



***Natural Light, Artificial Light, and Pollution:
Effects on Evolution, Behavior, and Photosynthesis***

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This curriculum unit is recommended for:
Teachers of high school self-contained Special Education classes
and for teachers of general education high school biology
and chemistry classes in order to provide laboratory experience.

Key Words: Light, opaque, translucent, transparent, bioluminescence, electromagnetic spectrum, infrared light, ultraviolet light, visible light, wavelength, frequency, photoelectric effect, wave, reflection, refraction, diffraction, speed of light, constant, photosynthesis, chlorophyll, chloroplast, autotroph, heterotroph, carbon dioxide, cyanobacteria, symbiosis, pollution, surface area, pigment, optic nerve, light pollution, behavior, adaptations, stimuli, photoreceptors, rods, cones, trichromatic, hue, intensity, fovea, lens, retina, cornea, pupil, iris, opsins, phototransduction, eye spots, occipital lobe, nocturnal, diurnal, and crepuscular.

Teaching Standards: See [Appendix 1](#) for teaching standards addressed in this unit.

Synopsis: This focus of this unit is to teach students with intellectual disabilities about light, the properties of light, light and plants, and light and animal vision. This unit will provide a completed adapted chapter and worksheets. The unit will begin with an introduction to light and a brief discussion on the properties of light. The second lesson will provide an overview of photosynthesis. The lesson will cover how it is essential to life on Earth. The students will explore how light from the sun influences food chains and how different autotrophs process sunlight in a similar way. The final lesson will provide information on light and perception. The students will explore the evolution of color vision in vertebrates, how different animals in different phyla have similar visual structures, and about the structure and function of the human eye. The plant and animal lessons will also have information on air pollution and the effect on plant development and light pollution and the effect on animal behavior. The lessons will involve hands-on experiences as well as adapted assessments and worksheets.

I plan to teach this unit during the coming year to 13 students in grades 9-12.

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Introduction

Individuals with disabilities are educated in a variety of settings in public schools. In order to receive special education services, the student must have a condition defined as a disability by the Individuals with Disabilities in Education Act 2004 (IDEA), the disability must have an adverse effect on educational performance, and, as a result, the student requires specially designed instruction in order to access the general education curriculum. Once students meet all three criteria, an educator writes an Individualized Education Program (IEP) in which a team creates student specific goals, objectives, and identifies other supports that help the student access the general education curriculum. Students with IEPs must have them addressed annually and adjusted based on student progress. IEPs ideally involve parental input. Collaborative IEPs have resulted in positive outcomes that address student needs more accurately¹. Most students with disabilities are educated using the inclusion model. The inclusion model of education has given many students with disabilities the opportunity to receive instruction along with their same age peers without disabilities. This movement has integrated students with and without disabilities into the school environment at large. Inclusion is most prevalent among students with higher incidence, or less severe, disabilities (learning disabilities, some Autism) than it is for students with lower incidence, or more severe, disabilities (students with intellectual disabilities).^{2 3}

The requirements of IDEA 2004 has changed how individuals with disabilities have received instruction in school. IDEA 2004, much like its predecessors, requires school districts to provide students with disabilities a Free and Appropriate Education (FAPE) in the Least Restrictive Environment (LRE). LRE refers to the amount of school time students with disabilities spend with peers without disabilities. The more time in a general education setting, the less restrictive the environment. Students with higher incidence disabilities are provided with fewer supports and less service time than students with lower incidence disabilities. Many students with high incidence disabilities are able to progress on the general curriculum and are able to take honors and Advanced Placement classes.^{4 5}

In contrast to students with high incidence disabilities, students with intellectual disabilities are served in classrooms where they are removed from their peers without disabilities for the majority of their school day. A mild intellectual disability is defined as having an IQ two or more standard deviations below the mean of 100 (50-70) and deficits in adaptive behavior. A moderate intellectual disability is defined as having an IQ three standard deviations below the mean of 100 (35-49) and deficits in adaptive behavior. Students served in the separate classrooms have significant delays in cognitive processing as compared to their peers without disabilities. According to Browder et al. (2007), prior to the implementation of No Child Left Behind (NCLB) and IDEA 2004, many students with significant disabilities were not exposed to academic content. Students were taught functional tasks and were not expected to take end of grade assessments⁶. However, after the passage of IDEA and NCLB, districts were held accountable for student performance.⁷ The change in law also lead to an increase of research based strategies for instructing students with intellectual disabilities. The majority of research on the academic development and skill acquisition of students with intellectual disabilities is

through single subject design experiments using Applied Behavior Analysis, behavior shaping, chaining, and systematic instruction, which involves the use of task analyses.^{8 9}

Following the requirements of the new laws, students with intellectual disabilities were expected to be exposed to and make progress on academic content. Students who receive instruction on academic content and standards have improved independence, demonstrate increases in self-determination, and an improved ability to make choices.^{10 11} However, students with intellectual disabilities have difficulties with accessing plain text information, writing information, reading, information recall, fluency, and generalization. In order to access grade level material, the students must receive information that has been adapted. Adaptations can be created in a variety of ways. The most popular research based methods are adapted text using picture symbols, use of videos, use of the prompt hierarchy and errorless learning, and development of materials using the Universal Design for Learning. These adaptations can be used in isolation, but they are more commonly used in combination in order to get the best outcomes and student responses. These adaptations also operate on the idea of developing stimulus discrimination and shaping behavior; which is typical in the use of applied behavior psychology strategies.¹²

Rationale

The purpose of the unit is to expand the educational opportunities for students with intellectual disabilities. Students with intellectual disabilities have limited options for academic programming. Science instruction in the self-contained classroom is largely limited to brief lessons about safety, different animals, brief discussions of illness, and health. This unit will expand the science curriculum offered to students in the Extensions Program and is designed to provide students with intellectual disabilities access to information provided to their peers without disabilities. The idea for this unit came from the initial seminar meetings in April 2018. The information on the relationship between vertebrate evolution in aquatic habitats and the development of color vision was intriguing. The students will learn about light and the relationship between light and life. The students will also learn about how air pollution affects photosynthesis and light pollution affects animal behavior. The unit will provide adapted text and assessment opportunities to promote literacy and independent reading. The goal for this unit is for the students to draw connections between sunlight, evolution, the cellular structure of plants, food chains, the evolution of color vision and the cells involved in detecting color in the habitat. Another aspect of the unit will be to teach students how to evaluate sources and to connect different aspects of science into a unified whole (biology, light chemistry, and physics). The courses will be conceptual and will provide opportunities for students to analyze information and construct learning opportunities.

