visible Light
   C. Microwaves
   D. X-Rays

3. This is a wave pattern diagram for two transverse waves. (6.P.1.1)



How do the waves compare?

A..Both waves have the same frequency
B. Both waves have the same wavelength
C. Wave 1 has a longer wavelength than Wave 2
D. Wave 1 has a higher frequency than Wave 2

4. Waves transmit _____ not _____. (6.P.1.1)
   A. light, sound
   B. matter, energy
   C. heat, energy
   D. energy, matter

5. The leaf of a plant looks green because _____. (6.P.1.2)

A. it absorbs green light.
B. it reflects only yellow light.
C. the leaves absorbs all other colors, causing the reflection to appear green.
D. it reflects the white light from the visible spectrum.

6. In the image, what is the pathway of light that allows the person to see the flower? (6.P.1.2)

A.. Sun → person's eyes → flower
B. Person's eyes → sun → flower
C. Flower → sun → person's eyes
D. Sun → flower → person's eyes

7. What do waves carry through objects? (6.P.1.1)

A. sound
B. light
C. energy
D. water

Appendix 5

Due to the demographic of students that I teach, some students will receive graphic organizers while others will take traditional notes. Students will research the different types of eye disorders and will fill out this graphic organizer to use for the upcoming case studies.

Developmental Eye Disorders	Effects of the Disorder	Complications during Development

Student Resources

"How the Eye Works." *The Children's University of Manchester*, www.childrensuniversity.manchester.ac.uk/learning-activities/science/the-brain-and-senses/how-the-eye-works/.
The Children's University of Manchester website is a helpful studentresource because it is an interactive website, which provides students with basic knowledge of the different parts of the eye. This website sets the foundation for the additional knowledge that the students will gain through this curriculum unit.

"The Future of Vision and Eye Care." *The Medical Futurist*, 10 May 2019, medicalfuturist.com/future-of-vision-and-eye-care/.
This website is a great source because it provides students with the knowledge of possible solutions to many different eye malfunctions. There are many different possibilities of solutions that can fix many of these problems.

Teacher Resources

Alberts, Bruce, et al. *Essential Cell Biology*. Garland Science, 2009.
This essential cell biology textbook provides teachers with the foundation of cell differentiation at a molecular level. The *Essential Cell Biology* also provides examples of cell differentiation. This book is used to gather solid information for teachers to build upon while teaching this curriculum unit.

Notes

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[1] B. Kern. (Meiosis to Gender]. 2019
[2] B. Kern. 2019.
[3] Scott Gilbert. “Chromosomal Sex Determination Mammals”. 1970
[4] B. Kern. 2019.
[5] Scott Gilbert. 1970
[6] Scott Gilbert. 1970
[7] Scott Gilbert. 1970
[8] B. Kern. 2019.
[9] Alberts Bruce et al. Essential Cell Biology Textbook. 2009.
[10] Alberts Bruce et al. 2009
[11] Graw. “Eye Development”. 2010
[12] Graw. 2010.
[13] Graw. 2010
[14] Pax6. Genetic NIH.
[15] Embryology. Eye Malformations.
[16] Healthida. “14 Parts of the Eye and its Functions”
[17] Healthida. “14 Parts of the Eye and its Functions”
[18] American Optometric Association. “How Your Eyes Work”.
[19] AOA. “Common Eye and Vision Conditions.”
[20] AOA. “Astigmatism”.
[21] “Ambylopia”. National Eye Institute
[22] SOX2 gene. Anophthalmia Syndrome. NIH
[23] Anophthalmia disorder. Genetics Home Reference
[24] Microphthalmia disorder. GHR.
[25] AOA. “Cataracts”.
[26] The Medical Futurist. “The Future of Vision and Eye Care”. 2019.

Bibliography

Alberts, Bruce, et al. *Essential Cell Biology*. Garland Science, 2009.

Alicia. "14 Parts of The Eye and Its Functions [COMPLETE]." *Healthida*, 19 Nov. 2019, healthida.com/parts-of-eye/.

"Amblyopia (Lazy Eye)." *National Eye Institute*, U.S. Department of Health and Human Services, nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/amblyopia-lazy-eye.

"Astigmatism." *American Optometric Association*, www.aoa.org/patients-and-public/eye-and-vision-problems/glossary-of-eye-and-vision-conditions/astigmatism.

"Coloboma - Genetics Home Reference - NIH." *U.S. National Library of Medicine*, National Institutes of Health, ghr.nlm.nih.gov/condition/coloboma#genes.

Graw, Jochen. "Eye Development." *Current Topics in Developmental Biology*, U.S. National Library of Medicine, 2010, www.ncbi.nlm.nih.gov/pubmed/20691855.

Gilbert, Scott F. "Chromosomal Sex Determination in Mammals." *Developmental Biology. 6th Edition.*, U.S. National Library of Medicine, 1 Jan. 1970, www.ncbi.nlm.nih.gov/books/NBK9967/.

"How the Eye Works." *The Children's University of Manchester*, www.childrensuniversity.manchester.ac.uk/learning-activities/science/the-brain-and-senses/how-the-eye-works/.

"How Your Eyes Work." *American Optometric Association*, www.aoa.org/patients-and-public/resources-for-teachers/how-your-eyes-work.

"Human Abnormal Development." *Embryology*, embryology.med.unsw.edu.au/embryology/index.php/Human_Abnormal_Development.

Jacobs, Nathan S. "How Optical Illusions Trick Your Brain." *TED*, www.ted.com/talks/nathan_s_jacobs_how_optical_illusions_trick_your_brain?language=en.

Kern, B. (2019). (From Meiosis to Gender]

"Lazy Eye (Amblyopia)." *Mayo Clinic*, Mayo Foundation for Medical Education and Research, 7 Aug. 2019, www.mayoclinic.org/diseases-conditions/lazy-eye/symptoms-causes/syc-20352391.

Ludwig, Parker E. "Embryology, Eye Malformations." *StatPearls [Internet]*., U.S. National Library of Medicine, 4 Feb. 2019, www.ncbi.nlm.nih.gov/books/NBK482496/.

"Microphthalmia - Genetics Home Reference - NIH." *U.S. National Library of Medicine*, National Institutes of Health, ghr.nlm.nih.gov/condition/microphthalmia#genes.

"Nutrition and Cataracts." *American Optometric Association*, www.aoa.org/patients-and-public/caring-for-your-vision/nutrition/nutrition-and-cataracts.

"PAX6 Gene - Genetics Home Reference - NIH." *U.S. National Library of Medicine*, National Institutes of Health, ghr.nlm.nih.gov/gene/PAX6.

"SOX2 Anophthalmia Syndrome - Genetics Home Reference - NIH." *U.S. National Library of Medicine*, National Institutes of Health, ghr.nlm.nih.gov/condition/sox2-anophthalmia-syndrome#genes.

"SOX2 Gene - Genetics Home Reference - NIH." *U.S. National Library of Medicine*, National Institutes of Health, ghr.nlm.nih.gov/gene/SOX2.

"The Future of Vision and Eye Care." *The Medical Futurist*, 10 May 2019, medicalfuturist.com/future-of-vision-and-eye-care/.