LESSON 16: I've Got the POWER!
Solar Energy Potential at Your School

PURPOSE/QUESTION
To use NASA satellite data to help determine greatest solar energy potential in any given region and to estimate number of solar panels needed and potential solar panel efficiency.

GRADE LEVELS
7-12

TIME TO COMPLETE
1 day

LEARNING OUTCOMES
- Contrast amounts of solar energy with average cloud coverage in a given area in order to determine the most efficient location for establishing a solar collector
- Produce graphs in Excel
- Explain how solar energy can benefit society

LINK TO STANDARDS
Go to page 16-5

STUDENT OBJECTIVES
- Investigate the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on the Earth's surface
- Identify appropriate uses and locations for a solar collector
- Draw conclusions about solar energy's societal benefits

TEACHER BACKGROUND

Solar energy is radiant energy that is produced by the Sun. Every day the Sun radiates an enormous amount of energy. How much solar energy a place on Earth receives depends on several conditions. Most importantly, it depends on latitude (as it relates to the season of the year and the amount of daylight hours), but also the clearness or cloudiness of the sky.

In this lesson, you will explore real NASA satellite data for energy from the Sun and cloud cover for your area to determine if you can harness this solar energy, a renewable energy source, by using a solar collector.

A solar collector is one way to collect heat from the sun. A closed car on a sunny day is like a solar collector. As sunlight passes through the car's glass window, it is absorbed by the seat covers, walls, and floor of the car. The light that is absorbed changes into heat. The car's glass windows let light in, but don't let all the heat out. This is also why greenhouses work so well and stay warm year-round.

For more information on this subject, go to The NEED Project link under Lesson Links. The two links under Lesson Links to the Energy Kids Place sites provide discussions of renewable and non-renewable resources.

PREREQUISITES
- Familiarity with latitude and longitude positions on a map
- Basic familiarity with producing graphs in Microsoft Excel
- Clouds and Radiation
- Renewable Energy Resources

MATERIALS & TOOLS
- World and US map or atlas
- Computer with Internet access and Microsoft Excel

VOCABULARY
- Solar Insolation
- Renewable energy
- Solar collector
- Solar radiation

LESSON LINKS
- Live Access Server
- Radiation Budget Diagram
- Opening MY NASA DATA Microsets in Microsoft Excel
- Lesson 13 Excel Spreadsheet

ESSENTIAL QUESTIONS PART 1

1. What is the average annual solar energy your area receives with and without clouds?
2. Explain why knowing the average amount of cloud cover in a given area would be important when deciding whether or not to use solar energy as a power source.
3. How does the solar insolation in your location vary through the seasons? Why is there this seasonal cycle?

PROCEDURE PART 1 - Gathering data on solar energy in your area

1. Access average monthly solar energy data for your school location.
   a. Determine latitude and longitude for your location.
   b. In the My NASA Data Live Access Server (Advanced Edition), click on ***Atmosphere > Atmospheric Radiation > Surface > Monthly Surface Clear-sky SW Downward Flux (SRB).*** Then click ***Next***.
   c. In the drop down menu for view, select ***Time series (t).*** For Output, select ***Text File (ASCII).*** Write in the latitude and longitude coordinates for your location. Select the time range between ***Jul 1983*** and ***Jun 2007.*** Then click ***Next***.
   d. A new window with a link to an ASCII file will pop up. Click on this link and then follow the instructions in the tools menu (or the link above) for "Opening My NASA Data Microsets in Microsoft Excel". Using the template spreadsheet provided, put the raw data in the tab titled "Raw Data – Clear-sky".
   e. Repeat steps b-d for ***Atmosphere > Atmospheric Radiation > Surface > Monthly Surface All-sky SW Downward Flux (SRB).*** Put the data into the Excel worksheet tab titled "Raw Data – All-sky".
2. Calculate and plot the long-term average solar energy flux.
   a. Copy the values for Clear-Sky and All-Sky radiation into the appropriate columns in the worksheet tab titled "Average Fluxes".
   b. The long-term averages for each month should be automatically calculated.
   c. Create a graph with both clear-sky and all-sky variables on the same panel, and with month on the x-axis.
3. Calculate average annual solar energy received at your location for clear-sky and all-sky conditions.