The science curriculum for students with intellectual disabilities is very broad and general. Prior to 2008, the Extensions Program of Charlotte Mecklenburg School System's EC Department did not have a standard curriculum or materials for teachers to use in the classroom. Many teachers were not given age appropriate teaching materials. The focus was more on functional education and grade appropriate education, which was based on IQ, reading ability, and adaptive behavior. Beginning in 2007, teachers were required to teach students grade appropriate science that would prepare students to access the North Carolina alternate assessment for 10th graders called the Extend 1. Many teachers began to adapt grade appropriate textbooks

in order to provide instruction; however, the teacher made curriculum varied in complexity and depth. In 2008, the system adopted Attainment's *Teaching to Standards: Science* by Ginevra Courtade as the science curriculum. The book was based on peer-reviewed research in teaching students with intellectual disabilities. The curriculum included picture symbols, choice cards, instructions for use with the prompt hierarchy and the use of systematic instruction when teaching lessons.¹³ The book covered topics on earth science, plants, cells, and the water cycle and was designed for grades 6 to 12. The book did not have information about different animals, food chains, pollution, etc. Therefore, many high school teachers were required to develop content using available high school science texts. Another shortcoming of *Teaching to Standards: Science*, is the depth of information presented.¹⁴ Each of the chapters presented a survey of the topics and did not require much complexity of thought in terms of vocabulary, information presented, assessments, and hands on activities. The scarcity of adapted and complex content and the age of the district provided materials has created an opportunity for the development of a new unit that will stimulate and challenge students in the separate classroom.

School Setting

William A. Hough High School is a large suburban high school in Cornelius, North Carolina. Hough is a comprehensive high school that offers a variety of educational opportunities. Hough offers 26 Advanced Placement classes, an Exceptional Children's Program, an English Language Learner program, a Junior ROTC program, a Visual Arts and Fine Arts program, and a variety of Career and Technical Education (CTE) courses. Hough is becoming more culturally diverse as the communities it serves continue to grow. The school has a total enrollment of 2,572 students during the 2018-2019 school year. The student body is 76% White, 11% African American, 7% Hispanic, 3% Asian, 2% multiracial, and 1% other nationalities. 16.8% of Hough students receive free and reduced lunch. Hough had a 94% graduation rate in 2017-2018. .

I teach in a program for students with mild to moderate intellectual disabilities. The students can also have concomitant Autism or physical disabilities. The four classrooms for students in my program comprise the Extensions Program (EP). The program has 28 students. All students are educated on the Extensions of the Common Core course of study. The Extended content standards are based on the standard course of study, but are adapted to address only the basic ideas and concepts presented in the standard course of study. For example, students on the standard course of study are expected to analyze sources of energy for organisms and to analyze different adaptations. Students on the extensions are only expected to identify very concrete examples of energy and animal relationships. Students on the extensions are not expected to develop a deeper understanding of the curriculum. However, teachers of the extensions are given significant leeway in how to design lessons and to vary the complexity of the content presented to the students.

The four classrooms are divided by grade band. The students in the 9-12 grade band are in the high school program. Once the students turn 19, the student is placed in the transitions program; which seeks to prepare students for life after high school. Each of the teachers has a homeroom that meets daily. My homeroom of eight students completes writing or typing a daily schedule, a daily journal entry, and collects weather data. Prior to beginning science, my homeroom completes a daily KWL/Scientific Method activity where students collect data during the day. The daily meteorologist records and compares the data to the hypotheses from the previous day and from student homework. Following homeroom, I teach the 12 students in the

9-12 grade band science and social studies. My science units are on the features of organisms, application of the features of organisms to real life examples and videos, the study of reproduction, cells, food chains, systems, energy, taxonomy, evolution, and the different chordates. My social studies lessons are on psychology and sensory processes. All of the Extension Program teachers teach different applied vocational activities in order to give the students a survey of skills required to complete different jobs (packaging, clerical, custodial, etc.).

Background

My Science Class

I have created an adapted textbook covering the features of organisms, taxonomy, and the different chordates. I have made different assessments and worksheet activities that involve application and analysis level student responses. I use a wide variety of YouTube videos, pictures, preserved specimens, and word cards to supplement and extend the content. I am not interested in the speed with which I move through the different topics. I prefer to work on depth of understanding and helping students to discover connections between the different organisms discussed. I also use models and specimens to demonstrate the similarities between humans and different animals. My lessons will usually last one month or more with time for review and continual assessment. I have started to teach my students on the importance of sunlight on the development of different terrestrial and aquatic ecosystems. My lessons involve analyzing food chains described in videos and pictures. The students are also beginning to draw connections between evolution, the involvement of food chains, and organism growth and development. I use an interactive whiteboard to project adapted chapters, tests, and information. The students also receive adapted textbooks with information adapted from grade appropriate texts so they can access the lessons. Adapted text provides pictures with words, which help students to read using context clues. My books and lessons are updated with new information and research continually.

Teaching Strategies

Picture symbols (see Figure 1) involve combining a picture with a word to provide context cues in text. The symbols can be either abstract drawings or concrete pictures. They can be presented in isolation or as a part of a whole narrative. Picture symbols can help improve independent reading and comprehension in students with intellectual disabilities.¹⁵ When text is supplemented by picture symbols, students are able to point to the picture and word combination. The association helps to promote retention, especially following repeated trials learning and repetition of the content. Evmenova and Behrmann (2011) also discussed the use of videos in instruction. When coupled with picture symbol text, closed captioning, and frequent checks for understanding, videos help to provide concrete examples to abstract and difficult topics. *For example,*

