**Teacher Handout–Solar Panels and Soybean Leaves!**

Guidelines for NGSS 3-Dimensional Learning

**NGSS Alignment:** HS-LS1: Matter and Energy in Organisms and Ecosystems

 **Performance Expectations:**

* HS-LS1-5: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
* MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

**HS-LS1.C: Organization for Matter and Energy Flow in Organisms**

**●** The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

### **MS-LS1.C**[**:**](http://www.nap.edu/openbook.php?record_id=13165&page=194) **Organization for Matter and Energy Flow in Organisms**

* Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

**PS3.D: Energy in Chemical Processes and Everyday Life**

* The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary)

### [**ETS1.B: Developing Possible Solutions**](http://www.nap.edu/openbook.php?record_id=13165&page=175)

* [When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary)*](http://www.nap.edu/openbook.php?record_id=13165&page=206)

**Science and Engineering Practices:**

* Developing and using models
* Planning and carrying out investigations
* Analyzing and interpreting data
* Using mathematical and computational thinking
* Engaging in argument from evidence

**Crosscutting Concepts:**

* Cause and Effect
* Energy and matter
* Systems and system models

**Alignment to Illinois Career Tech Courses:**

* Basic Environmental Science
* Crop Science
* Environmental Science
* Introduction to the Agricultural Industry
* Precision Agriculture
* Specialty Crop Production
* STEM in AFNR

**Overall lesson objective:**

Using the anchoring phenomenon of the Solar Panels, students explore the ways in which humans harness solar energy. Building on that model, students are introduced to the ways in which plants harness the same energy in photosynthesis and explore the impacts of different variables on that process. Finally, students design solutions to improve the use of solar energy by both solar panels and plant leaves.

**Accommodations for students on IEPs and ELL students:**

Provide additional explanations on directions to ELL students or students on IEPs. Allow students to dictate written work to a teacher or paraprofessional. Provide opportunities for the articles to be read aloud as students need.

**Teacher Handout Engagement Phase**

 ***Solar Panels Activity***

**Purpose of Solar Panels Activity:** The purpose of Solar Panels Activity is to engage students in thinking about solar energy and the ways in which it can be used by humans.

**Learning Objective Addressed in Solar Panels Activity:** Students do a close read of an article about solar energy to provide a summary of the article.

**Driving question**: How do humans harness the power of the sun?

**Overview ofSolar Panels Activity:** Students will read carefully and provide a “$2 summary” based on teacher instruction.

**Time:** One 50-minute class period

**Materials:**

*Student materials:*

* Article: [Solar Energy](https://www.nationalgeographic.com/environment/article/solar-power)
* Student handout: Solar Energy: A $2 Summary

*Teacher materials:*

* Article: [Solar Energy](https://www.nationalgeographic.com/environment/article/solar-power)
* Image of a soybean leaf
* Image of a solar panel

**Procedure--Part I--Article Introduction:**

The teacher will show the video accompanying the article to the class. Next, the teacher will instruct the students to read the article carefully, highlighting and looking up any words they do not know, and circling the main ideas. Give students time to read the article.

**Procedure--Part II--Introduce the $2 Summary:**

The teacher will introduce the structure:

“You have $2 to spend to write a summary of the article. Each word costs 10￠. Your summary should spend exactly $2.”

Provide students time to write their summaries. As students work, circulate the room to check their work and offer help as needed.

**Procedure–Part III–Share Summaries:**

Have students share out their summaries in small groups, comparing and contrasting. Each group will either choose the best summary or work together to craft a group summary that they will subsequently share with the whole class.

**Procedure–Part IV–Connect to Explore Phase:**

* Display a picture of a healthy soybean leaf beside an image of a solar panel.
* Instruct students to use roundtable format to list all of the similarities between the two. (Give each group one piece of paper and ask all students to get out a pencil. Give students 30 seconds of silent think time before beginning. Then students take turns writing down one similarity on the paper then passing it to the left. Continue until the teacher calls time–about 90 seconds.) Have each group share out similarities they found.
* Repeat this procedure with differences between the two items.

Introduce the explore phase by explaining that the leaf is the soybean plant’s method of harnessing solar energy much like humans do with solar panels. Explain that we will investigate how this works in the next lesson.