Photographs by Waynes National (2), Forst, Dominic's Pics, DanKulpinski, and MJ Monty

Solar ovens are a simple and effective way to provide the energy needed for cooking to people without access to other energy sources. (Photograph courtesy SSE project)

ESSENTIAL QUESTIONS PART 2

1. What fraction of your school's energy needs could solar energy reasonably provide?
2. What are some limitations of the estimate of area needed for solar panels?
3. Do you think it would be cost efficient to build or buy a solar collector? Why or why not?
4. Some states allow residences or businesses to sell some power back into the grid. Would this be an option for your school? During which months might it be most sensible?

PROCEDURE PART 2 - Use POWER to estimate the solar energy potential for your school

1. We'll use NASA's Prediction of Worldwide Energy Resource Project (POWER) resource to roughly estimate the amount of solar energy available for converting into electric power.
    a. Go to the POWER website at http://power.larc.nasa.gov/. We'll be using the Renewable Energy Parameters. Under the Access Data column heading, click on "SSE-Renewable Energy".
    b. On the next page, click on the link for "SSE Web Site".
    c. On the next page, under Data Retrieval, click on "Meteorology and Solar Energy".
    d. On the next page, under Data tables for a particular location, choose "Enter latitude and longitude".
    e. Login on the next pages with your email address and a password of your choosing.
    f. When you get to the page titled "NASA Surface meteorology and Solar Energy – Location", enter the latitude and longitude for your location. Note that West longitude and South latitude will need to be entered as negative values. Then, click Submit.
    g. Now a form with lots of variables will come up. Under the "Parameters for Sizing and Pointing of Solar Panels and for Solar Thermal Applications" highlight "Insolation on horizontal surface (Average, Min, Max)"
    h. Copy the mean values from the resulting table to your Excel spread sheet in the tab titled "POWER output" in the appropriate row.

2. Determine how many 1 m^2 solar panels your school would need to meet its energy needs
    a. From the Energy Audit conducted as part of Lesson 1, find the estimate of average monthly energy usage by your school in kWh/month. Enter the monthly values into the Excel spreadsheet, in the tab called "POWER output". If you only have average monthly energy use, enter the same value for every month.
    b. In your spreadsheet, calculate the monthly averaged insolation incident on a Horizontal Surface in units of **kWh/m^2/month**, by multiplying the daily average value by the number of days/month.
    c. Now, divide the (average monthly energy usage by your school) by (Monthly averaged Insolation Incident on a Horizontal Surface in kWh/m^2/month).
    d. Finally, divide the value by 0.20 to account for solar panel inefficiencies.
    e. The resulting value is a rough estimate of the area (in units of m^2) of solar panels needed to meet the school's energy needs each month.
    f. Estimate the area of your school's roof and/or any ground locations where solar panels could be located. Compare this estimate to the estimate of how much area is needed to meet the school's energy needs.

ESSENTIAL QUESTIONS PART 3

1. How does latitude affect the amount of energy that reaches the Earth's surface?
2. Why is it important to examine the insolation in both July and January, when comparing the different continents?
3. What other factors might affect the distribution of insolation across the landscape?
4. Identify the six places among the continents that have the best solar energy potential?

PROCEDURE PART 3 - Put what you learned into a global context.

1. To get a better idea of the availability of solar energy across the country or around the world, we will create maps of solar insolation across the globe. Divide the classroom into 6 groups and assign each a different continent (not including Antarctica, where there's very little sunlight on average!).
    a. Return to the page "Surface Meteorology and Solar Energy". Click on "Global or regional plots".
    b. Use the map to create a box around your continent.
    c. Under "Parameters for Solar Systems", select "Insolation (kWh/m^2/day) key: dmaco". For Day, select "ALL". For Month, select "July". For Year, select "ALL". Click "Select".
    d. Print out the resulting map.
    e. Now go back and create a map for January and print it out.
2. Reconvene as a class and compare the maps of solar insolation for different continents, as you answer the following questions.