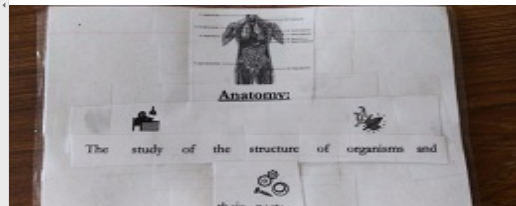
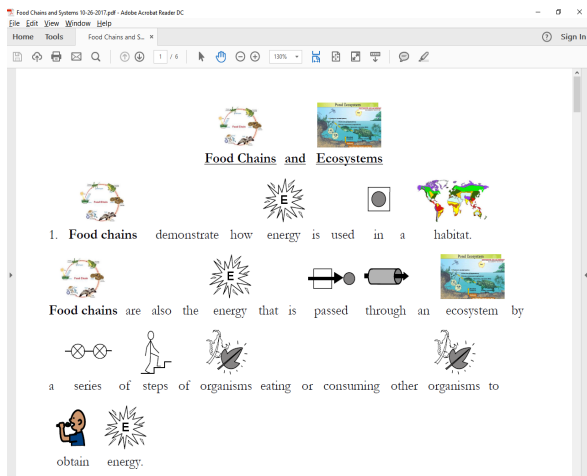
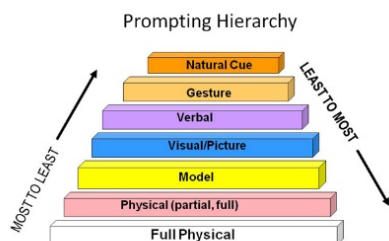


Figure 1.

The prompt hierarchy (see figure 2) is a continuum that is used to indicate the level of support required by a student when presented with academic materials and activities. The levels of the prompt hierarchy are, from least intrusive prompting to most intrusive prompting: independent, gestural, verbal, visual/picture, modeling, partial physical, and full physical. Errorless learning is teaching the correct response over the incorrect during trials. Prompting is used to make sure the student focuses on the correct response and not the incorrect in order to promote generalization and fluency. Independent means that the student is able to access the academic material or activity without supports from the teacher. Independence is different for different students based on ability level. For example, one student may be able to complete a worksheet by writing the answers, another student may be able to complete the activity with a worksheet with picture symbol answer choices, and another student may be able to answer the same questions with the answer choices presented in an array and the worksheet items one at a time. Gestural prompting involves the use of pointing to the choices after the instruction is given and the student has not responded or has responded incorrectly. Verbal prompting involves the use of a sound, word, or phrase to prompt correct responding by the student. Verbal prompts can be non-specific, using only a small sound, or specific, using a whole word or phrase. Picture/visual prompt involves the use of a picture symbol in isolation in order to prompt the correct response following an instruction. Modeling prompts involve the teacher or peer modeling the correct response following an instruction or question. Physical prompts are used when the student is unable to complete the correct response following use of all other prompts. Best practice with the prompt hierarchy is to expect independent responding and to move down from least intrusive prompts to most intrusive prompts until the student is able to perform the correct response. The goal with prompts is to fade the use until the student is able to respond independently.

Figure 2 (M.A.S.T.)¹⁶



The students are also provided information and academic materials based on their ability to read and understand symbolic representation of information. The levels are Readers/Level 3, Level 2, and Level 1. Students

who are classified as Readers/Level 3 are able to read some words and are able to access information presented in either plain text or using abstract symbols. These students are able to write or read with more independence than students classified as either Level 2 or Level 1. Students classified as Level 2 are beginning to associate abstract symbols or letters/words with concepts or words. However, these students require concrete images to help them understand concepts without error. For example a students may need a picture or drawing of a ball to represent the word ball. Students classified as Level 1 are just beginning to associate words and information with objects. These students require actual objects or concrete representations of concepts in order to demonstrate comprehension. Many students in self-contained classrooms are unable to speak (are non-verbal). These students are provided with Augmented and Alternative Communication (AAC) devices such as a “cheap talk”, a Big Mack, etc. These devices allow an instructor to record vocabulary or requests. The student can then push the button in order to play the word or request in order to participate in class verbally.

Universal Design for Learning (UDL) is a classroom practice based on architectural principles (the curb cut, handicap access, etc.). The goal is to create lessons or materials that provide access for the most students and making the classroom accessible to all learners.¹⁷ UDL combines all of the teaching strategies, especially the use of videos and picture symbols. Picture symbols are paired with words. Therefore, the students who are able to read plain text can access the material and use the pictures for context cues to help them define the word. The pictures will also allow the student who is unable to read to access the academic content. UDL also involves the use of technology to present information and to create communication adaptations.¹⁸ Many of the classrooms for students with intellectual disabilities in Charlotte Mecklenburg Schools come equipped with interactive whiteboards. Students use the interactive whiteboards to see class information, control videos, complete adapted writing activities, and to make presentations. UDL promotes inclusion in the classroom by making the content accessible to all students.

All of these strategies are common practice in the self-contained classroom. There is a wide variation in ability level among students; however, all can benefit from use of the best practice methodology. Some students in self-contained classes are able to read and write. Simple picture symbols promote independence by allowing them to use the picture to determine meaning. Other students, who are unable to read, can use the picture symbols to make choices. All of the students benefit from the use of the prompt hierarchy to learn correct responses and to increase independence in responding to learned and novel stimuli.

Content Research

Light is all encompassing. The study of light informs research in biology, physics, chemistry, computer science, and art. Light provides a window into how life is sustained and provides a counterpoint to the exceptions (deep ocean, caves, etc.). Light can be studied in terms of colors and human perception of visual stimuli; therefore, connecting light to animal behavior and sensory processing. With regard to biology, the study of light also necessitates the study of photosynthesis, how light affects animal behavior, the effect of pollution on light reception, and animal photoreception. The unit on light can be taught as a stand-alone unit or the information

can be embedded into lessons on food chains, animal behavior, and psychology. The unit will take a month or two to teach.

