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Plant, Watch, and Grow

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Introduction

Young children are incredibly inquisitive about the world around them. They love to ask questions, especially if it relates to inquiry and their everyday lives. *How does that work?* They always want to know. This unit will feed off the student's natural curiosity about energy as it pertains to photosynthesis and the life cycle of a plant.

This unit will be beneficial for early childhood classrooms in urban districts. The theme should be an interesting one, and the content appropriate for larger cities with students from diverse backgrounds. Young learners from diverse backgrounds can all relate to the natural world and the greenery found in both urban and suburban environments.

Background environment

Celia Clinton Elementary is a public urban school serving prek-6 grade students. The school is located in north Tulsa and is considered a neighborhood school. Celia Clinton serves a diverse population of almost 700 students. Our almost 700 students come from a variety of social and economic backgrounds. Our student background is 16% African American, 12% Caucasian, 68% Hispanic, 3% Native American, and 1% Asian. Unfortunately, north Tulsa is considered by many Tulsans to be the "bad" part of town. This part of town has historically struggled economically as well as with crime. North Tulsa has traditionally been African American dominated, and in the early 20th century held the distinction of being an economic and cultural center often referred to as "The Black Wall Street." In 1921, the Tulsa race riots destroyed homes, property, businesses and the lives of many African American Tulsans. Followed by inequitable public policy throughout the following decades, north Tulsa has struggled to recover its former achievements; while the neighborhood of Celia Clinton has diversified in terms of a growing Hispanic population, this part of town remains disadvantaged.

With this diverse background, it naturally follows that the common pull of background knowledge surrounding the themes in this unit will be shallow, and I will spend most of the time developing background knowledge and vocabulary for our English Language Learners (ELL) for lessons in this unit. I am a kindergarten teacher at Celia Clinton, and our school has four kindergarten classes. Class sizes typically fluctuate between 20 and 28 students. My class last year consisted of 21 students, 12 males and 9 females; within that class I had two students on Individualized Education Plans (IEP), 14 students who received services as English Language

Learners (ELL), and one child who was on an accommodating behavior plan. This class make-up was similar to the other kindergarten class demographics. I anticipate a similar class structure this year.

As such, this unit must be engaging and accessible for all of the diverse learners in my classroom. As a result, Tulsa no doubt mirrors other primary schools that have diverse learners with diverse needs; this unit should find a wide audience for educators interested in bringing knowledge about the natural world and photosynthesis to students at a young age. Starting education around Science, Technology, Engineering and Math topics is critical, especially at a young age when the imaginations of our students are so open and creative.

Whom the unit serves

My students are amazing young people who have significant language barriers. These barriers slow down English language learners not because they lack the same knowledge as their English-speaking peers, but because there is a barrier to their communicating knowledge as easily as their native English-speaking peers. When working with such a high population of English Language Learners, the majority of my time will be spent building vocabulary and basic content knowledge for my students. Working with kindergarteners is like building a brick wall. You are laying those very first bricks on the ground, the foundation for all their learning to come.

Background

History of Photosynthesis

Who and how was photosynthesis discovered?

While teaching this unit on plants, it is important for students to understand what photosynthesis is and how it was discovered. Photosynthesis is the process by which plants get energy from a light source, usually the sun. This has been happening since the earliest days of life on earth. Although photosynthesis has been occurring naturally since the early conception of our earth, scientists and the general public were completely unacquainted with the photosynthetic process until the late nineteenth century. Consider: Although photosynthesis has been utilized by life forms since their earliest evolution, it wasn't until the late 19th century that we gained a deeper understanding of this natural process.

Is there something in the water? Jan Baptista van Helmont certainly thought there was. He was a contributor in the partial discovery of photosynthesis. Van Helmont was a Belgian physician, physiologist, and chemist. He is most well known for his use of chemistry to understand medicine, which made him a leading physician-chemist of his time. Van Helmont's well known "willow tree experiment" was performed over a five-year time period in the 1630s. The prevailing common theory at the time was that plants grew by eating and digesting the soil, but Van Helmont disagreed, and constructed an experiment to test this. In this experiment, he planted a willow tree in a pot with soil and placed in a controlled environment. He weighed the mass of the soil in the pot and carefully watered the willow tree over the next five years. At the end of his experiment Van Helmont removed the tree from the soil, weighed it, and weighed the dry pot of soil. The soil had barely changed in weight. [1] Following this finding, Van Helmont came to the conclusion that the willow tree growth was in turn from the water and not the soil. We now know his findings were generally inaccurate; however, they did prove that water was a contributing factor to the growth of plants, and that plants did not “eat” or “digest” soil.

