

Teaching Phenology using the CLEAN-NGSS Unit Planning Template

Unit Title:	Phenology: A place-based study to understand climate change		
Grade Level and Class:	Middle School Integrated Earth & Life Science	Instructional Time:	4-week unit that can be an ongoing year-long investigation
1. Select the NGSS Performance Expectation(s) (PEs) based on grade level and content-focus and list the learning objectives.			
<p>MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons</p> <p>MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.</p> <p>MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations</p>			
2. What phenomena, problem, or project would best suit the PE(s)?			
(Learn more about phenomena)			
<p>Students collect and analyze data from their own site and compare to global data from other schools to understand phenological changes at school.</p> <p>When the seasons change, we notice changes in the length of the day, air temperature, and the plants and animals. Keeping track of these changes can help us see other changes related to climate. Using data we can answer questions like</p> <ul style="list-style-type: none"> ● Is this year different than past years? ● Is there a trend in seasonal changes? ● How might these trends affect the organisms in our environments? 			
3. Describe an overview of how the phenomena, problem, or project would best suit the PE(s).			
(Revise, as needed)			
<p>Students connect patterns of solar radiation, seasons, and phenological cycles to examine how seasons might be changing due to anthropogenic climate change.</p> <p>Driving Questions:</p>			

- What causes Earth’s seasons and why are seasons different on different parts of our planet? (MS-ESS1-1)
- What can seasonal data and evidence tell us about how climate change is happening? (MS-ESS3-5)
- How are organisms in different regions responding to climate-driven change in seasons? (MS-LS2-4)

Students will ...

1. collect and analyze data from local weather stations to observe atmospheric variables and changes in length of day during seasonal changes and use hands-on and computer models to understand why seasonal variation occurs. (MS-ESS1-1)
2. conduct field studies to examine the changes in plants and animals during seasonal change. (MS-LS2-4)
3. analyze previous years atmospheric and seasonal onset data to determine if/how the timing of seasonal onset is changing, identify the causes of those changes, and debate the costs and benefits of those changes. (MS-ESS3-5)

4. What type of strategy works best for teaching and learning about the phenomena, problem, or project?

(For ideas, see the [Teaching Strategies for Units](#))

Project-Based Field Study

5. Identify (unpack) the Performance Expectation(s) components embedded in the PE(s) in the NGSS Matrix.

(For guidance, see [Access the NGSS Science Standards by Topic](#)):

MS-ESS1-1

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
<p>Developing and Using Models to describe phenomena.</p>	<p>ESS1.A: The Universe and Its Stars: Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with model</p> <p>ESS1.B: Earth and the Solar System: This model of the solar system can explain eclipses of the sun and the moon. Earth’s spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.</p>	<p>Stability and Change: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.</p>

<u>MS-ESS3-5</u>		
Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
<p>Asking Questions and Defining Problems: Ask questions to identify and clarify evidence of an argument.</p> <p>Constructing Explanations and Designing Solutions: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</p>	<p>ESS3.C: Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.</p> <p>ESS3.D: Global Climate Change Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.</p>	<p>Patterns can be used to identify cause-and-effect relationships.</p> <p>Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems: Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation</p> <p>Develop and use a model to describe phenomena: Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.</p>
<u>MS-LS2-4</u>		
Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)

<p>Engaging in Argument from Evidence: Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.</p> <p>Connections to Nature of Science - Scientific Knowledge is Based on Empirical Evidence Science disciplines share common rules of obtaining and evaluating empirical evidence.</p>	<p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience: Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.</p>	<p>Stability and Change: Small changes in one part of a system might cause large changes in another part.</p>
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6. How will you assess students' learning of the PEs with summative assessments and/or rubrics?

Students can

- model and explain the factors that affect seasonal changes
- differentiate seasonal change from climate change
- identify local phenological indicators and explain how they change as a result of both seasonal and long term climate change
- identify and describe multiple lines of evidence for climate change.
- predict a variety of impacts of climate change on seasons and phenologies.
- propose and argue for possible ways to minimize impacts of climate change on ecosystem phenologies.

7. Create an instructional plan by building a unit storyline:

Assess Students' Prior Knowledge

- Develop a plan to determine students' prior knowledge (e.g. pre-test, class discussion, etc.) based on the NGSS standards listed below that students should have learned throughout elementary school:

Performance Expectations (PE)

1-ESS-1 Use observations of the sun, moon, and stars to describe patterns that can be predicted.