WEBSITES FOR FURTHER LEARNING

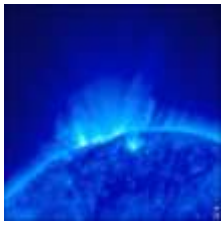
- SRoeCo Solar
- National Energy Education Development (NEED) Project
- Solar Schools
- Energy Star Kids
- Saving Energy
- NRDC's The Green Squad: Solar Energy in Schools
- Solar Power Plus

STUDENT READING RESOURCES

- Europe and Western Russia-Climate
- Baking in the Sun
- Warren Schools Energy Conservation Saves District More than $200,000
- Sunshine Mapping from Space Means Brighter Solar Energy Future
- NJ Gets One of Nation's Largest Solar Farms
- Solar Power Mandatory in All Future NJ Schools
- Measuring Solar Insolation

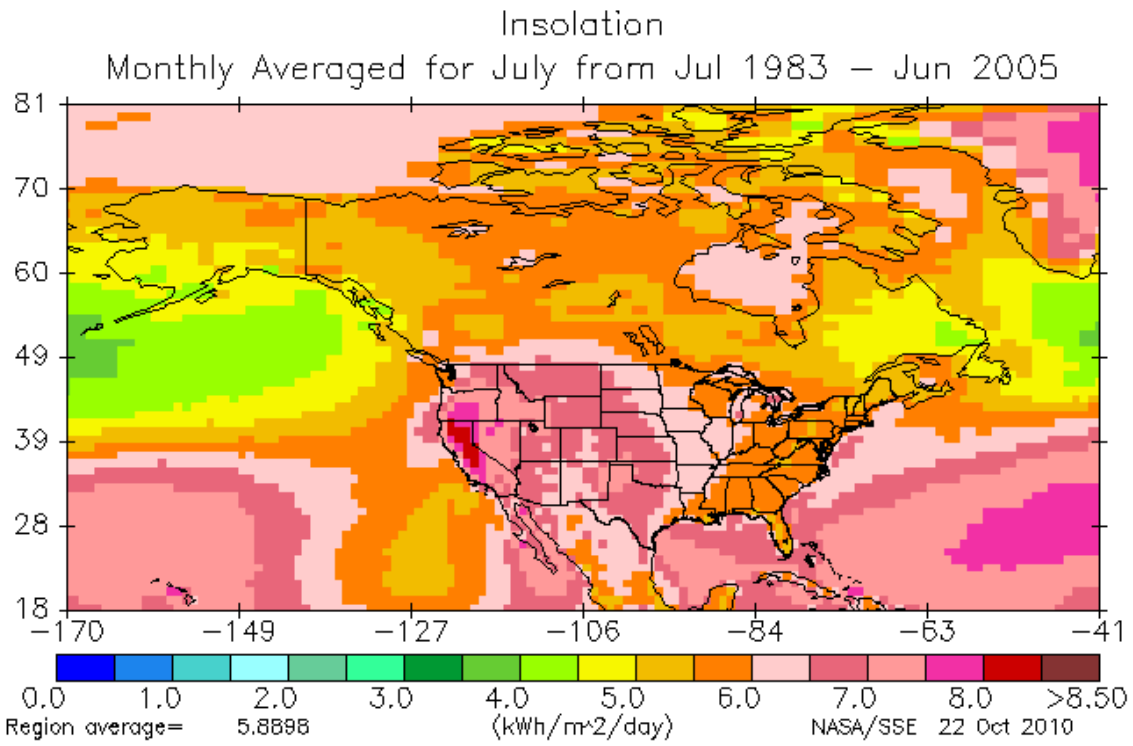
TOOLS FOR ASSESSMENT

- **Essay – page 16-9**
- **Concept Quiz – page 16-10**
- **Student Reading Assessment Tool – page 16-13**
- **Science Notebook – page 16-15**


REFERENCES

Adapted from My NASA Data Lesson 44 by Cindy Henry



Standards and STEM Connections

Lesson 16: I've Got the POWER! Solar Energy Potential at Your School

National Science Education Standards

Unifying Concepts & Processes

- **a.** Systems, Order, and Organization
- **b.** Evidence, Models, and Explanations
- **c.** Change, Constancy, and Measurement

Standard A-Science as Inquiry

- **a.** Abilities necessary to do Scientific Inquiry
- **b.** Understanding about Scientific Inquiry

Standard C-Life Science

- **a.** Matter, Energy, and Organizations of Living Systems

Standard D-Earth and Space Science

- **a.** Energy in the Earth System

Standard E-Science and Technology

- **a.** Abilities of Technological Design
- **b.** Understandings about Science & Technology

Standard F-Science In Personal & Social Perspectives

- a. Science and Technology in Local, National, and Global Challenges

Standard G-History of Science

- **a.** Science as a Human Endeavor
- **b.** Nature of Scientific Knowledge

National Education Technology Standards

- Understand and use technology systems.
- Select and use applications effectively and productively.
- Use models and simulations to explore complex systems.
- Identify trends and forecast possibilities.
- Apply digital tools to gather, evaluate, and use information.