Is there something in the air? Joseph Priestly wanted to find out, and made a significant advancement in the discovery of photosynthesis. Born in 1733, Priestly became a chemist, minister, philosopher, and political theorist over the course of his lifetime. In 1772 Priestly was credited with being the first to discover the evidence that gases participate in the photosynthetic process.[2] In a series of experiments, he placed a burning candle inside a sealed chamber. Soon the candle went out after the flame exhausted the supply of combustible oxygen inside the sealed chamber. As the underlying mechanisms that affected these experiments were still scientifically unknown, Priestly continued his experiments by then placing a mouse inside an identical sealed chamber. Soon the mouse perished, prompting further experimental replication wherein Priestly placed a mint plant in the jar with another mouse, yielding a different result: the mouse lived. He had made a significant breakthrough – that plants produce a substance that is life giving to animals. Priestly went on to describe this substance as ‘dephlogisticated air’, which thanks to French Chemist Antoine Lavoiser, soon became known as ‘oxygen’.[3]

The next scientist to make a major breakthrough in the area of photosynthesis was Jan Ingenhousz. He was a Dutch chemist, physiologist, and biologist who performed experiments proving plants produce oxygen in the late 1770s. Ingenhousz performed several experiments including placing leaves submerged in water in the shade and in the sunlight. Ingenhousz noticed the leaves submerged in water in the sunlight produced bubbles. While not fully understanding what was happening inside the plant, he still concluded that the green parts of plants, while exposed to light, produce oxygen.[4] He knew light was essential to this process because when he moved all the leaves into the shade the bubbles disappeared. The sunlight was necessary for the plants to produce oxygen and give off bubbles on the leaves. While Ingenhouz knew he had made a breakthrough, he wasn’t fully aware of his historical photosynthetic discovery and its full implications.

Around the same time Jean Senebier, a Swiss botanist, naturalist, and pastor from Geneva became interested. Senebier was very interested in Jan Ingenhousz’s work and his finding that plants produced oxygen. Senebier went to work investigating the fixed air to which the plant is exposed. Senebier found and provided evidence that plants must have access to fixed air (carbon dioxide) in order to produce oxygen with the assistance of sunlight.[5] Senebier’s discovery of carbon dioxide’s importance in the production of oxygen by a plant is one of the photosynthesis advancements that is at times overlooked and misstated.

As the science progressed, scientists wondered if for photosynthesis to occur we need water, oxygen, and carbon dioxide. Nicholas-Théodore de Saussure, a close friend of Jean Senebier, certainly had the same question. Saussure was a Swiss chemist who had an intense interest in plant physiology. Nicholas-Théodore de Saussure is particularly known for his demonstrations, concluding that water is directly involved in photosynthesis. Saussure also provided evidence that plants obtain carbon dioxide from the atmosphere rather than from the soil humus. He was particularly interested in the plant physiology and discovered that plants obtain minerals vital to their survival from the potting soil.[6] While he did not make the initial discoveries regarding the water, oxygen, and carbon dioxide, I feel as if he was the one to put all the pieces together.

The final piece of the puzzle for solving the riddle of photosynthesis is of course energy. The early pioneers of photosynthesis, from Van Halmont to Saussure all focused on the chemical components of photosynthesis. The theory of energy relating to photosynthesis had yet to have been discussed. In the 1840’s all the ground work had already been laid for the understanding of photosynthesis. A German physician and physicist by the name of Julius Robert Mayer contested that energy was conserved in biological as well as in physical systems. His findings reported that a plant carrying out photosynthesis stored energy from the sun in a form of chemical energy.[7] After his discoveries, it was now understood that plants could also be a source of stored energy.

The discovery of the underlying mechanisms for photosynthesis did not occur in one day, nor did any single individual scientist make the breakthrough independently. In the greatest traditions of science, one discovery led to or inspired another. As is often the case with scientific breakthroughs, some scientists are forced to go beyond societal norms and take personal risks in order to prove claims or demonstrate evidence that may not be acceptable to either those in power or to the broader base of society. The discovery of photosynthesis is no exception.