1-ESS1-2 Make observations at different times of year to relate the amount of daylight to the time of year.

5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

Science and Engineering Practices (SEP)	Disciplinary Core Ideas (DCI)	Crosscutting Concepts (CCC)
<p>Planning and Carrying Out Investigations: Make observations (firsthand or from media) to collect data that can be used to make comparisons. (1-ESS1-2)</p> <p>Analyzing and Interpreting Data: Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (1-ESS1-1)</p> <p>Obtaining, Evaluating, and Communicating Information: Obtain and combine information from books and other reliable media to explain phenomena. (3-ESS2-2)</p>	<p>ESS1.A: The Universe and Its Stars: Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted. (1-ESS1-1)</p> <p>ESS1.B: Earth and the Solar System: Seasonal patterns of sunrise and sunset can be observed, described, and predicted. (1-ESS1-2)</p> <p>ESS2.D: Weather and Climate: Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2)</p> <p>ESS1.B: Earth and the Solar System: The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)</p> <p>ESS2.A: Earth Materials and Systems: Earth's major systems are the geosphere (solid and molten rock, soil,</p>	<p>Patterns: Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. (1-ESS1-1), (1-ESS1-2)</p> <p>Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems: Science assumes natural events happen today as they happened in the past. (1-ESS1-1) Many events are repeated. (1-ESS1-1) Patterns of change can be used to make predictions (3-ESS2-1), (3-ESS2-2) Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2)</p> <p>Systems and System Models A system can be described in terms of its components and their interactions. (5-ESS2-1), (5-ESS3-1)</p>

<p>Represent data in graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. (5-ESS1-2)</p> <p>Develop a model using an example to describe a scientific principle. (5-ESS2-1)</p>	<p>and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)</p>	
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Identify Learning Activities

Select learning activities from CLEAN ([NGSS and CLEAN at a Glance](#) and [Search the CLEAN Collection by NGSS Topic](#)) and other resources that build towards the PEs.

MS-ESS1-1:

- [What can we learn about our Seasons?](#)
- [What are Some Factors that Affect Seasonal Patterns?](#)
- [Modeling the Reason for the Seasons](#)
- Seasonal Change on Land and Water <http://cleanet.org/resources/33945.html>

MS-ESS3-5:

- Changes in Hardiness Zones <http://cleanet.org/resources/42862.html>
- Climate Change and Citizen Science <http://cleanet.org/resources/43023.html>
- Blooming Thermometers <http://cleanet.org/resources/41839.html>
- Analyzing the Data: It's time to tell the story about buds, leaves and global warming <http://cleanet.org/resources/44749.html>
- Why fly south? How climate change alters the phenology of plants and animals <http://cleanet.org/resources/45142.html>
- Changes Ahoof: Could Climate Change Affect Arctic Caribou? <http://cleanet.org/resources/41916.html>
- How do Seasonal Temperature Patterns Vary Among Different Regions of the World? <http://cleanet.org/resources/41825.html>
- Native Voices: [Navajo](#), [Inuit](#), [North Dakota United Tribes](#)

MS-LS2-4:

- A First Look at Phenology, [Phenological Gardens](#)
- [Ruby Throated Hummingbird](#)

- Blooming Lilacs
- [Investigating Leaf Pigments](#)
- Chemistry of Fall Colors <http://cleanet.org/resources/44749.html>
- [Limiting Factors in Ecosystems](#)
- Global Patterns in Green Up and Green Down <http://cleanet.org/resources/41847.html>

Develop Unit Timeline and Formative & Summative Assessments

By completing the selected resources, students can

1. model and identify the factors that affect seasonal changes
2. explain and differentiate the terms “seasonal changes” and “climate change” incorporating concepts of time, astronomical relationships, and atmospheric conditions.
3. conduct protocols to record plant phenology data.
4. analyze plant phenology data.
5. identify and explain different lines of evidence for climate change
6. evaluate how seasonal changes are affected by climate change.

Activity/prompt, etc. that will enable students to demonstrate mastery of the above items are incorporated into the unit timeline.

The timeline and sequence of activities for a 4-week unit or ongoing throughout the year. Each “day” is a typical 45-50 minute class period. All the activities have embedded formative assessments. GLOBE training for teachers is available at

<https://www.globe.gov/get-trained>.