Light

Britannica Publishing (2013) provided a very easy to read overview on the general concept of light. The slim volume covered the interaction between light and objects. In this section, the book covered how light travels in a straight line. When the light strikes an object, the light scatters or is absorbed leading to an image of the object. This section covered the different types of objects, transparent, translucent, and opaque. The section covered the concepts of reflection, refraction, and diffraction. The final three sections covered the speed of light, and the particle and wave theories of light. The book provided information on research that led to our current understanding of light and the scientists that were responsible for the advances.¹⁹

Photosynthesis

Hopkins (2006) wrote a slim book on photosynthesis and respiration in plants. He covered the structure of plants and the mechanism of photosynthesis. There was also a discussion on the effect of pollution and the Greenhouse Effect. The book provided the basics about photosynthesis and plant development, but went in more detail than I can use with my students.²⁰

Ballare, et al (2012) discussed that light and an increase in light interception improves plant immunity to diseases. Shade, a lack of light, affected the ability of plants to fight disease and herbivores. Access UV-B radiation improved plant resistance to disease and herbivory. Ballare found that plant density reduced photosynthesis and leaf area.²¹

Air Pollution and Plants

Cotrozzi, et al (2017), addressed climate change and air pollution. The researchers used spectroscopy to assess the effect of pollutants on plants in the Mediterranean. He determined that air pollutants affect the growth and longevity of plants. The main pollutant observed was ozone from vehicle exhaust. The article also focused on the development of spectroscopy. Their literature review found that plant biologists focused on light from the sun, both visible and invisible. Pollutants in the atmosphere absorbed a significant amount of sunlight. The radiation that reached the plants was diffuse or reflected. The plants affected by pollution reflected more light and aged prematurely.²²

Dhir (2016) also researched the effect of air pollution on plants. He found that pollutants increase plant aging and reduce the ability of plants to absorb light. Pollution reduced the leaf area and, therefore, reduced the number of photoreceptors available for the plants. The reduction in the ability of the plant to harvest light reduced the ability of the plants to fight diseases. Too much pollution damages leaves and reduces the ability of plants to photosynthesize light.²³

Saunders (2017) researched photochemistry and the ability of sunlight to excite electrons. Sunlight excites the electrons in pollutants and fundamentally changes the structure of the pollutants. Saunders also found that the polycyclic aromatic hydrocarbons (PAH) absorb solar energy.²⁴

Perception

Myers (2014) provided a psychological and physiological of the development of the eye and human visual perception.²⁵

Morshedian and Fain (2017) explored the evolution of the vertebrate eye. They discussed the presence of rods and cones in lamprey eyes. Lampreys are similar to early aquatic vertebrates. The number of rods and cones in lampreys is comparable to the number of rods and cones in mammals. Jawed vertebrates (gnathostomes) evolved from vertebrates without jaws (agnathans). Therefore, light adaptation occurred early in vertebrate development and evolution.²⁶

Fernald (2006) determined that the evolution of the animal eye was based on available light. Most animals have image forming eyes. The genes of fruit flies and mice were explored. He found that cephalopods and fish eyes evolved similarly despite differences in structure. The similar genes and function of the photoreceptors point to convergent evolution in a similar habitat. Fernald also discussed that habitats influence light sensitivity, such as clear water and swamps. Vertebrates and invertebrates have different eye structures and use different proteins (opsins) for wavelength discrimination. However, the eyes of most animals function in similar ways.²⁷

Light Pollution

Ouyang, et al (2017) researched the effect of artificial lighting and light color on the behavior of organisms in their natural habitat. Certain wavelengths of light increased stress hormones, suppressed immunity, increased stress, and disrupted sleep patterns in certain animals. Increased artificial light increased the activity of predators and the activity of birds near the light. They found that white light had more of an effect than red or blue lights.²⁸

Bliss-Ketchum, et al (2016) observed the effect of artificial light on the animal use of a passage. The light disrupted habitat connectivity, physiology, and animal behavior. The light reduced habitat connectivity for organisms negatively affected by artificial light. Certain organisms did not use the passages when there was light and chose riskier methods for crossing. These animals were more likely to become prey because of the light. They found that darkness encouraged the use of the passages.²⁹

Solano-Lamphar and Kocifaj (2013) tested the vision of insects and humans. They tested different types of lights and the sensitivities of the different organisms. They found that humans were sensitive to LED lights, aphids were sensitive to yellow lights, and that butterflies were sensitive to sky glow. They also found that diurnal insects were attracted to artificial light. The activity of the diurnal insects changed the predation patterns of some bats, spiders, and birds. The predators began eating the diurnal insects. They also explored the differences in the rod and cone levels required for scotopic, mesopic, and photopic vision.³⁰

Prerequisites

Prior to teaching the unit, teachers should instruct students on the basics of food chains, discuss the difference between heterotrophs and autotrophs, and differentiate how animals obtain body heat. The teacher should also provide general information on taxonomy; specifically, on the taxonomy of the Eukarya domain. Finally, teachers can use Brain Pop videos on the Sun ³¹, Color ³², and the Eyes ³³ to provide a preview for some of the concepts in the unit. Brain Pop offers short and humorous videos that provide great overviews on information in all academic disciplines. The videos can be used again in the unit to review and to support current learning.

Unit Lessons

The instructional unit will involve lessons on the interaction between light and biology. Lesson 1 will provide a general overview of light, the electromagnetic spectrum, light and life, and a brief overview of light and evolution. Lesson 2 will focus on photosynthesis and plants. Lesson 3 will involve light and perception. Finally, lesson 4 will focus on light and air pollution. All lessons will provide adapted text from different textbooks and research.

Lesson 1 will discuss light in a conceptual manner. The lesson will describe the composition of light, the electromagnetic spectrum, and the influence of light on the development of life on Earth.^{34 35} The lesson will involve the use of videos, activities using different sources of light, and adapted text. Lesson 1 will also involve art activities using different colors and using a camera to take pictures in different sources and levels of light.

Lesson 2 will involve an overview of photosynthesis.³⁶ The students will learn how plants get their energy from sunlight. The students will also learn about the role of plant cells and chlorophyll in providing energy for the plant. The lesson will involve an overview of general information about plants and students will differentiate plant and animal energy sources. Finally, the students will review how sunlight affects the health of a plant and its ability to fight disease and herbivores.³⁷ The lesson will provide an overview of the current research on air pollution and its effect on photosynthesis.³⁸ The students will learn about reflectance and the reduction in leaf area. To assess the effects of pollution at a local level, the students will collect leaf samples and learn to use a spectroscope.³⁹ Lesson 2 activities will involve aquaponics and an experiment involving light and the density of plants in an area.

Lesson 3 will discuss light and perception. This lesson will involve an overview of the human eye and its photoreceptors. The students will learn about how the eyes collect light information and turn the information into images. The students will also relate visual stimulus processing to animal behavior. This lesson will also provide information on the evolution of animal eyes and, more specifically, chordate eyes.^{40 41} The students will create art projects based on the eyes of different animals. The students will also take pictures in different levels of light and determine the effect of level of light on the image. The students will also learn about the effect of artificial light and light pollution on the behavior of different animals.^{42 43 44} The students will compare the behavior of animals in locations that are darker at night to areas that have artificial lighting. The students will also connect the effect of air pollution and the coverage of artificial light to create a longer lasting crepuscular effect for urban areas. This

lesson will involve the use of a critter cam to observe the nighttime activities of animals around the school.