Photosynthetic Process

While teaching this unit on plants and the plant life cycle it is essential for educators to understand the process of photosynthesis and how it occurs in order to accurately teach it to students. As I said, photosynthesis is the process by which plants get energy from a light source, usually the sun. This has been happening since the earliest days of life on earth. While my main focus is on teaching my students the process of photosynthesis and how plants are powered from the sun, engaging students will require that I explain how my students are powered by those very same plants, and by association, energy from the sun. I would like to tie the unit back to my students being solar powered by eating fruits and vegetables. In order to prompt students, as well as to draw on their prior knowledge, I would lead with questions like “What happens to plants if they don’t get sunlight?” and “What would happen to you if you weren’t able to eat?” Students should be able to relate their own experience with food to photosynthesis in plants. Also, students must understand how important photosynthesis is to their everyday lives. As explained by trophic levels that show how energy is distributed in the food chain, students will learn that they receive all their excess food energy from the sun, whether they are eating plants directly or eating animals who, in turn, ate vegetation. My students will become familiar with trophic levels as expressed by the pyramid graphic as well as the concept of food webs. Here we go; let’s dive into the photosynthetic process.

How do plants breathe and make their own food? Something many of my students will find interesting is that plants do not eat or ingest food like we and animals do. Plants produce and make their own food from sunlight, air, and water. Photosynthesis happens in the leaves and sometimes in the stems of green plants. Inside those leaves and stems there are small plant cells, and inside those cells are chloroplasts. The chloroplast is where the photosynthetic process is actually carried out. There is no other place in the plant cell that the photosynthetic process can occur. Plants absorb both carbon dioxide (CO_2) from the atmosphere as well as energy from sunlight. Additionally, plants must absorb water (H_2O) from the soil through the root system. These compounds and light energy are then rearranged to create glucose, with oxygen left over as a byproduct.

$6CO_2 + 6H_2O + \text{Light} \rightarrow C_6H_{12}O_6 + 6O_2$

Carbon Dioxide + Water + Light -> Glucose + Oxygen

The sun radiates light energy to the chloroplasts in the leaves of the plant. There, the light initiates a reaction with the water taken up by the roots to start what is known as the light reactions of photosynthesis or the light-dependent reactions. This happens inside the chloroplast in a part called the thylakoids. Inside the thylakoids is where the light energy is converted into electrical energy.

Next come the light-independent reactions also known commonly as the “Calvin Cycle” and the “Dark Reactions”. The light-independent reactions also occur in the chloroplast; however, they do not happen inside the thylakoids like the light reactions; instead they occur outside the thylakoids in what is called the stroma. The purpose of this is to harvest energy from the light reactions and start carbon fixation. Carbon fixation is the addition of carbon dioxide to growing sugar molecules. Once this happens and the chemical reaction takes place, a sugar commonly known as glucose is formed; oxygen is released into the air, as a byproduct.[8]