- What can we learn about our seasons? (field study)
 - <http://www.globe.gov/documents/356823/3fedb06a-a17d-40db-a506-4fbe373be983>
- GLOBE Phenological Field Study (this can take as little as 2 days or can be ongoing in your location)
 - Throughout the year
 - Phenological Gardens <http://www.globe.gov/documents/355050/1ad6afd0-0901-4827-b8ee-7fa224898e09> and <http://www.globe.gov/documents/355050/c3f65ccd-b256-407a-986d-9c2a36d86d1e>
 - Ruby Throated Hummingbird <http://www.globe.gov/documents/355050/5b71b051-92a9-40a5-b4a1-a14de00d604b>
 - Autumn
 - Investigating Leaf Pigments <http://www.globe.gov/documents/355050/c71db6b8-8fde-4400-8345-7162c8192bbc>
 - Green Down <http://www.globe.gov/documents/355050/849d4a1a-96dd-4965-ab36-0ae77a447cd9>
 - Ruby Throated Hummingbird <http://www.globe.gov/documents/355050/5b71b051-92a9-40a5-b4a1-a14de00d604b>

- Spring

- Green Up <http://www.globe.gov/documents/355050/ac287b49-8559-4f98-b9e5-a1421f5ae336>
- Lilac <http://www.globe.gov/documents/355050/b094faa7-85b5-446d-91c1-3a839df7734b>
- Ruby Throated Hummingbird
<http://www.globe.gov/documents/355050/5b71b051-92a9-40a5-b4a1-a14de00d604b>

Week 1 - An introduction to phenology and seasonal changes. This is an exploratory phase of learning. Students have a chance to go outside, see the changes themselves and invest in their own curiosity. The role of the teacher is to facilitate this exploration.

- A First Look at Phenology (2 days field study)
<http://www.globe.gov/documents/355050/fa49c394-2f14-410e-abb8-6d73d329df64>
- What are Some Factors that affect Seasonal Patterns? (3 days computer lab/in-class)
<http://www.globe.gov/documents/348614/d2cb0054-5c7b-4d83-809e-7f2546f97665>
- Assessment goal: students can define phenology and are able to describe what causes seasonal changes.

Week 2 - Students dig deeper into the causes of seasons by building models and examining how seasonal changes affect variations in light and heat, as well as organisms' responses to those changes. Students begin to make connections between the astronomical, seasonal, and ecological systems.

- Modeling the Reason for the Seasons (1-3 days in-class)
<http://www.globe.gov/documents/356823/e40fed2f-4476-4d27-b062-74a684d583db> or
- Seasonal Change on Land and Water (1 day in-class) <http://cleanet.org/resources/33945.html>
- Project BudBurst: The Climate Connection (1 day in-class)
http://budburst.org/documents/871408/879751/PBB_climateconnection.pdf/8dbb67bf-944a-4842-9459-71b4c25c48bd
- Assessment goal: students are able to accurately model seasons and make predictions on possible phenological impacts of seasonal variation.

Week 3 - Conducting the Phenological Field Study at least one full day this week. If doing this unit in the fall, focus on the changes in leaf colors, patterns of green-down, and emigration of species. If doing this in the spring, focus on green-up, blooming, and immigration of species. Students investigate ecological limiting factors.

- Introduction -- Chemistry of Fall Colors
<https://www.nbclearn.com/portal/site/learn/freeresources/chemistry-now/chemistry-of-changing-leaves>
- Global Patterns in Green Up and Green Down (1-2 days in class) <http://cleanet.org/resources/41847.html>
- Limiting Factors in Ecosystems (1-2 days in class)
<http://www.globe.gov/documents/355050/96e0a41c-55cc-447c-bb51-8e4e584664db>
- Assessment goal: students are able to explain changes in leaf colors and predict green-up and green-down patterns; students can identify factors that limit organisms' ability to survive and thrive.

Week 4 - Connecting Phenology to Climate Change - Students apply what they have learned about seasons and phenology to how both are changing in the modern era. Starting with hardiness zone maps, bird migrations, or the timing of plants flowering, students can go further by looking at regional or global data sets mapping out the impacts of climate change on ecosystems and agricultural systems.

➤ Introduce with one or more of the following (each takes ~1 day)

- Students examine and describe how the U.S. Hardiness Zones have changed from 1990 to 2015 <http://cleanet.org/resources/42862.html>. Be sure to help students define hardiness, “A **hardiness zone** (a subcategory of **vertical zonation**) is a geographically defined area in which a specific category of **plant** life is capable of growing, as defined by climatic conditions, including its ability to withstand the minimum temperatures of the zone. For example, a plant that is described as ‘hardy to zone 10’ means that the plant can withstand a minimum temperature of $-1\text{ }^{\circ}\text{C}$ ($30\text{ }^{\circ}\text{F}$). A more resilient plant that is ‘hardy to zone 9’ can tolerate a minimum temperature of $-7\text{ }^{\circ}\text{C}$ ($19\text{ }^{\circ}\text{F}$).” -- https://en.wikipedia.org/wiki/Hardiness_zone
 - Have students discuss their observations and answer the following questions either for a homework assignment or presented to initiate a class discussion:
 - What trends do you see?
 - Given what you have learned about seasons what might be causing the shift of hardiness zones?
 - Given what you have learned about phenology, how might the shift in hardiness zones affect ecosystems and agriculture?
 - Have students generate questions based on their observations. Review students’ questions to ensure that they are making the connections between seasonality, phenology and climate change.
- Climate Change and Citizen Science Introduction (<http://cleanet.org/resources/43023.html>) provides two different slide shows, one for the eastern US and one for the west. The message is the same. There are multiple lines of evidence that indicate that spring is arriving earlier and fall is arriving later. This shift in the seasons is affecting species, migrations, and the overall phenology of ecosystems around the U.S.
 - Slide 21 provides discussion questions.
 - Students generate questions based on their observations.
 - This resource could be used as a homework assignment or presented to initiate a class discussion.
- Blooming Thermometers (<http://cleanet.org/resources/41839.html>) - of the three suggested options, this lesson is the most structured and traditional.
 - Students use data and graphs to examine phenological shifts since 900 AD.
 - Students generate questions based on their observations.
 - Students answer questions and need to come up with suggested data sets that would help them determine if the shifts in blooming time are caused by climate change.

➤ Days 2-5 End of Unit Summative Assessment. Students work in small groups of 3-4 students to identify how climate change is affecting different regions. Students prepare a poster (or some other presentation mode) to share with the class showing how their region is being affected by climate change, proposing strategies for dealing with the changes, minimizing the impacts on ecosystems, and arguing for solutions. The following are possible resources for students to use as they create their presentation.

○ Regional Resources:

- New England - Analyzing the Data: It's time to tell the story about Buds, Leaves and Global Warming (2 days) <http://cleanet.org/resources/44749.html> (Activity - 2 days; advanced; computers needed)
- Midwestern US - Why Fly South? How Climate Change Alters the Phenology of Plants and Animals <http://cleanet.org/resources/45142.html> (Activity - 2 days; graphing data with computers)
- Colorado Plateau - Land Surface Phenology Monitoring - <https://www.nps.gov/articles/land-surface-phenology-monitoring-in-the-scpn.htm> and https://science.nature.nps.gov/im/units/ncpn/monitor/land_surface.cfm (Articles posted on USPS websites)
- The National Parks Service has numerous articles, data sets, graphs, and presentations that could be used in the classroom at <https://www.usanpn.org/nps>
- Arctic - Changes Ahoof: Could Climate Change Affect Arctic Caribou? <http://cleanet.org/resources/41916.html> (Activity - 1 day, computer modeling of how changing climate conditions affect caribou)

○ Global Studies

- How do Seasonal Temperature Patterns Vary Among Different Regions of the World? <http://cleanet.org/resources/41825.html> (Activity - 3 days, data analysis)

○ Native Voices:

- Navajo - <http://cleanet.org/resources/43801.html> (short video)
- Inuit - <http://cleanet.org/resources/42858.html> (short video)
- North Dakota United Tribes - <http://cleanet.org/resources/43800.html> (short video)

○ Readings

- <http://www.newsweek.com/early-spring-shorter-winter-thanks-climate-change-382968>
- <http://www.naturescalendar.org.uk/findings/spring/arrivingearlier.htm>

8. Unit Reflection:

- What parts of the unit were a success?
- What were some challenges about the unit?
- How could the unit be changed or improved?

(To be completed after unit instruction)