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Teaching Science Using the Language of Nature: Winter Comes to Our Campus*

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Abstract

Through science education that provides integration with nature, students can enter into a positive relationship with scientific knowledge and find the opportunity to have a meaningful learning experience. This study on the theme "winter comes to our campus" was carried out with the interwoven techniques of observation and experimentation. The concept of photosynthesis, a subject of biology, has been treated here with an integrated approach that combines geography (the world's axis, natural phenomena), chemistry (the method of separation of molecular structures), physics (the interaction between light and matter) and fine arts (the harmony of colors displayed by plants at the changing of the seasons). The project stimulates students to adopt an integrated perspective on science.

Keywords: light-chlorophyll interaction, photosynthesis, chromatography, integrated thinking and learning, scientific observation

Introduction

Nature, in matchless harmony and interaction as it harbors within it all entities, alive or dead, reveals so many phenomena for us to observe every day. The story behind the scenes of these events, which seem to us so ordinary, is much more complicated than we think. Most of us have witnessed the efforts of ants as they prepare for the winter by gathering food for themselves all through the summer or the behavior of animals that settle down to hibernate in order to maintain their body temperatures. In the same way, plants too, make preparations for the approaching winter season. The leaves on some of these plants change in color, turn yellow and fall off. These ordinary events that can be observed by any one of us are a sign of the continual changes that take place in nature. In one of our science classes, we found ourselves tracking the answer to a question about one of these changes: "How do trees that shed their leaves get nourished in

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the wintertime?" Do the changes we observe in the trees as the seasons revolve have anything to do with changes in the level of energy (light) reaching the plant or in the amount of chlorophyll it contains?

This project was undertaken to explain the phenomenon of falling leaves in some trees in the winter, using one of the chemical methods of separation, chromatography, and combining this with concepts of light and chlorophyll. The study was carried out with the interwoven techniques of observation and experimentation. Studying the interaction of light and chlorophyll, a factor that leads to physiological changes in plants at the changes of season, is a recommended introductory activity to facilitate the comprehension of photosynthesis, a subject in school curriculums (National science educational standards, 1998) that is generally difficult to understand. A secondary objective of the endeavor has been to stress the importance of observation in science education while at the same time creating awareness about the skills required in the scientific process that combines observation and experimentation.

Misconceptions study participants had about photosynthesis before the activity

In order to determine the level of knowledge students had about the interaction of light and chlorophyll, which is the beginning of the process of photosynthesis, and identify possible misconceptions, the students in the classroom environment were asked: "How do trees that shed their leaves get nourished in the wintertime?" Several misconceptions that some were common with previous studies were determined. Students' misconceptions and some examples from previous studies were presented as follow:

- Photosynthesis only occurs in the green leaves of plants (e.g., Amir & Tamir, 1994; Giordan 1990).
- Chlorophyll is only contained in the green leaves of plants (e.g., Mikkila, 2001).
- A plant that sheds its leaves in the winter months does not go through photosynthesis and is therefore nourished until the spring by the minerals it absorbs from the earth (e.g., Cañal, P. 1999; Ray & Beardsley, 2008).
- Plants get their food from the earth through their clusters of branches.
- In sunny seasons they prepare for winter by producing their own food and storing it (e.g., Cañal, P. 1999).
- Because plants go through the dark stage of photosynthesis in winter, they don't need chlorophyll.
- The falling of leaves has nothing to do with the seasons; shedding leaves is a method of excretion for plants.

Light - Chlorophyll Interaction

Photosynthesis brings about the formation of all bacterial, plant and animal life, or what is today known as organic life on the earth, through its source, the sun. A plant is able to survive without freezing, even at the earth's poles, by using its own photosynthesis factory; this factory enables it to be born, to grow, die and be re-born. In that case, whenever the questions surrounding the miracle of photosynthesis can be fully answered, a multitude of more questions and problems on this earth will also have been answered or solved (İçli, 2009).

The source of the energy that ensures the continuation of life on the earth is the stimulation of a pigment molecule electron by a photon emitted from the sun (Keeton & Gould, 1999). This phenomenon is the beginning of photosynthetic reactions. In plants that go through the process of photosynthesis, electrons in the chlorophyll molecules of plants are excited to a higher energy level by solar energy. The electron jumps to the next level of energy and returns to its ground state. The atoms, molecules and ions tend to be released from the absorbed energy. This process is achieved through phenomena such as heat or light emission. Chlorophyll is then converted, by means of chloroplasts and a series of reactions catalyzed by various enzymes, into a type of energy that can readily be used by the plant. This energy is chemical energy (Gurel & Kuleli, 1991). Photosynthesis is not a phenomenon that only occurs in green plants. Yellow and orange pigments are always found in leaves but are generally masked by chlorophyll. Depending on the physical conditions of the environment, these auxiliary pigments become more visible. The auxiliary pigments in the plants absorb different wavelengths of light than what chlorophyll a is able to capture (Keeton & Gould, 1999). These pigments make the process of photosynthesis in the plant possible even when there are only small amounts of chlorophyll present.