National Council of Teachers of Mathematics Education Standards

- Analyze change in various contexts.
- Understand measurable attributes of objects and the units, systems, and processes of measurement.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Solve problems that arise in mathematics and in other contexts.
- Recognize and apply mathematics in contexts outside of mathematics.

Climate Literacy Principles

- Principle 1: The sun is the primary source of energy for Earth's climate system.
- Principle 2: Climate is regulated by interactions among components of the Earth system.
- Principle 3: Life on Earth depends on, is shaped by, and affects climate.
- Principle 4: Climate varies over space and time through both natural and man-made processes.
- Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
- Principle 6: Human activities are impacting the climate system.
- Principle 7: Climate change will have consequences for the Earth system and human lives

Essential Questions – Answer Key

Lesson 16: I've Got the POWER! Solar Energy Potential at your Campus

Essential Questions-1

1. What is the average annual solar energy your area receives with and without clouds?
   [Depends on the school and location chosen.]
2. Explain why knowing the average amount of cloud cover in a given area would be important when deciding whether or not to use solar energy as a power source.
   [Clouds block solar radiation from hitting the surface, thus cloudy areas receive less energy than areas that have more clear skies.]
3. How does the solar insolation in your location vary through the seasons? Why is there this seasonal cycle?
   [Solar insolation is highest in the summer months, when the Sun is more directly overhead. Solar insolation is at a minimum in winter months.]

Essential Questions-2

1. What fraction of your school's energy needs could solar energy reasonably provide?
   [Depends on the school and location chosen]
2. What are some limitations of the estimate of area needed for solar panels?
   [The value is an optimistic estimate because it does not account for the inefficiencies in transporting the electricity from the solar panels to the places it is used around the school. Also, it does not account for any limitations in terms of shading from trees or inability to get the solar panels at a good angle.]
3. Do you think it would be cost efficient to build or buy a solar collector? Why or why not?
   [Depends on school and location chosen.]
4. Some states allow residences or businesses to sell some power back into the grid. Would this be an option for your school? During which months might it be most sensible?
   [Depends on the school and location chosen.]

Essential Questions-3

1. How does latitude affect the amount of energy that reaches the Earth's surface?
   [Higher latitude locations (toward the poles) receive less sunlight on average throughout the years than lower latitude locations (closer to the equator). This means that their solar energy reaching the surface is less at higher latitudes.]
2. Why is it important to examine the insolation in both July and January, when comparing the different continents?
   [When comparing solar energy received at southern hemisphere locations to those at northern hemisphere locations, it is important to compare the insolation during the same season.]
3. What other factors might affect the distribution of insolation across the landscape?
   [The average distribution of clouds would be the largest factor affecting the solar insolation across the landscape.]
4. Identify the six places among the continents that have the best solar energy potential?
   [Students will identify locations.]

Student Name
Teacher/Class
Date

Lesson 16: I've Got the POWER!
Solar Energy Potential at Your School

Based on your analyses, collaborations, and writings provide evidence for understanding what solar insolation is, how it varies seasonally, and how this affects your decision to potentially install solar collectors at your campus. Elaborate further by also providing evidence for understanding how POWER could be a beneficial tool for the global community.

What Is the Expectation?

Accurate science relating to solar insolation, local renewable energy potential, and the societal benefits of the POWER project.

Evidence supporting your claims

Visual representations

Key vocabulary

Evidence of on grade level spelling and grammar usage

Name: _____ Date: _____

Science Concept Quiz

Lesson 16: I've Got the POWER! Solar Energy Potential at Your School

Use the map that shows the average solar insulation for January and April 1984-1993 to answer the question.

What is one conclusion that can be draw from the information analyzed in the map?

A. The southwest region of North America is not a good candidate for solar panel insolation based on their low level of kWh/m^2/day.