**Teacher Handout Explore Phase**

***Photosynthesis–Leaf Disk Flotation***

**Purpose of Leaf Disk Flotation Activity:** The purpose of this activity is for students to observe photosynthesis happening and explore the impacts of variables on the process.

**Learning Objective Addressed in Leaf Disk Flotation Activity:** Students explore and make observations of a photosynthesis under different conditions and collect quantitative data of the results

 **Driving question**: What variables impact the rate of photosynthesis?

**Overview of Leaf Disk Flotation Activity:** Following an introduction to photosynthesis ([see slide deck](https://docs.google.com/presentation/d/1mL1VnGTE2-A0oZQYKqMJ4Qi-TMrZSkUH9o7c49hSLJk/edit?usp=sharing)),students will carry out a leaf disk flotation demonstration of photosynthesis and manipulate light variables to impact the rate of photosynthetic activity.

 **Time**

● 2 or 3 50-minute class periods

**Procedure:**

1. The teacher will lead the class in an introduction to photosynthesis using the [provided slide deck](https://docs.google.com/presentation/d/1mL1VnGTE2-A0oZQYKqMJ4Qi-TMrZSkUH9o7c49hSLJk/edit?usp=sharing).
2. The teacher will lead students through the process of planning their investigations using [this slide deck](https://docs.google.com/presentation/d/1BjujkfkgzrIzDz8CTjhA6fsJNES8RgmBc6EZe4NdxwE/edit?usp=sharing). Students will complete their lab planning forms at this time.
3. Students will carry out the leaf disk flotation investigation using the following methods.

**Investigation Materials:**

Each group will need:

* Three or four clear plastic punch cups
* Spinach leaves
* Drinking straws
* Water
* Desk lamp
* Food coloring, colored transparency paper, or colored light bulbs
* One 20 mL syringe
* Dish soap
* Small paint brush
* Stopwatch or timer
* Lamp

**Investigation Procedure:**

1. Use the drinking straw (or a hole punch) to cut 30–40 disks from the spinach leaves.
2. Fill each cup about two-thirds full of water and a drop of dish soap. Mix the soap in well.
3. Place 10 leaf disks in the syringe with about 20 mL of solution drawn from the cup. Push the plunger to remove any air. Covering the end of the syringe with a finger, pull back on the plunger as far as possible, then let go (while keeping your finger over the end of the syringe). You should see air bubbles come out of the leaf disks. Push the released air out. Repeat the process until the leaf disks no longer float.
4. Holding the syringe, plunger down, over your cup, remove the plunger to allow the water and leaves to fall into the cup. You may need to use the paint brush to remove any remaining leaves.
5. Repeat steps 2 and 3 for each water sample.
6. Place the cups under the lamp. In 10-second intervals, record the number of leaves floating to the top.

Each lab group may choose a variable to manipulate. These may include color of light (can be changed using food coloring in the water, colored plastic sheets over the cups, or the color of the light bulb), intensity of light (can be changed with varying light bulbs or by placing screens over the cups), or another variable the teacher approves. This investigation is focused on light; however, instructors may expand this to include varying amounts of carbon dioxide present in the water, temperature of the water, etc.

As students carry out the investigation, they record their observations on the Student Handout: Photosynthesis and Leaf Disk Flotation Data Sheet. In 10 second intervals, students count and record the number of leaf disks floating in each cup. Lab groups should assign roles for data collection including time keeper, leaf counter, and recorder.

**Teacher Handout Explain Phase**

**Purpose of Leaf Disk Flotation Manuscript.** The purpose of the lab manuscript is for students to engage in argument from evidence as they support their claim and make sense of what they have figured out about the impact of variables on photosynthesis. Students explain the impact of changing conditions on photosynthesis in written form.

**Learning Objective Addressed in Leaf Disk Flotation Manuscript.** Students argue from evidence that changing factors can result in changed reactions.

**Driving question.** How do changing variables impact the rate of photosynthesis?

**Overview of Leaf Disk Flotation Manuscript.** Using the data collected in the Explore phase, students write a lab manuscript complete with introduction, methods, results, and discussion sections.

**Time, Two 50-minute class periods**

**Materials**

***Student materials***

* Student Explanation Handout: Lab report template
* Word processing software

***Teacher materials***

* How to Write a Lab Manuscript slide deck
* Lab report rubric

**Set-up**

* Prepare student lab report templates (paper copies or share online).
* Set up slide presentation.