The Changes of Seasons and Plants

The seasons occur because of the slant in the Earth's axis and its orbiting motion around the Sun. The slant is 23.5◦. During the period June 21 – September 23, when the northern hemisphere is inclined toward the sun, rays of sunlight hit the regions of the Earth that are even the farthest from the equator. As a result, the northern hemisphere experiences longer days and more moderate climates. In the same period, the southern hemisphere experiences shorter days and the winter season. As from December 22, more rays of sun start hitting the southern hemisphere, this time causing the northern hemisphere to experience winter (American Forest Foundation, 2002).

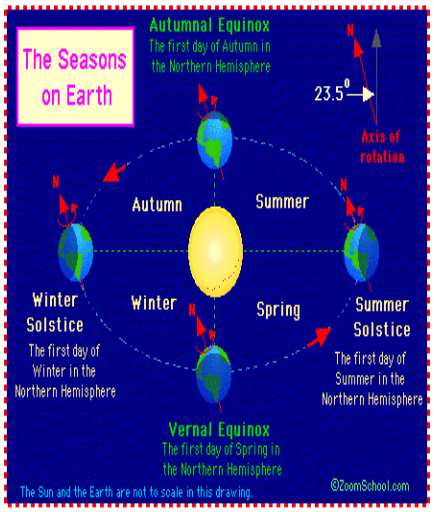

Figure 1. The Slant of the Earth's Axis and its Orbit around the Sun. (Zoom Astronomy, http://www.enchantedlearning.com/subjects/astronomy/planets/earth/Seasons.shtml).

Because of the tilt of the Earth's axis and the path of its orbit around the sun, the angle of the Sun's rays and therefore the wavelengths of these rays and their energy change. This is why the sun appears to be red at sunset. The color scale for the electromagnetic spectrum is shown below.

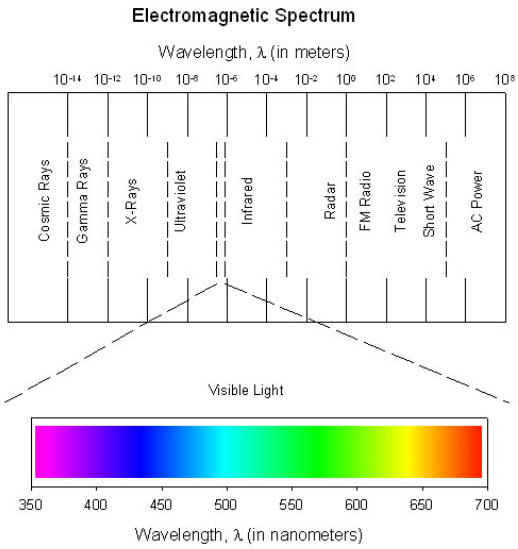

Figure 2. Color Scale in the Visible Electromagnetic Spectrum (McCourt, http://www.psych.ndsu.nodak.edu/mccourt/Psy460/Light%20as%20a%20stimulus%20for%20vision/electromagnetic%20spectrum.JPG).

The differences in the angles in which the rays of the sun are emitted are what cause plants to perceive the seasons. The effects of these changes

can be seen in the amounts of chlorophyll produced by plants. Establishing what these amounts are through the use of a chromatographic technique will enlighten us in our project.

Chromatographic Technique

Chromatography involves the chemical separation of mixtures with similar chemical and physical properties whereby the analyte is separated and flushed through the system by passing mixtures dissolved in their mobile phases through a stationary phase at different rates (Karaer, 2007). This activity will make use of paper chromatography, which is one of the chromatographic techniques, simply because it is a method that requires simple materials that can be found in every environment.

A better term for paper chromatography here is "dispersion chromatography" because of the use of the filter paper that easily and strongly absorbs water and performs the function of the stationary phase in the process of chromatography (Karaer, 2007).

Performing the Experiment

This project is carried out with activities both inside and outside of the classroom. In the first stage, the students are taken outdoors in the fall or winter season and asked to make observations about the signs of winter (particularly about trees that are shedding their leaves). The students are first asked how plants get their nourishment. Then, a problem is posed with the question, "How do trees that shed their leaves get nourishment?"

The second stage involves the students' trying to find an answer to the question resulting from their observation of nature, centering around a laboratory experiment. A tree is chosen from the area of observation and some green, yellow and dried leaves as well as fresh and dry branches are gathered. The tree chosen from the area for the experiment can be seen below (Figure 3). Equal amounts of green, yellow and dry leaves are gathered from the tree (Figure 4) as well as some fresh and dry branches (Figure 5).