B. When looking to install solar panels for your campus you should only look at solar insulation for the summer months.

C. Solar panel installation would be feasible in Norway, but not for Northern Australia.

D. Solar panel installations are not recommended for North Pole region due a low level of kWh/m^2/day.

_____ points out of 20

I. Answer

A. ◯ B. ◯ C. ◯ D. ◯ E. ◯

_____ points out of 15

II. What is the main concept behind the question?

1. Drawing conclusions based on evidence
2. Solar panel installation
3. Solar insolation
4. Reading scientific graphs

_____ points out of 25

III. Provide the reasoning for choosing your answer in part II.

_____points out of 40

IV. Why are the other responses in part I not the best answer choice?

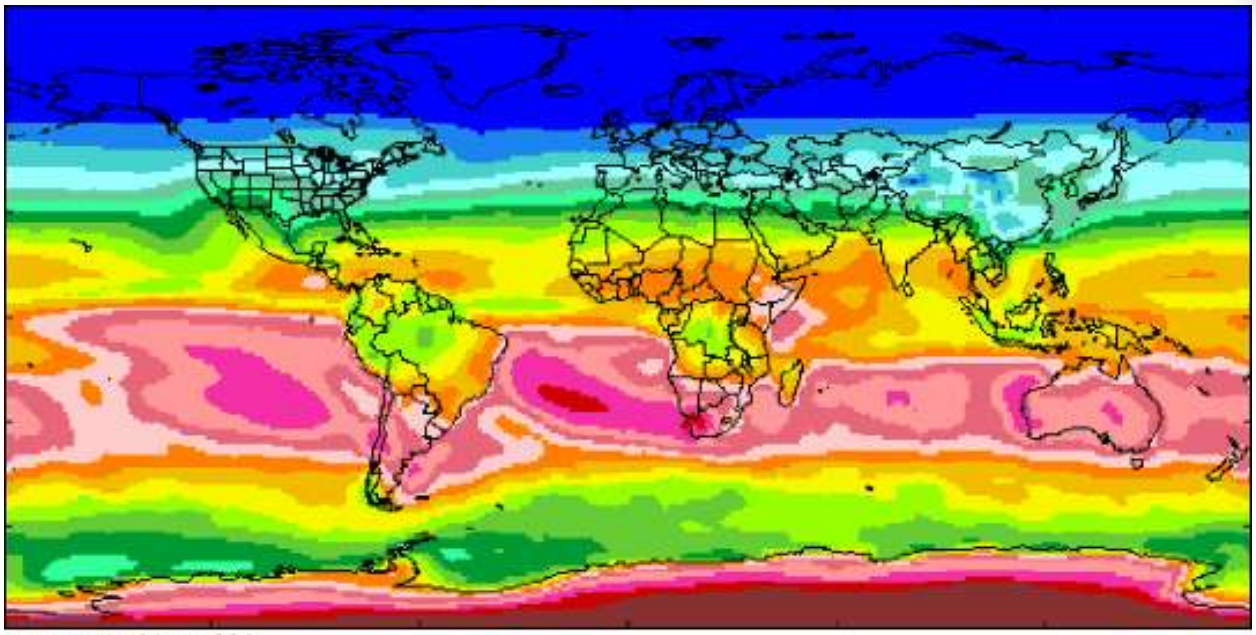
1.

2.