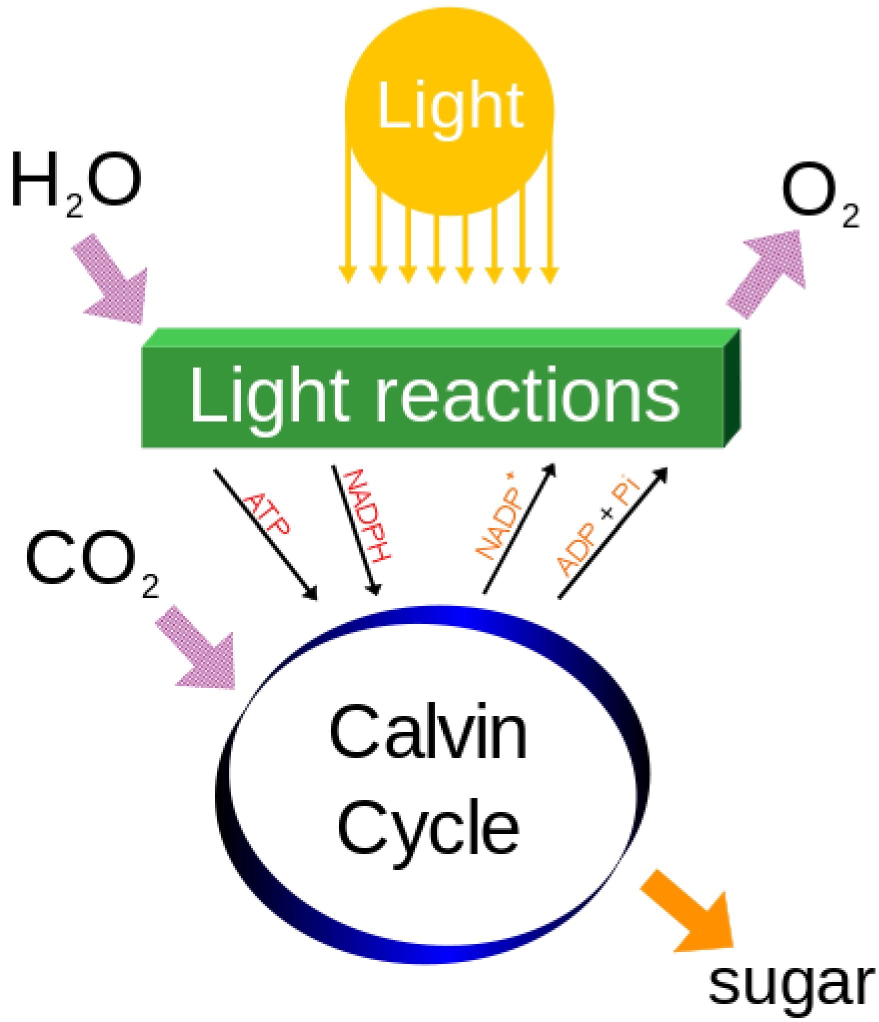

Fig. 1: Simple Photosynthesis Overview. Image credit: Daniel Mayer. GNU1.2

The plant uses the sugar produced from the photosynthetic process as food to grow and thrive. When the oxygen released from this natural process goes into the atmosphere, we are then supplied with what we need to breathe while plants retain and utilize carbon dioxide. This basic cellular process utilized by plants – photosynthesis – is essential to all life on earth and makes up the base of all energy utilized by life on earth and is the first link in the food chain known as producers. On the surface of the planet, the food chain moves up from plants to grazing animals and then to predators. Similarly, photosynthesis takes place in the oceans powering food chains for the aquatic biome of earth.

Plant Structure

While photosynthesis is the main focus of my unit, in order to build sufficient background knowledge, I plan to touch on the structure of a plant prior to the unit study. This is an ever important topic especially for building vocabulary and the foundational knowledge of how a plant works. I will engage the students by bringing in hands-on activities and/or art projects for them to manipulate or create the structure of a plant.

For my students, we will talk about general plant structures, utilizing various examples from different species as needed. Starting from the bottom of any typical plant, we of course have the roots. Roots are essential for the growth and development of a plant. Growing below the ground, roots serve as an anchor of plants and trees. This protects them from the wind and weather conditions, as to not be knocked over or blown away. Roots are there for the absorption of water and minerals from the soil into the plant. They provide the plant with vital nutrients and store the byproducts of photosynthesis: carbohydrates, sugars or glucose, and proteins. The roots are classified and broken up in a couple ways. A taproot is a main root that grows directly down into the soil with very limited branching. A common taproot example would be a carrot. The second primary root structure is fibrous roots. These are roots typically growing shallow in the soil with excess branching. A common fibrous root would be potatoes. Both root structures have lateral roots also known as side roots, and root hairs. Root hairs are small delicate hair like structures that are the main source of intake for water and minerals. These root hairs are most commonly destroyed in transplanting.[9]

Many of my students will no doubt be curious as to how the water travels from the roots all the way to the leaves. This is where we can talk about vascular and nonvascular plants. Vascular plants are simple green plants and trees that have tubes or vessels running from the roots to the leaves and buds. This vascular system of a plant is similar to our human bodies. In our circulatory system, our heart pumps blood through veins to reach different parts of the body. The vascular system is composed of two types of vessels that are flowing throughout the plant known as the xylem and the phloem. The xylem starts in the roots of plants and carries the water absorbed from the roots up into the leaves. The phloem runs opposite of that, carrying the sugars/glucose made from the process of photosynthesis throughout the rest of the plant to supply it as a food source. Nonvascular plants, such as moss, do not have these tube-like structures. They are usually small in size and absorb water needed for growth and development.

Shooting above the surface, we have the stems and leaves. As we just covered, the stems are essential for the xylem and phloem systems pumping nutrients throughout the plant. Leaves are critical to the plant due to that is where the process of photosynthesis is occurring. Without the leaves the plant would not be able to produce sugar/glucose as food. Shooting off from the stem, a plant will develop buds. Buds growing from the plant’s stem can either produce leaves or flowers also referred to as vegetative or reproductive shoots.