Figure 3. The tree chosen for the experiment from the area of observation

Figure 4. Equal amounts of green, yellow and dry leaves gathered from the chosen tree

Figure 5. The fresh and dry branches gathered from the chosen tree

Paper chromatography is undertaken in the laboratory: Equal samples of the green, yellow and dried leaves and of the fresh and dry branches (2g) are extracted from the group and ground in separate mortars with an equal amount of alcohol (25 ml). Long bands of filter paper are dipped into the solution that has formed and left to stand for 15-20 minutes. During this period and at its completion, the pupils are asked to observe the changes in the filter papers and take notes. The setup of the experiment is shown below (Figure 6).

Figure 6. Experiment Set-up

Experiment Results

As time passes, it is seen that the solution from the green leaves turns into yellow, green and orange on the filter paper. The solution from the yellow leaves is observed to exhibit less of a green color compared to the green leaves but more yellow and orange. The solution attained from the dry leaves however shows no color change at all. The filter paper after the chromatography of the green, yellow and dry leaves is shown below (Figure 7).

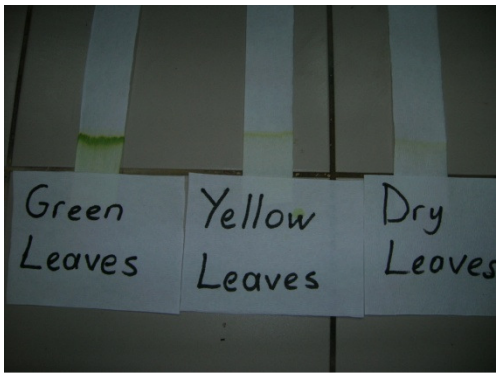

Figure 7. Results of chromatography of green, yellow and dry leaves on filter paper

When the filter paper in the different solutions resulting from the fresh and dry branches are studied, it can be seen that the fresh branches display less of a green color. The dry branches show no color at all. The chromatography of the fresh and dry branches on the filter paper can be seen below (Figure 8).

Figure 8. Results of paper chromatography of fresh and dry branch

What the experiment teaches about photosynthesis

Cold weather and short days affect plants as well. Trees that shed their leaves start going through certain changes. The cells on the leaves attached to their stems begin to die and therefore water and nutrients can no longer

be transported to the tree. Chlorophyll activity in the leaves slows down as the other color pigments become active. This is how the yellow, orange and red leaves that we see in the fall are formed. Due to the dying cells, the stems holding the leaves to the branches weaken and eventually break off, causing the leaf to fall. When its leaves fall off, the tree is less affected by the cold. Because the leaves that carry out photosynthesis have fallen, the tree's metabolism slows down. New leaves appear with the warming of the weather (American Forest Foundation, 2002). We can actually observe this phenomenon that takes place especially in the leaves of plants by studying the changes in the amounts of chlorophyll contained in the leaves.

While students were saying before the activity that chlorophyll was contained only in the green leaves of the plants, at the end of the experiment, they were able to detect the chlorophyll in the tree branches that were of brown tones. This helped them to completely dispel the misconception that trees that shed their leaves do not contain chlorophyll. Thus the students had the opportunity to show, in the environment of the laboratory, how a tree that had shed its leaves could remain alive. The experiment also dispelled the misconception that "photosynthesis takes place in only green plants." This new knowledge meant that photosynthesis takes place when chlorophyll is present; therefore, since the yellow leaves and the fresh branches had chlorophyll in them, they too could undergo photosynthesis.

The question posed by the experiment about how light and chlorophyll interact to cause the physiological changes that plants go through at the changes of season is explained by the answer given to the question, "How do trees that shed their leaves get nourished in the wintertime?" The way that trees shed their leaves in winter is a method of adaptation that ensures that the plants will be less affected by the cold.

Through science education that provides integration with nature, students can enter into a positive relationship with scientific knowledge and find the opportunity to have a meaningful learning experience. This activity on the theme "Winter comes to our campus" can be used to increase students' skills of observation. The project can be used to explain the interaction of light and chlorophyll through observational skills with the support of a laboratory experiment.

The concept of photosynthesis, a subject of biology, has been treated here with an integrated approach that combines geography (the world's axis, natural phenomena), chemistry (the method of separation of molecular structures), physics (the interaction between light and matter) and fine arts (the harmony of colors displayed by plants at the changing of the seasons). In short, the project stimulates students to adopt an integrated perspective on science, providing them with the opportunity to internalize their experiences in nature and in the laboratory, and to incorporate these into their own lives.

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