Learning Experiences

Lesson 1: Light: The Basics (see appendix 2 for adapted text and appendix 3 for materials)

Objective

1. Given AAC devices and adapted text, and videos on the Smart Board, the students will read the adapted information on the conceptual nature of light and light as energy.
 - a. Given adapted information on light, the students will interact with the information by choosing either the correct vocabulary word presented as a choice card or in text that describes the properties of light (photon, energy, wave, particle, diffraction, etc.).
 - b. Given information on the different types of Electromagnetic radiation, the students compare and contrast the visible and invisible spectrums of light.
 - c. Given different photographs, the students will determine the type of light used to take the photograph (X-ray, thermal, standard, etc.).
 - d. Given information on different organisms (snake, bee, human), the students will observe videos and images from animal perception to compare and contrast the spectra of light available to the organism.
 - e. Given different sources of visible light, the students will compare and contrast artificial and natural sources of light (sun, vents, volcanoes, bioluminescence, etc.).
2. Given AAC Devices, adapted text, and videos on the Smartboard, the students will learn about how light interacts with different objects.
 - a. Given different types of objects (transparent, translucent, and opaque), the students will compare and contrast how light interacts with each.
 - b. Given a mirror, water, and an opaque object (desk), the students will compare and contrast the different types of reflection (mirror or diffuse reflection).
 - c. Given a mirror, a desk, and a camera flash, the students will demonstrate different types of reflection.
 - d. Given information on refraction and white light, the students will compare and contrast what happens to white light during reflection and refraction.
3. Given AAC Devices, adapted text, and videos on the Smartboard, the students will learn about the wave and particle theories of light.
 - a. Given a light and shadows of different objects in the classroom, the students will learn how Newton determined light to be comprised of particles based on the borders of the shadows.
 - b. Given metals and a source of light with heat energy, the students will put the light on metal to demonstrate and define the photoelectric effect.
 - c. Given a video and adapted text on the Thomas Young slit experiment, the students will observe how the behavior of light is wave like.
 - d. Given information on wavelengths and different colors, the students will compare and contrast the wavelengths of different colors

- i. Given pictures of the sun at different points on the horizon, the students will determine the points with different wavelengths and the colors observed.
4. Given information on the speed of light, the students will learn how the speed of light stays the same no matter the location.
 - a. The students will identify the speed of light when given a choice.
 - b. Given two flashlights and a stop watch, the students will perform the Galileo experiment from different distances.
5. The students will answer the following questions in groups:
 - a. How do people use light?
 - b. How do different animals perceive light?
 - c. How do light and objects interact?

Readers/Level 3

- The students will identify/apply new vocabulary, such as light, opaque, translucent, transparent, bioluminescence, electromagnetic spectrum, infrared light, ultraviolet light, visible light, wavelength, frequency, photoelectric effect, wave, reflection, refraction, diffraction, speed of light, constant, independently given a choice of four response options as choice cards
- The students will analyze how light interacts with different objects in their environments.
- The students will complete a cloze (fill in the blank) worksheet analyzing the different wavelengths of different colors
- The students will be able to compare and contrast the wave and particle theories of light using observations and activities based on the work Newton and Thomas.
- The student will compare and contrast object detail in pictures with no light, low light and normal lighting.

Level 2

- The students will do the same activities as above with more intrusive prompting for errorless learning.
- The students will listen to and read the text using AAC devices.
- The students will complete a response option worksheet or cloze worksheet with key words determining the wavelengths observed in videos with more intrusive prompting as needed.
- Students will attempt to say the vocabulary word(s) and point to the word on the definition sheet.
- Students who have difficulty speaking will press the “Big Mack” to hear the word and will point to the correct vocabulary word on the definition sheet or on the word card given a choice of three response options.

Level 1

- The students will do the same activities as above with more intrusive prompting for errorless learning.
- The students will listen to and read the text using AAC devices.

- The students will complete a response option worksheet that has been turned into discrete response choices in order to determine the wavelengths observed when given more intrusive prompting as needed.
- Students will point to the vocabulary word on the definition sheet or on the word card given a choice of three response options and more intrusive prompting as needed

Links to Prior Learning:

Prior to warm-up, the students will review the steps of the scientific method and sequence the order of inquiry. The students will also identify the steps of the order of science and the relationship to the method.

Lesson Procedures: (What the teacher will do)

- **Assistants:** will work with a small group of students to help them to respond to questions and focus on the textbooks. They will monitor behavior and take data. They will also assist with the use of AAC devices. They will provide data on the level of support provided to the students.

Readers/Level 3

- The teacher will provide the adapted textbooks and word card choices.
- The teacher will then read the vocabulary with the students to prepare them for the reading.
- The teacher will read the adapted light text with the students
- The teacher will have the students follow along with the text. The Smart Board will display the adapted text to help the students follow along.
- The teacher will identify the new vocabulary for the Velcro Word wall (light, opaque, translucent, transparent, bioluminescence, electromagnetic spectrum, infrared light, ultraviolet light, visible light, wavelength, frequency, photoelectric effect, wave, reflection, refraction, diffraction, speed of light, constant).

Level 2

- The teacher will do the same as above.
- The teacher will handout three vocabulary words
- The teacher will read the three vocabulary words and have the students along.
- The teacher will have the students point to the different vocabulary words and use augmentative communication devices if non-verbal.
- The students will point to pictures in the book.

Level 1

- The teacher will do the same as above.
- The teacher will have the students listen to the text.
- The teacher will have the students to eye-gaze or point to the correct vocabulary word out of a choice of three.

Independent Practice

- Given a vocabulary test on light and light concepts, the students will choose the correct response to demonstrate comprehension and application of vocabulary. The students will receive immediate praise after selecting a correct response and immediate correction and feedback following incorrect responses. Students, who respond incorrectly, will be provided with an opportunity to provide a correct response.
- Given a quiz on light concepts and the classroom experiments with multiple choices, the students will answer the questions with staff assistance as needed and access to the adapted text. The teacher and assistant will provide praise for correct responses and prompting to promote errorless learning.
- Given an object to draw or photograph and different levels of light, the students will first describe the features of the object in the different levels of light. Second, the students will attempt to draw the object in different levels of light. Finally, the students will report the level of ease or difficulty in performing the task based on the level of light.