**Procedure--Part I--Manuscript introduction:**

Introduce the lab report template, which follows the format of a scientific manuscript. Take time to explain each section with the *How to Write a Lab Manuscript* presentation provided. Laboratory manuscripts are expected to be three or four pages in length, typed, double spaced in twelve-point font.

* Introductions should include two or three paragraphs of background information about the investigation. Introductions include brief explanations of the natural phenomena addressed, provides relevant biological information about the species studied and the relationships among them, and introduces the research question and hypothesis.
* The methods section describes, in detail, the steps used to carry out the investigation and identifies the independent variable, dependent variable, constants, control group, and experimental group. Encourage students to use past tense, active voice, and write in narrative form rather than numbered steps.
* In the results section, students report the data collected in their investigation, with the inclusion of tables and appropriate graphs. Explain that it is expected that they describe overall trends and comparisons in this section of the manuscript. Remind students not to interpret any findings in this section (do not explain the trends or state whether the hypothesis is supported).
* The discussion section includes a thorough explanation of their findings, in the CRE format--Claim, Evidence, Reasoning. The claim states whether the initial hypothesis was supported. The evidence provides an overview of specific data from the lab that backs the claim. The reasoning explains why the evidence supports the claim, describes the strengths and weaknesses of the claim, and relies on currently accepted explanations to determine the merits of their arguments.

**Procedure--Part II--Manuscript writing:**

Check student work, offer suggestions, and ask probing questions to help students arrive at appropriate conclusions as they make sense of the data they have collected. Depending on students’ prior experience with this kind of writing, you may want to spread the lab report work up across multiple days.

*Note: Your role as the teacher is to guide students to be able to make a clear argument using their evidence and the evidence of others to support their argument. Their argument does not need to be in support of their hypothesis.*

**Procedure--Part III--Manuscript review:**

Evaluate the manuscripts using the grading rubric.

Manuscript Rubric

Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| **Category**  | **NGSS Component Addressed**  | **Unacceptable** **(0)**  | **Marginal (1)**  | **Adequate** **(2)**  | **Good (3)**  | **Excellent** **(4)**  | **Comments**  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Title** **(5%)**  |   | Missing  |   | Uninformative  |   | Descriptive & engaging title   |   |
| **Introduction (15%)**  | HS-LS2.C  | Objectives are unclear; no rationale is given for the research. Hypothesis is missing, poorly written, or untestable.  |   | Objectives are somewhat clear and complete. Background and rationale are presented but the link to the study question is not entirely clear. Hypothesis is adequately written and testable but the link to the objectives lacks clarity.  |   | The question and objectives are clearly stated. Concise background information is provided. Hypothesis is well-written, testable, and addresses the question.  |   |
| **Methods (20%)**  | SEP: Planning and carrying out an investigation.  | Methods are poorly described or do not match hypotheses.  |   | Most of the steps are described adequately, but the link to the hypothesis is unclear.  |   | All steps are described fully and are clearly related to the hypothesis. There are clear experimental and control groups.  |   |
|  **Results (20%)**  | SEP: Planning and carrying out an investigation.   | Results are poorly presented. Graphs / tables are missing or cannot be interpreted. No relevant data collected or analysis.  |   | Sufficient data is collected. Results are presented and explained clearly. Graphs or tables may lack some clarity. Interpretation is present when it should not be.  |   | Sufficient data is collected. Clear and concise presentation of results. Graphs / tables are appropriate, clearly labeled, descriptively captioned, and referenced in the narrative. Results are described with trends indicated clearly but not interpreted. Analysis is well conducted and appropriate.  |   |
| **Discussion (25%)**  | HS-LS2-6 HS-LS2.C SEP: Engaging in Argument from Evidence CCC: Stability & Change  | Interpretation is absent or inappropriate with respect to the original hypothesis. Science is inaccurate. Claim, Evidence, and Reasoning are each addressed.  |   | Interpretation addresses the original hypothesis adequately. Consideration of alternative potential interpretations is weak or missing. Implications of future research are discussed minimally. Science is accurate. Claim, Evidence, and Reasoning are each addressed.  |   | Interpretation is well-reasoned, entirely consistent with the original hypothesis and well supported by data. Alternative potential interpretations are addressed. Implications and future research discussed well.  |   |
| **References (5%)**  |   | References are inadequate; there is minimal attempt to paraphrase and cite materials properly.  |   | References are used adequately. All work is properly paraphrased and cited.  |   | Authors provide a comprehensive list of properly cited current literature. All citations are included with no additional references. All work is properly paraphrased and cited.  |   |
| **Communication and Style (10%)**  |   | Demonstrates poor communication skills.  |   | Demonstrates adequate communication skills.  |   | Demonstrates excellent communication skills. Clear, concise, and well-organized. Writing is grammatically correct and flows well.  |   |
| \*\*Level 1 indicates achievement of some characteristics of levels 0 and 2.  Level 3 achievement indicates some characteristics of levels 2 and 4.  |   |