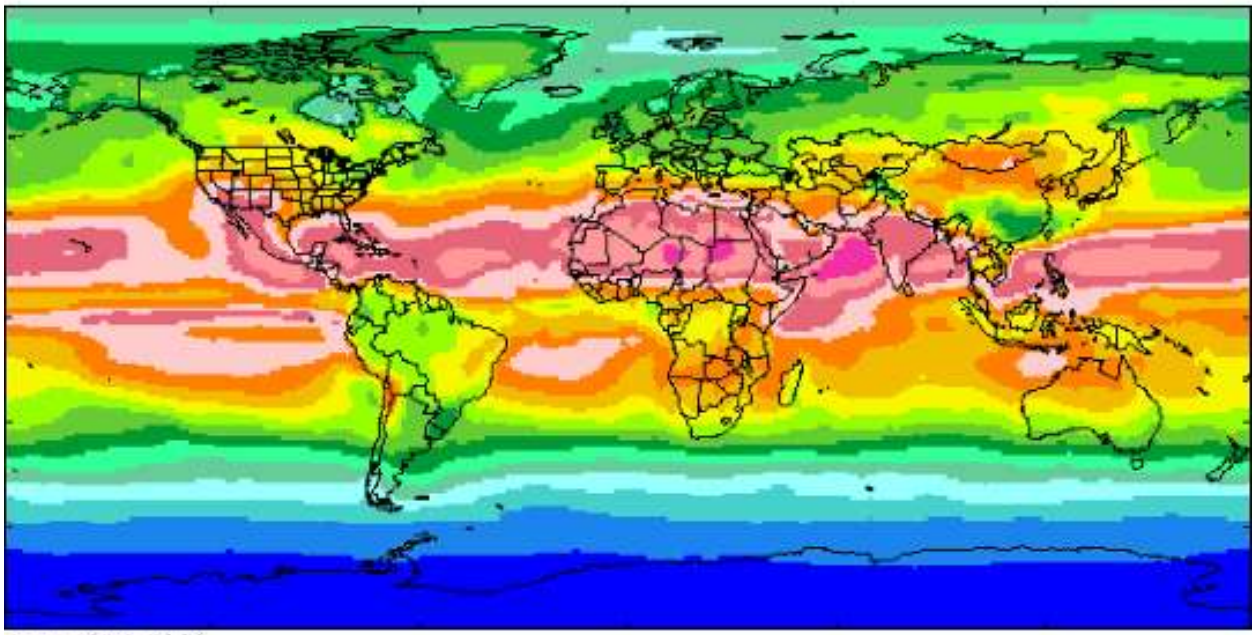
3.

4.

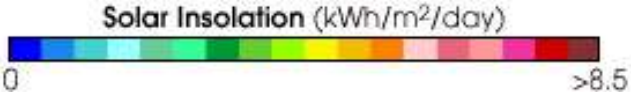
Use the rest of this page if more room is needed to fully communicate your thoughts.



January 1984–1993



April 1984–1993



Using Student Reading Resources as an Assessment Tool

DIRECTIONS

REQUIREMENTS

1. Using the Student Reading Resources *or articles that you allow students to use related to the topic*; write a summary meeting the following guidelines.
   a. **Half to whole** page
   b. **Double spaced**
   c. **12pt** font size
   d. **Times New Roman** font
2. **Do not** print out the article. At the end of your summary write an endnote with the correct **bibliographic information** (http://www.easybib.com/) for your article.

ARTICLE SUMMARY FORMAT

1. **Name, date, class, and period**
2. **Paragraph #1-Introduction**
   a. What is the title of the article (should be in quotes or italics)?
   b. Who is the author?
   c. What source or publication did the article come from?
   d. What is the date of the article?
   e. Write one to two sentences about what the article is about
3. **Paragraph #2-Summary (Abstract) of Article**
   a. Give a summary of the article; what is the article about?
   b. If necessary, you can write more than one paragraph summarizing the article
4. **Paragraph #3- What did you think of the article (critique)**
   a. Do you agree or disagree with the author(s)?
   b. Did it support or change your opinion of the topic; if not, why or if so, how?
   c. Did the writer demonstrate that he/she did sufficient research?
   d. What would you have added to enhance the article?
5. **Paragraph #4-Conclusion**
   What are your reasons for choosing your particular article and how does it relate to what we are studying now?

Article Summary Rubric

CATEGORY	4	3	2	1
Requirements	All written requirements completed accurately and turned in on time.	4 of the 6 requirements were met.	3 of the 6 requirements were met.	Only 1 or 2 requirements met.
Spelling, Grammar, and Punctuation	There are no spelling, grammar, or punctuation errors in the summary. RUN SPELL CHECK BEFORE PRINTING!	There are no more than 2 spelling, grammar, or punctuation errors in the summary.	There are 3-4 spelling, grammar, and punctuation errors in the summary.	The summary has 5 or more spelling, grammar, and punctuation errors in the summary.
Summary of Article	The summary covers all the main points of the article.	The summary covers all but one of the main points of the article.	The summary covers all but 2 of the main points of the article.	The article is not well summarized. Most main points are missing.
Critique	All four questions under "Critique" are answered clearly and completely.	Three questions under "Critique" are answered clearly and completely.	Two questions under "Critique" are answered clearly and completely.	One or none of the questions under "critique are answered.
Overall Paragraph Construction	All paragraphs include introductory sentence, explanations or details and concluding sentence.	Most paragraphs include introductory sentence, explanations or details, and concluding sentence.	Paragraphs included related information, but were typically not constructed well.	Paragraphing structure was not clear, and sentences were not typically related within the paragraphs.