Lesson 2: Light: Photosynthesis, Autotrophs and Pollution (see appendix 2 for adapted text and appendix 3 for materials)

Objective

1. Given AAC devices and adapted text, and videos on the Smart Board, the students will read the adapted information on photosynthesis.
 - a. Given adapted information on light, the students will examine that light is a source of energy.
 - b. Given information and videos on of terrestrial and deep aquatic habitats, the students will compare and contrast photosynthesis to chemosynthesis.
 - c. Given adapted information on food chains, a food chain analysis worksheet, and different videos, the students will analyze the source of energy for the food chain and determine which autotroph is the base of the ecosystem.
 - d. Given information on terrestrial autotrophs, the students will compare how the different organisms (protists, plants, and bacteria) use light to create energy.
2. Given AAC Devices, adapted text, and videos on the Smartboard, the students will learn about the parts of plants, protists, and bacteria that convert light to energy.
 - e. Given information on pigments, the students will define the pigment of plants, algae, and cyanobacteria and how it is used in photosynthesis.
 - f. Given information on the parts of plant cells, the students will identify the organelle responsible for light absorption.
 - g. Given information on the parts of protist cells (algae), the students will identify the structures related to photosynthesis.
 - h. Given information on cyanobacteria⁴⁵, the students will identify the parts of the cell that promote light absorption.
 - i. Given the information on plants, algae, and cyanobacteria, the students will compare and contrast how the organisms complete photosynthesis and their usual ecosystems.
 - j. Given information on cyanobacteria, the students will trace the phylogeny of the organism and determine their relationship with eukaryotic cells⁴⁶.

3. Given AAC Devices, adapted text, and videos on the Smartboard, the students will learn about plant movement and energy use.
 - a. Given information on plant leaves, the students will learn how the plant leaf collects sunlight for the plant.
 - b. Given information on plant movement and stimuli, the students will describe how plants move in relation to collection of energy.
 - c. Given information on plant grouping, the students will explain the effect of canopy crowding on plant development based on readings, videos, and an experiment.
4. Given grass planted in both aquatic and terrestrial settings, the students will first develop a hypothesis and then observe the effect of crowding on the ability of plants to absorb and use light.
5. Given information on air pollution and the effect on plants, terrariums, and different plants, the students will develop an experiment where they assess the effect of different pollutants on the leaf area of different plants.
6. The students will answer the following questions in groups:
 - a. How do plants use light?
 - b. Explain the difference between autotrophs and heterotrophs.
 - c. How do different photosynthetic organisms obtain and use light?
 - d. How does ecosystem influence photosynthetic organism development?
 - e. Why are cyanobacteria important to plant and algae development?
 - f. How do eukaryotic and prokaryotic cells differ in light absorption?
 - g. How does the pigment of plants, algae, and cyanobacteria determine the color of the organism?

Readers/Level 3

- The students will identify/apply new vocabulary, such as light, photosynthesis, chlorophyll, chloroplast, autotroph, heterotroph, carbon dioxide, cyanobacteria, symbiosis, pigment independently given a choice of four response options as choice cards
- The students will analyze how light interacts with different autotrophs to produce energy for the organism.
- The students will complete a cloze (fill in the blank) worksheet to compare and contrast the different autotrophs.
- The students will complete an adapted food chain analysis, where they analyze the role of light in the establishment of food chains and food webs.
- The student will compare and contrast the energy use and development of plants in crowded and sparse settings.

Level 2

- The students will do the same activities as above with more intrusive prompting for errorless learning.
- The students will listen to and read the text using AAC devices.
- The students will complete a response option worksheet or cloze worksheet with key words to compare and contrast the different autotrophs.
- Students will attempt to say the vocabulary word(s) and point to the word on the definition sheet.

- Students who have difficulty speaking will press the “Big Mack” to hear the word and will point to the correct vocabulary word on the definition sheet or on the word card given a choice of three response options.

Level 1

- The students will do the same activities as above with more intrusive prompting for errorless learning.
- The students will listen to and read the text using AAC devices.
- The students will complete a response option worksheet that has been turned into discrete response choices in order to compare and contrast the different autotrophs.
- Students will point to the vocabulary word on the definition sheet or on the word card given a choice of three response options and more intrusive prompting as needed

Links to Prior Learning:

- Prior to warm-up, the students will review the steps of the scientific method and sequence the order of inquiry. The students will also identify the steps of the order of science and the relationship to the method.
- Given information on light, the students will review the structure and behavior of light.

Lesson Procedures: (What the teacher will do)

- **Assistants:** will work with a small group of students to help them to respond to questions and focus on the textbooks. They will monitor behavior and take data. They will also assist with the use of AAC devices. They will provide data on the level of support provided to the students.

Readers/Level 3

- The teacher will provide the adapted textbooks and word card choices.
- The teacher will then read the vocabulary with the students to prepare them for the reading.
- The teacher will read the adapted light text with the students
- The teacher will have the students follow along with the text. The Smart Board will display the adapted text to help the students follow along.
- The teacher will identify the new vocabulary for the Velcro Word wall (light, photosynthesis, chlorophyll, chloroplast, autotroph, heterotroph, carbon dioxide, cyanobacteria, symbiosis, pollution, surface area, pollution, surface area, and pigment).

Level 2

- The teacher will do the same as above.
- The teacher will handout three vocabulary words
- The teacher will read the three vocabulary words and have the students along.
- The teacher will have the students point to the different vocabulary words and use augmentative communication devices if non-verbal.
- The students will point to pictures in the book.

Level 1

- The teacher will do the same as above.
- The teacher will have the students listen to the text.

- The teacher will have the students to eye-gaze or point to the correct vocabulary word out of a choice of three.

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Independent Practice

- Given a food chain analysis activity and a video, the students will use the information in text and the videos, to determine the ecosystem and the autotroph anchoring the food chain.
- Given a quiz on photosynthesis with multiple choices, the students will answer the questions with staff assistance as needed and access to the adapted text. The teacher and assistant will provide praise for correct responses and prompting to promote errorless learning.
- Given grass in aquatic and terrestrial habitats, the students will develop a hypothesis on and observe the effect of crowding on the ability of plants in both aquatic and terrestrial ecosystems.
- Given different terrariums and three of the same plant, the students will first develop hypotheses about the effects of different pollutants, and will then place the plants in the different terrariums with the different pollutants. Next, the students will observe the effects of the pollutants on the leaf size of the different plants.