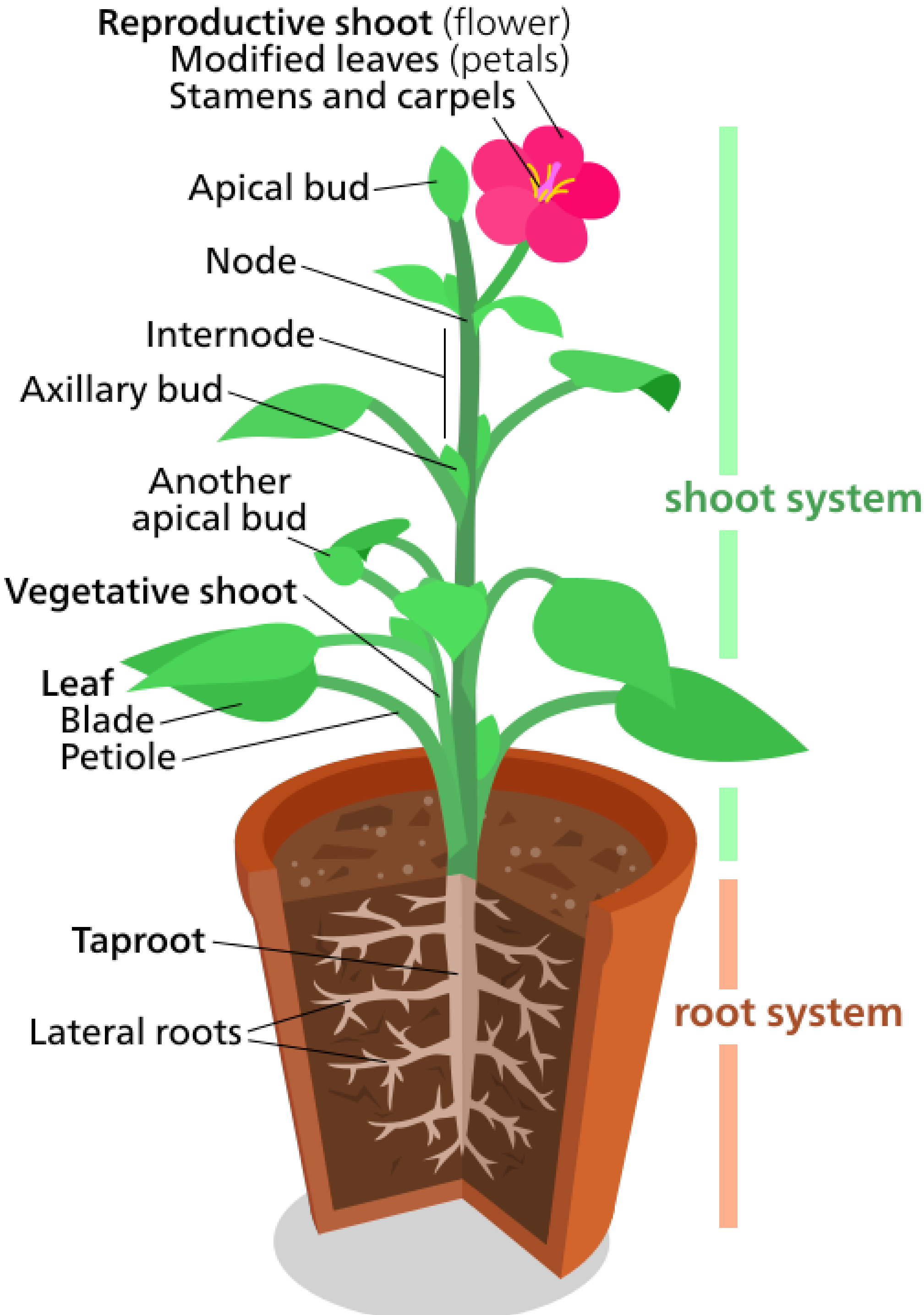

Fig. 2: A diagram of a highly idealized eudicot. Image credit: Kelvinsong. CC3.0

The most attractive part of a plant is of course the flowers. Flowers are often referred to as the reproductive structure of a plant. There are two ways that flowers can be identified: perfect and imperfect flowers. A perfect flower contains all the necessary parts to pollinate itself for reproduction. What is to be considered for the male/stamen parts of a flower are the anther and filament. The anther is where the pollen grains are formed, and which are needed for the reproduction process. The female/carpels parts of the plant include the stigma, style, ovaries, and ovules. If pollen is introduced to the stigma, it will travel down the style tube-like structure holding it up, down through the ovary and into the ovules. The pollen and the ovules will then form a seed and thus complete the plant reproduction process. Imperfect flowers are either lacking the necessary carpels or stamen; thus they will need pollinators to transport pollen for proper reproduction. The pollen is transported by insects who are attracted to flowers or by the wind. Interestingly, petals, which some might consider the most attractive part of a plant, are only there for necessary protection of the carpels and stamen.[10]