Total Rubric Points	Grade Equivalent
16-20	A
11-15	B
6-10	C
1-5	F

Self Assessment: _____Grade Equivalent: _____

Teacher Assessment: _____Grade Equivalent: _____

Student and or teacher comments:

Assessing Science Notebooks

Student science notebooks are meant to be a record of student learning and tool for students to redefine their thinking, ask questions and make claims without penalty, and by having a collection of their work students will build up prior learning and begin to demonstrate growth in their scientific understanding as the year progresses. Scientist never "get it" the first time, which is evident when looking at the notebooks of some of our greatest creators, such as Thomas Edison, Albert Einstein, and Marie Curie. Allow students to make changes to improve their grade; it will also improve their learning.

Rubric range: 3 points-12 points

Less than 3 points	**F**
3-6 points	**C**
7-9 points	**B**
10-12 points	**A**

Science Notebooking Resources

Araceliruizprimo, M. "On the Use of Students' Science Notebooks as an Assessment Tool." *Studies In Educational Evaluation* 30.1 (2004): 61-85.

Butler, Malcolm B., and Catherine Nesbit. "Using Science Notebooks to Improve Writing Skills and Conceptual Understanding." *Science Activities: Classroom Projects and Curriculum Ideas* 44.4 (2008): 137-46.

Campbell, Brian, and Lori Fulton. *Science Notebooks Writing about Inquiry*. Portsmouth, NH: Heinemann, 2003.

Douglas, Rowena. *Linking Science & Literacy in the K-8 Classroom*. Arlington, VA: NSTA, 2006.

Klentschy, Michael P. *Using Science Notebooks in Middle School*. Arlington, VA: NSTA, 2010.

Marcarelli, Kellie. *Teaching Science with Interactive Notebooks*. Thousand Oaks, CA: Corwin, 2010.

Waldmen, Cheryl, and Kent J. Crippen. "Integrating Interactive Notebooks." *The Science Teacher* 76.1 (January 2009): 51-55.

There are many examples on Slideshare of how teachers at different grade levels instruct their students on how using science notebooks in the classroom.

Student Name **Teacher/Class**

Date

Assignment Topic

UNDERSTANDING SCIENCE CONCEPT	Self Assessment	Teacher Assessment	Notebooking Reasoning
+ 1-Limited			The information given is incomplete and or inaccurate.
+2-Developing			Work shows partial understanding, but also has significant inaccuracies or misconceptions.
+3-Acceptable			Work shows evidence of understanding the main ideas of the topic, though some information is missing or inaccurate.
+4-Accomplished			Work shows mastery of the topic's concept(s). Supporting work, such as graphs and diagrams support understanding and there is evidence of links between new and old learning.

SCIENTIFIC THINKING	Self Assessment	Teacher Assessment	Notebooking Reasoning
+ 1-Limited			Work lacks connections between evidence and conclusions. Ideas seem random and disconnected. Reporting is inaccurate.
+2-Developing			There are limited inferences, little if any questioning and few connections between evidence and conclusions. Reporting is limited and contains many inaccuracies.
+3-Acceptable			Inferences are reasonable, though they may be incomplete or have inconsistencies. Reporting is honest, shows awareness of scientific process skills.
+4-Accomplished			Inferences are strongly supported through evidence that process skills are well understood and used appropriately.

EXPOSITORY WRITING	Self Assessment	Teacher Assessment	Notebooking Reasoning
+ 1-Limited			Ideas are unclear, information is absent or irrelevant. Organization is random or absent. Key vocabulary no incorporated.
+2-Developing			Ideas are incomplete, details minimal, Organization is weak or inconsistent. Key vocabulary used minimally sometimes inaccurately.
+3-Acceptable			Ideas are clear and include many details. Organization is mostly logical and uses transition words. Many key vocabulary words included accurately.
+4-Accomplished			Ideas are fully developed with relevant evidence and details. Organization is sequenced logically, transitions words are present. Accurate use of key vocabulary. Voice is confident and may include self reflection and on target sentence structure is used to develop work

Total Points Earned:

Adapted from Shelia Gaquin, How to Score Science Notebooks

Point Grade Equivalent:

Comments: