Lesson 3 - Application: Using climate and phenology data and models to make predictions

Time Needed	50 minutes
Materials/Prep	1. Teacher Slides (slide 41) a. Ensure ability to play audio clips from computer. 2. KWL Worksheet a. See KWL (Know-Want to Know-Learned) overview for teachers here. b. Provide opportunities throughout the lesson for students to make entries in each column of the worksheet. 3. Lesson 3 Student Worksheet & Homework (printed) - have Lesson 1 & 2 Worksheets available for reference. 4. Student Laptops (with ability to access/download Model Spreadsheet). 5. Extra graph paper 6. Calculator 7. Pencils and Rulers 8. Have students sit in groups
Student Learning Outcomes	Students will be able to: 1. Explain the utility, strengths and limitations of their model and models more generally. 2. Examine and explain how new data is incorporated to improve model accuracy. 3. Use model to predict impact of regional climate change on the Michigan cherry industry. 4. Explain how Citizen Science data contributes to climate and phenology research. 5. Understand, propose and evaluate potential solutions to mitigate and adapt to the negative impacts that a shifting climate has on cherry trees.
Additional Resources	Online graphing resources: (If teachers want students to use computers to graph): • Google Sheets • http://illuminations.nctm.org/Activity.aspx?id=4186 • http://knowpapa.com/trend-line/
Next Generation Science Standards	
HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	

Review: Using our graph to make Bloom Date predictions based on March Temp.

1. **Review homework, questions about last lesson, and where we left off (Slide 42).**
   a. *"How can you use the line of best fit to predict the bloom date when average March temperature is 25 degrees? 45? 30?"*
   b. *"What does the equation for this line man? Why would we want the equation for the line?"* (Get student ideas.)

2. **Review: What did you find?** After discussing, reveal answers (bloom date) based on temperature.

Strengths/utility and weaknesses of our model

1. **Discuss scientific models, why we use them, their strengths, limitations:**
   a. ***Did you know this is a scientific model! What is a "model"?***
      i. A representation of part of the real world/
      ii. Created by combining real data from many variables to estimate processes and systems over time.
   b. **Click again. Ask students, *"What are other examples of models? Do you see any around the room?"*** (Slide 45)
      i. Models on slide:
      A. This model shows the relationship between the sun, earth, and moon. It simulates the movements of the sun, earth, and moon in space relative to each other.
      B. This model shows different types of animals. It diagrams how different animals are related by evolution.
      C. This model shows the layers of the earth. It helps us visualize the inside of the earth, which we can't typically see.
      D. Graphs like this can also be scientific models. This one shows temperature and growth for 8 northern red oak trees. It helps us predict what the relationship between temperature and tree growth will be in the future.
      E. This model shows the water cycle. It helps us understand how water moves through different physical states and locations on the planet.

2. **Strengths & Limitations of Model**
   a. **Ask students, *"Why are models useful? Why do we use them?"***
      i. Shows relationships between different variables.
      ii. Make part of the world easier to understand: Condenses complex dynamics into a few terms so that we can more easily understand what is happening.
      iii. Allow us to make predictions about the future: We cannot run experiments on the earth as a whole, so we use models to help us predict and explain (rather than just guessing).
   b. **Click- Ask students, *"Why is our model useful? What are its strengths?"***
      i. This model gives us relatively strong power to predict (as you just saw): You used the graph and the line/equation to predict bloom date and how this benefits farmers.

ii. Like we discussed above, we cannot run experiments on the earth as a whole, so creating a model can help us make predictions rather than just guessing about what will happen.

c. **Click- Ask students, *"What can we not do with this model or what does this model not tell us? (What are its "limitations"?) What kinds of other information or data could we collect to make it even more useful to us?"***

i. **Variability:** Discuss the fact that there is some variability around the line. Most observations do not fall right on the line, there are deviations, thus the line predicts a particular date but the actual date could be below or above the line. Then estimating how much higher or lower it could go would give us an estimate of the uncertainty around our predictions. Our predictions are not exact, but give us our best possible estimates.

ii. **What can make it more accurate?** Collecting more data (over a longer period of time, or from more cherry trees) can help make our model more accurate.

iii. **We can't necessarily extrapolate beyond the line:** If we extrapolate beyond the curve we don't have data to back up that the relationship will be the same.

iv. **Generalizability:**

1. Doesn't apply to other species of trees. (We would need to have data on other tree species to see if they react the same way to warmer temperatures.)
2. Doesn't apply to cherry trees in other geographical locations. *"Why can't we use this model to predict date of bloom for the cherry trees in Washington, D.C. or Japan, for example?"*

a. Individual trees are adapted/ acclimated to the local conditions they grew under. If we were to transplant a cherry tree from the South to the North, it would likely bloom at a different date than the local trees. We would need to collect this same kind of data for those trees in those locations

v. ***"Is there anything else the model doesn't include that might be helpful?"***

1. The model does not include any data about the dates or risk of frosts. Frost is the most relevant consequence of early phenology in the case of the cherry trees. Are late frost events getting more common? Is the last frost date moving later into the year?