Lesson 3: Light: Perception and The effect of Pollution on Animal Behavior (see appendix 2 for adapted text and appendix 3 for materials)

Objective

1. Given AAC devices and adapted text, and videos on the Smart Board, the students will read the adapted information on light and visual perception.
 - a. Given adapted information on vision and examples of how different animals use vision, the students will compare and contrast the vision of different animals.
 - b. Given adapted information on light and sight, the students will compare and contrast how different animals use light for sight; comparing the depth perception of binocular vision with the vision of animals with eyes on the side of their heads.
 - i. Given two toilet paper tubes, the students will simulate the vision of prey vertebrates and vertebrates with binocular vision.
 - c. Given different optical illusions, the students will apply information on light, wavelengths, and perception to explore the different images.
2. Given AAC Devices, adapted text, and videos on the Smartboard, the students will learn about the parts of the human eye.
 - a. Given information on the human eye, the students will:
 - i. Define the retina, lens, iris, pupil, cornea, and fovea.
 - ii. Explain how each part of the eye works together to interpret light.
 - iii. Explain the functions of rod and cone cells. Explore the differences in color vision in different vertebrates.
 - iv. Explore information about how neurons, nerves, and the brain interpret visual information.

3. Given AAC Devices, adapted text, and videos on the Smartboard, the students will explore the evolution of color vision in animals.
 - a. Given adapted information on the development of animal vision, the students will explore the phylogeny of the vertebrate eye from lampreys to primates.
 - b. Given information on the structure of eyes of different animals, the students will compare and contrast the eyes of insects, vertebrates, and worms.
 - c. Given information on different habitats (aquatic, cave, deep ocean, terrestrial) and different periods of activity (diurnal, nocturnal, crepuscular), the students will use information to draw conclusions about the development of organism eyes.
4. Given videos, AAC devices, and adapted text, the students will learn about artificial light pollution and the effect on animal behavior.
 - a. Given information on light pollution, the students will:
 - i. Define light pollution and determine when it occurs.
 - ii. Compare and contrast pictures of light pollution and typical night.
 - iii. Explore the effect on the behavior of nocturnal animals.
 - iv. Predict if an animal will adapt to the changes in habitat.
 - v. Research a specific organism and explore how it has adapted or not adapted to light pollution.
5. The students will answer the following questions in groups:
 - a. How do animals use light to see?
 - b. How can researchers determine the evolution of color vision in vertebrates?
 - c. How does light pollution affect the behavior of animals?
 - d. How does habitat influence the development of vision in different animals?

Readers/Level 3

- The students will identify/apply new vocabulary, such as light, optic nerve, light pollution, behavior, adaptations, stimuli, photoreceptors, rods, cones, trichromatic, hue, intensity, fovea, lens, retina, cornea, pupil, iris, opsins, phototransduction, eye spots, occipital lobe, nocturnal, diurnal, crepuscular independently given a choice of four response options as choice cards
- The students will analyze how light interacts with different parts of the eye to produce vision in animals.
- The students will complete a cloze (fill in the blank) worksheet to compare and contrast the different parts of the eye.
- The students will compare and contrast different habitats and the development of vision.
- The student will compare and contrast the effect of artificial light and natural light on animal behavior and adaptations.

Level 2

- The students will do the same activities as above with more intrusive prompting for errorless learning.
- The students will listen to and read the text using AAC devices.
- The students will complete a response option worksheet or cloze worksheet with key words to compare and contrast the different parts of the eye.
- Students will attempt to say the vocabulary word(s) and point to the word on the definition sheet.

- Students who have difficulty speaking will press the “Big Mack” to hear the word and will point to the correct vocabulary word on the definition sheet or on the word card given a choice of three response options.

Level 1

- The students will do the same activities as above with more intrusive prompting for errorless learning.
- The students will listen to and read the text using AAC devices.
- The students will complete a response option worksheet that has been turned into discrete response choices in order to compare and contrast the different parts of the eye.
- Students will point to the vocabulary word on the definition sheet or on the word card given a choice of three response options and more intrusive prompting as needed

Links to Prior Learning:

- Prior to warm-up, the students will review the steps of the scientific method and sequence the order of inquiry. The students will also identify the steps of the order of science and the relationship to the method.
- Given information on light, the students will review the structure and behavior of light.
- Given information on plants, the students will review photosynthesis, pollution, and food chains.

Lesson Procedures: (What the teacher will do)

- **Assistants:** will work with a small group of students to help them to respond to questions and focus on the textbooks. They will monitor behavior and take data. They will also assist with the use of AAC devices. They will provide data on the level of support provided to the students.

Readers/Level 3

- The teacher will provide the adapted textbooks and word card choices.
- The teacher will then read the vocabulary with the students to prepare them for the reading.
- The teacher will read the adapted perception text with the students
- The teacher will have the students follow along with the text. The Smart Board will display the adapted text to help the students follow along.
- The teacher will identify the new vocabulary for the Velcro Word wall (optic nerve, light pollution, behavior, adaptations, stimuli, photoreceptors, rods, cones, trichromatic, hue, intensity, fovea, lens, retina, cornea, pupil, iris, opsins, phototransduction, eye spots, occipital lobe, nocturnal, diurnal, crepuscular).

Level 2

- The teacher will do the same as above.
- The teacher will handout three vocabulary words
- The teacher will read the three vocabulary words and have the students along.
- The teacher will have the students point to the different vocabulary words and use augmentative communication devices if non-verbal.
- The students will point to pictures in the book.

Level 1

- The teacher will do the same as above.
- The teacher will have the students listen to the text.
- The teacher will have the students to eye-gaze or point to the correct vocabulary word out of a choice of three.

Independent Practice

- Given a cloze worksheet and a diagram, the students will identify and define the parts of the human eye.
- Given a multiple-choice quiz on the evolution of the eye, the students will choose the correct answer to demonstrate comprehension on the relationship and similarities between the parts of the eye and different vertebrates. The teachers will provide immediate praise for a correct answer and the use of prompts to promote errorless learning.
- Given access to different “Critter Cams” in urban, suburban, and rural areas, the students will make a hypothesis about the similarities and differences in behaviors of the animals in those areas. Second, the students will observe the behaviors to assess the accuracy of their hypotheses.