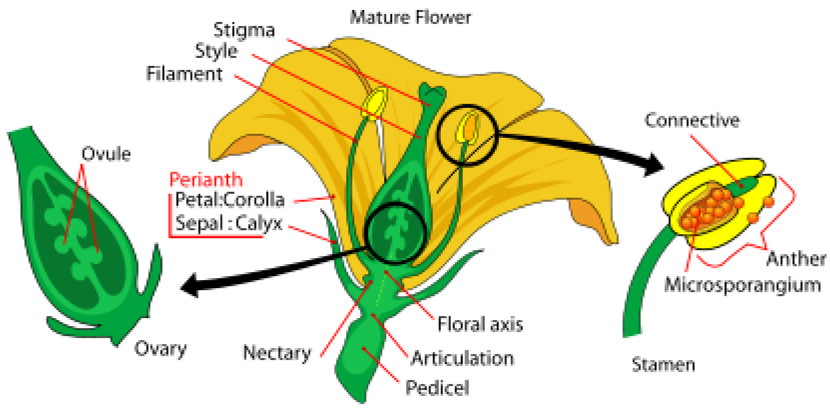

Fig. 3: A Mature Flower Diagram. Image credit: Mariana Ruiz. Public Domain

The Sun

In the same context as I covered plant structure, I plan to touch on some basic information regarding the sun and solar energy. I expect for my students to have several questions about the sun, especially considering how inquisitive they are at this age. What is it made of? How is it hot? These are just a few that come to mind. My main focus with my students will be introducing the concept of solar energy. My goal for the students is for them to understand the basic concept that the heat radiating from the sun is energy.

The sun is the center of our solar system, a bright star formed around 5 billion years ago. What is it made of? Your students might ask. The sun is a big ball of hot gas made of hydrogen and helium. On the surface the sun is an astounding 10,000 degrees Fahrenheit.[11] Without the sun, Earth would be a dark frozen planet with no life. The sun provides us with light and heat for all human life to survive. The ancient romans called the sun “sol”. This is the origin of the modern term, solar system.

Heat and light travel from the surface of the sun all the way through space and our atmosphere onto the Earth’s surface. This process takes about 8 minutes for the light waves to leave the sun and hit Earth’s surface. The light waves emitted from the sun vary and only some can be seen. Most harmful light waves are absorbed by our Earth’s atmosphere. When the light hits the Earth’s surface it warms our planet which makes Earth livable for all life.

Heat and light radiating down from the sun onto Earth’s surface is solar energy. The light carries energy; this in turn is what is being used to drive and power the photosynthetic process. Light is critical for the plant to grow and develop. Photosynthesis would not happen without the energy from light.

Conclusions

Over the course of this curriculum unit, I reviewed a handful of the key players in the sciences who helped to push the science of photosynthesis forward by discovering the underlying mechanisms before discussing a basic model that describes the action of photosynthesis itself. Additionally, I described the chemical formula that illustrates the underlying reaction that makes photosynthesis possible, before illustrating the relevant structures of plants that engage in the process, describing the different structures and their uses.

While much of the science of photosynthesis will be outside of the scope of what kindergarteners need to know, I believe that it is critical for all educators to instill a love for scientific concepts in students at an early age. Educators will benefit from having access to the research and deeper understandings marshalled and presented in this curriculum unit.

The implications of this process fall well outside of the utilization of photosynthesis by plants. In exposing students from an early age to these concepts, I hope to see a lifelong love of science that will inspire our young learners and future leaders to look to nature for solutions to problems of pollution, energy availability, and global climate change.

Implementation Strategies

Journaling will be used extensively in this unit as a way for the students to track their plant's progress. For my own students, journaling in the beginning will just be drawing pictures and labeling. This form of developmental writing is great for students at the beginning of the year. As they become more familiar with the process, their labels will turn into short sentences about what is happening and what they are observing. Journaling is a great way for my students to record scientific data. They will do this by also measuring how tall their bean plant becomes and making these additions to their journal entries. This allows them to learn at their own pace and be allowed to express what is unique to them and thus create individualized learning.

Listening Comprehension is a strategy I use often in my classroom. Due to the age of my students they are not quite reading text on their own at this point. This makes listening comprehension critical especially for nonfiction texts. There are several things one can do while reading to engage the students and increase their comprehension of the story or concept. I use turn and talks during my read alouds to give the students a chance to discuss key concepts with a partner and then report back to the group. I also use think alouds to bring up a problem to use in prompting a class discussion.