Adapted from French, Donald P. *Investigating Biology: A Laboratory Resource Manual*. Harcourt, 2021.

To transition into the Elaborate phase, the teacher says, “You have figured out what variables impact photosynthesis. Now you will explore ways to improve efficiency in the ways both plants and humans harness the power of the sun.”

**Teacher Handout Elaboration Phase**

**Purpose of Improving Efficiency Activity:** The purpose of this activity is for students to think of effective solutions for increasing efficiency in both solar panels and soybean leaves, relating the two together.

**Learning Objective Addressed in Improving Efficiency Activity:** In this activity, students will design possible solutions for real world problems.

 **Driving question**: How can efficiency be increased in harnessing the sun’s power?

 **Overview ofImproving Efficiency Activity:** Students will research factors that impact efficiency in solar panels,design solutions to those barriers, and relate those same solutions to possible improvements in increasing soybean leaves’ efficiency in collecting solar energy.

**Time:** 2 50-minute class periods

 **Materials:**

* Student handout: Increasing Efficiency

**Procedure:**

* Students will research and list factors impacting solar panel efficiency.
* Based on this list, they will develop possible solutions to these barriers.
* Finally, students will apply these ideas to soybean leaves.
* Following this initial work, students will choose one of the solutions to present to the class by creating a 30 second promotional talk or video to present ideas to the class. Students should be sure to include visual aids!
* Score student work using the provided rubric.

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Score: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Oral Presentation Rubric**

|  | 4—Excellent  | 3—Good  | 2—Fair  | 1—Needs Improvement |
| --- | --- | --- | --- | --- |
| Delivery  | • Holds attention of entire audience• Speaks with fluctuation in volume and inflection to maintain audience interest and emphasize key points | • Consistent use of direct eye contact with audience• Speaks with satisfactory variation of volume and inflection | • Displays minimal eye contact with audience, • Speaks in uneven volume with little or no inflection | • Holds no eye contact with audience • Speaks in low volume and/ or monotonous tone, which causes audience to disengage |
| Content/ Organization | • Demonstrates full knowledge by answering all class questions with explanations and elaboration • Provides clear purpose and subject | • Is at ease with expected answers to all questions, without elaboration • Has somewhat clear purpose and subject | • Is uncomfortable with information and is able to answer only rudimentary questions • Attempts to define purpose and subject | • Does not have grasp of information and cannot answer questions about subject • Does not clearly define subject and purpose |
| Visual aids–creativity and relevance | The visual aid was creative in showing the necessary information. | The visual aid was mostly creative in showing the necessary information. | The visual aid was somewhat creative in showing the necessary information. | The visual aid was not or barely creative in showing the necessary information or it did not relate to the work. |
| Visual aids–neatness | The visual aid was neat and organized and followed a logical flow. | The visual aid was mostly neat and organized and followed a logical flow. | The visual aid was sometimes neat and organized and followed a logical flow. | The visual aid was not or barely neat and organized and followed a logical flow. |
| Comments |  |

**Teacher Handout Evaluation Phase**

The lesson includes multiple opportunities for assessment to monitor students’ understanding of both science content knowledge and scientific practices. In the Explore phase, students demonstrate their ability to design and carry out an investigation. In the Explain phase students demonstrate their ability to use data to support a claim in a formal lab manuscript. This array of assessments is designed to meet the needs of students’ diverse academic strengths.