Appendix 1: Implementing Teaching Standards for North Carolina Standard Course of Study

Extended Essential Standards

High School Biology

EX.Bio.1 Understand structures and functions of living organisms.

EX.Bio.1.1 Identify that plants make their own food through a process called photosynthesis

EX.Bio.1.3 Identify that the cell is the smallest basic unit of life and most living things are composed of many cells.

EX. Bio.2.1 Understand the interdependence of living organisms within their environments.

EX. Bio.2.1.2 Identify that plants and animals get energy from food.

EX. Bio.2.1.3 Identify sources of energy for plants and animals (e.g., oats for horses, grass for cows, apple for people, fertilizer for plants).

EX. Bio..2.1.4 Understand simple food chains (e.g., grass gets energy from the sun, grasshoppers from grass, snakes from grasshoppers, and hawks from snakes).

EX. Bio.2.1.5 Understand ways living things compete with each other to get the things they need to live in their environment

Bio.2.1.2 Analyze the survival and reproductive success of organisms in terms of behavioral, structural, and reproductive adaptations

EX.Bio.2.2 Understand the impact of human activities on the environment

EX.Bio.2.2.1 Identify natural resources (e.g. water, air, land) impacted by human activity.

EX.Bio.2.2.2 Understand how pollution (e.g. waste dumping, littering, smog) affects natural resources.

9-10 English Language Arts: Reading Standards for Literature

2. Determine the theme or central idea of the text and select details that relate to it; recount the text.

Appendix 2: Adapted Text, Worksheets, and Videos

The adapted text is divided into chapters on Light, Photosynthesis and Light, and Perception and Light. Chapter 1 is a general discussion of light, the properties of light, and the behavior of light. Chapter 2 involves a discussion of photosynthesis and light. The chapter traces the photosynthesis from cyanobacteria to the use of chloroplasts in plants and algae. The chapter also addresses research on plant health and the effect of pollution on plant development and light absorption. Chapter 3 is on light and perception. The chapter discusses the relationship between light and the human eye, the parts of the eye, and theories on color vision. The chapter also includes research on the evolution of the animal eye and the effect of light pollution on animal behavior and health. The unit ends with tests for each chapter. There are activities and videos embedded in the chapters to help with concepts. The login for the Brain Pop video is metrobp/brainpop.

The adapted text can be printed out and provided to students. To make word cards, print out the adapted text, cut out the highlighted vocabulary and paste or tape to index cards. These cards can be used for multiple choice checks for each student throughout the lesson.

All adapted material: <https://tinyurl.com/zscti2018>

Adapted Chapter: <https://tinyurl.com/yan3sqcl>

Food Chain Analysis: <https://tinyurl.com/yan3sqcl>

Thomas Young Double Slit Experiment:

<https://www.instructables.com/id/How-To-Make-a-Simple-Double-Slit/>

<https://www.youtube.com/watch?v=nuaHY5lj2AA>

Activity Worksheets

Lesson 1 Activities

Photoelectric Effect

1. Use alkali metals (sodium, potassium, or cesium)
2. Shine an incandescent or heat generating light on the metal
3. Does the metal feel hot to the touch?
4. Why do you think this occurs?

Low Light and High Light Questions

1. Turn the lights down
2. Describe the appearance of the object:
 - a. Colors: _____
 - b. Size: _____
 - c. Shape: _____
 - d. What is on the object? _____
3. Turn the lights on.
 - a. What was the same in the low light?
 - b. What was different in the low light?
4. How difficult was it to draw the object in low light?
5. In which condition was it easier to observe the object?

Lesson 2 Activities

Photosynthesis Activity 1: Density and Habitat:

1. Condition 1: Three to four grass plants planted in an aquatic habitat.
2. Condition 2: Three to four grass plants planted in a terrestrial habitat.
3. Condition 3: One grass plant planted in a terrestrial habitat.
4. Condition 4: One grass plant planted in an aquatic habitat.
 - a. Generate hypotheses:

5. What was the effect of habitat on plant growth? _____
6. How did grouping or crowding affect the grass? _____
7. Which condition produced the healthiest grass? _____

Photosynthesis Activity 2: The Effect of Pollution on Plants

1. Get three terrariums
2. Get three of the same plant
3. Place the plants in the different terrariums
4. Differ the conditions in the terrariums
 - a. Terrarium 1: Control
 - b. Terrarium 2: Aerosol
 - c. Terrarium 3: Smoke
5. Limit the ability of air to move in terrariums 2 and 3
6. Develop Hypotheses:
 - a. Hypothesis 1: _____
 - b. Hypothesis 2: _____
 - c. Hypothesis 3: _____
7. Make Observations
8. Conclusions about the effect of pollutants on the plants.

Lesson 3 Activity:

Candid Critters:

<https://www.nccandidcritters.org/>

1. Hypotheses:
 - a. Will the urban animals behave differently from the rural animals?
 - b. What effect will the presence of light have on the urban animals?
 - c. Will there be any difference in behavior.
2. Place cameras in woods and around buildings.
3. Watch the footage.
4. Observations:

5. Conclusions:

Appendix 3: Materials for Lessons

- Flashlights
- Adapted tests and quizzes
- Teacher made stimulus cards
- Different videos (YouTube, Brain Pop, Khan Academy, Young's Double Slit)
- Incandescent light
- Alkali metals
- Pictures and objects representing organisms, x-rays, thermal imagery, uv lights,
- KWL Chart
- Hypothesis, observation, and conclusion worksheets
- Online articles
- Adapted Binders containing definitions and examples made with *Writing with Symbols 2000*
- Smart Board
- Smart Board projections of light, the eye, photosynthesis information,
- Big Mack and other AAC communication devices
- Velcro board for light, perception, and photosynthesis vocabulary
- 3 Terrariums, potting soil, three identical plants, aerosol spray, matches, and water
- Aquarium, terrarium, grass, potting soil, light, and water
- Human eye chart
- Access to Candid Critters website for pictures and videos. Teachers are invited to set up cameras and observe animal behavior.
- Camera
- Crayons, pencils, and pens
- Afterimage Effect Examples
- Optical Illusions

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