Class discussions are essential to all early learning. They provide the students with a chance to ask questions and explore ideas in a safe environment. In my classroom, I use class discussion following a story or main idea. I usually reinforce this with the making of anchor charts of visual aids. I hang these in the class for the students to refer back to in context. This strategy, coupled with journaling, allows independent and group learning in the classroom.

Essential topics and questions

These questions are for general discussion as we read, but they are also intended to guide imaginations as my students explore hands-on within the unit. They may provide a framework for introductions or conclusions.

What is a life cycle?

What are the characteristics of living, nonliving, and dead things?

What can we observe about a pea plant over time?

What happens during each stage of a life cycle?

What is photosynthesis?

What does the sun do for our pea plant?

How can we measure our plant's growth?

What is energy?

Student Resources

Bang, Molly, and Penny Chisholm. *Buried Sunlight: How Fossil Fuels Have Changed the Earth*.

Buried Sunlight is an information book for students on fossil fuels. This book explains what fossil fuels are and how they came to exist.

Bang, Molly. *Common Ground: The Water, Earth, and Air We Share*. New York: Blue Sky Press, 1997.

Common Ground is a great simple story for students on the planet's natural resources. This story is about a town sharing a common green space and the needs of the townspeople. This book presents the challenge of handling our planet's natural resources.

Bang, Molly. *My Light*. New York: Blue Sky Press, 2004.

My Light is a great children's information book on the sun and solar energy. This book explains to the students how we get energy from light.

Bang, Molly, and Penny Chisholm. *Living Sunlight: How Plants Bring the Earth to Life*. New York: Blue Sky Press, 2009.

Living Sunlight is a great information book about the energy we share with all living things in nature.

Bang, Molly, and Penny Chisholm. *Ocean Sunlight: How Tiny Plants Feed the Seas*. New York: Blue Sky Press, 2012.

Ocean Sunlight is a great information book about life in the ocean. It is filled with simple science and information for students about plant and animal life in the ocean.

Carle, Eric. *The Tiny Seed*. Natick, MA: Picture Book Studio, 1987.

This is a great read aloud for the students. It follows the growth of a plant from a tiny seed into a thriving flower. This is a great resource with excellent illustrations.

Teacher Resources

MacKay, David J. C. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009.

This is a great and easy read for general background knowledge on sustainable energy. The author is based out of the UK; however, the information is still very pertainable to the United States.

Walker, David. *Energy, Plants and Man*. Brighton: Oxygraphics, 1992.

This is a great resource for in depth background knowledge relating to photosynthesis. This resource is very technical and specialized for the topic of photosynthesis.

Yergin, Daniel. *The Quest: Energy, Security and the Remaking of the Modern World*. New York: Penguin Press, 2011.

This is a great resource for the political and economical aspects of energy. This book dives into political issues in the past and present regarding all energy.

Student Activities

To introduce this unit, we will start with the initial life cycle study. Students will be introduced to key vocabulary, parts of a plant, and their functions. This component is crucial and not to be overlooked for this age group. Providing purposeful exposure to new words impacts a student's reading comprehension and future academic success.

The seed in a bag activity. Students will engage in planting a seed in a bag with a wet paper towel. I give the students a lima bean, a wet paper towel, and a Ziploc bag. The students "plant" the seeds and hang them on a window with direct sunlight. They log journal predictions and observations over the course of several days in a special plant journal I will provide for them. Students will be introduced to photosynthesis by the reading of *Living Sunlight: How Plants Bring the Earth to Life.* With the shared reading and rich vocabulary introduction, students will then take part in a shared writing and building a pictorial anchor chart to express their knowledge of photosynthesis in its most basic form. I will instil in the students that plants take in light, air, and water into the plant to make sugar which is what they use as food for the plants to grow. Then the plants give off what they didn't use back into the air (O_2). With the conclusion of their seed activity, students will have been exposed to the most basic form of photosynthesis in the form of read aloud and videos. We will tie this back to their seeds and how plants are solar powered.

Students will engage in the planning of a classroom community garden. They will bring seeds from home to plant, watch, and grow. I will use a window box or small plastic pool for our classroom garden. The students will observe plants growing in partial shade, and direct sunlight. They will observe and note the differences. We will have many class discussions on the plant growth and the photosynthetic process. Students will measure growth of the plants using nonstandard units of measurement throughout the month of plant growth. Investigating, observing, and describing are all essential to students this age. This activity will allow the students to observe how the food they eat grows and where it comes from. The students will use these often while taking part in the classroom community garden. We will conclude the garden and tie it to fruits and vegetables being solar powered.

We will conclude with the tie back that we are solar powered. At this point, students have learned how essential the sun is to the life cycle of a plant and their community garden. They have been introduced to the basic concepts of photosynthesis. We will wrap up the unit with a shared writing activity. First, the students will be shown energy pyramids depicting energy flow in a community. This will show producers and consumers of energy and the food chain. Second, the students will take part in a fruit and veggie sampling from our classroom community garden. Lastly, the students will take part in a shared writing demonstrating all of their learning. The students will be told that they are going to create a story together to tell other kids about how the sun gives plants energy, and we in turn are solar powered. I will be facilitating this with the class whole group. Students will have the opportunity to provide illustrations and cover art for their class book.

Bibliography

Bassett, David A. "Johann Baptista Van Helmont." Chemistry Explained Foundations and Applications. 2016. Accessed July 15, 2016.

Kimball, John W. "Discovering the Secrets of Photosynthesis." Biology Pages. February 28, 2011. Accessed July 15, 2016. http://www.biology-pages.info/P/Photosynthesis_history.html.

MacKay, David J. C. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009.

Martin, Daniel, Andrew Thompson, Iain Stewart, Edward Gilbert, Katrina Hope, Grace Kawai, and Alistair Griffiths. "A Paradigm of Fragile Earth in Priestley's Bell Jar." *Extreme Physiology & Medicine*, 2012th ser., 1, no. 4 (September 4, 2012).

Sharkey, Thomas. *Photosynthesis Plastid Biology, Energy Conversion and Carbon Assimilation*. Edited by Jullian Eaton-Rye and Baishnab Tripathy. Vol. 34. New York, New York: Springer Science Business Media, 2012.

Walker, David. *Energy, Plants and Man*. Brighton: Oxygraphics, 1992.

Yergin, Daniel. *The Quest: Energy, Security and the Remaking of the Modern World*. New York: Penguin Press, 2011.

Endnotes

1. Bassett, David A. "Johann Baptista Van Helmont." Chemistry Explained Foundations and Applications. 2016. Accessed July 15, 2016.
2. Kimball, John W. "Discovering the Secrets of Photosynthesis." Biology Pages. February 28, 2011. Accessed July 15, 2016. http://www.biology-pages.info/P/Photosynthesis_history.html.
3. Martin, Daniel, Andrew Thompson, Iain Stewart, Edward Gilbert, Katrina Hope, Grace Kawai, and Alistair Griffiths. "A Paradigm of Fragile Earth in Priestley's Bell Jar." *Extreme Physiology & Medicine*, 2012th ser., 1, no. 4 (September 4, 2012).
4. Sharkey, Thomas. *Photosynthesis Plastid Biology, Energy Conversion and Carbon Assimilation*. Edited by Jullian Eaton-Rye and Baishnab Tripathy. Vol. 34. New York, New York: Springer Science Business Media, 2012.
5. Sharkey, Thomas. *Photosynthesis Plastid Biology, Energy Conversion and Carbon Assimilation*. Edited by Jullian Eaton-Rye and Baishnab Tripathy. Vol. 34. New York, New York: Springer Science Business Media, 2012.
6. Sharkey, Thomas. *Photosynthesis Plastid Biology, Energy Conversion and Carbon Assimilation*. Edited by Jullian Eaton-Rye and Baishnab Tripathy. Vol. 34. New York, New York: Springer Science Business Media, 2012.
7. Sharkey, Thomas. *Photosynthesis Plastid Biology, Energy Conversion and Carbon Assimilation*. Edited by Jullian Eaton-Rye and Baishnab Tripathy. Vol. 34. New York, New York: Springer Science Business Media, 2012.
8. Sharkey, Thomas. *Photosynthesis Plastid Biology, Energy Conversion and Carbon Assimilation*. Edited by Jullian Eaton-Rye and Baishnab Tripathy. Vol. 34. New York, New York: Springer Science Business Media, 2012.

9. Whiting, David. “Plant Structure: Roots.” Colorado State University. January 14, 2016. Accessed July 16, 2016. http://ext.colostate.edu/mg/gardennotes/132.html.
10. Whiting, David. “Plant Structure: Flowers.” Colorado State University. January 14, 2016. Accessed July 16, 2016. http://ext.colostate.edu/mg/gardennotes/135.html.
11. Grayzeck Ed. "Sun Fact Sheet." NASA. February 29, 2016. Accessed August 3, 2016. http://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html.

Appendix

Next Generation Science Standards

K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.

K-ESS2-2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

K-ESS3-1. Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.

K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.

K. Weather and Climate

K-PS3-1. Make observations to determine the effect of sunlight on Earth’s surface.