Improving/updating and updating our model

1. **How can we make our model more accurate?** *"Why do scientists need large data sets to accurately describe relationships between variables? Look at the graph on the left – it contains only 2 data points, and the pattern here is a negative one. Now look at the graph on the right. It contains the same 2 data points and a third data point. They trend is completely different; now it is positive! This is just one example of how more data helps reveal more accurate trends."*
2. **Let's try it! Students download model spreadsheet and add new**

data (for years 2013, 2014, and 2015) to their graphs.

a. Ideally, students do this on their own laptop. Students should download a copy the spreadsheet onto their computer first (we recommend pasting the link onto your course website for students to access), then students update the model by copying and pasting the new 3 rows (years) of data into the bottom of the existing data table. This should automatically update the graph to provide a new line of best fit.

b. If laptops not available for all students, students can work in groups or follow along while the teacher adds the data and projects on the screen.

3. **Updated model: *"How did the addition of 2013, 2014, and 2015 data change your model? How did the equation for the line of best fit change? How might this change in the future?"***

Climate change and its impact on Michigan cherries

1. **Online Research:** Ask students to spend a few minutes researching how climate change is expected to impact Michigan. Is Michigan expected to get warmer or cooler? If so, by how much? Ask students to share what they found about how Michigan's climate is expected to change. Click the next slide to reveal the overall trends.
2. **Trends:** Warmer winters: Late winter temperatures rising faster than other seasons + Variability in spring freezes→ May result in more freeze damage early in the growing season.
3. **Map Projections:** Map shows projected increases in annual average temperature by **2041-2070** as compared to the **1971 - 2000** period, assuming emissions of greenhouse gases continue to rise (A2 scenario). Northern areas will likely see greater warming by mid-century. The Eastern Upper Peninsula and Northern Lower Peninsula of Michigan may see particularly significant changes. The Traverse City area looks like it could see an increase about 5 to 5.5 degrees!
4. **Use your model to analyze the impact of climate change on Michigan cherries.** Ask students to consider how the bloom date would change if average March temperature increased by 2, 4, and 6 degrees. How might it impact cherry farmers and the greater population? Take student answers.

What's being done and what else might we want to research on this issue?

1. **Discuss what is being done to work on the cherry tree issue (Slide 53):**
   a. Get student ideas on what they would do to deal with this issue if they were a cherry farmer.
   b. Then, play the rest of the NPR story "Fruit Growers Try Tricking Mother Nature to Prevent Crop Damage" (start at 1:16 or replay the beginning for a refresher).
      i. Using technology to "trick" trees into blooming later
      ii. Diversifying their crops in order to mitigate the impacts of climate change. (Farmers lessen their risk by planting different crops like apples that respond differently to weather and climate than cherry trees.)
2. **Future Questions:** Have students come up with other questions related to this topic. *"What other data might we want*

to gather?" What about other factors we came up with earlier, such as wind, sunlight, precipitation, soil quality, pollination, other ideas?

a. For example, What about frost events? What would be useful to know about these events? What about different varieties of cherry trees? What if plants begin to flower earlier, but pollinators are not yet there to pollinate them? What would this do to our fruit crops?

The Big Picture: Why is this topic important, and how can you contribute to solving the problem?

1. **How can you help mitigate climate change?**
   a. "*What you can do in your own life to help mitigate climate change?*" (Explain definition of "mitigate" if necessary: Mitigate means to lessen, reduce, make less severe. (Discuss student ideas)
   b. Encourage students to "Do One Thing" to help mitigate climate change. Students can find lots of ideas on page 14 of the *Ann Arbor Energy Challenge Handbook*, availavle for download where this lesson was downloaded. If time in class, teacher can have students visit the Handbook during class time.
   c. Do some research and share with your classmates next class. You can even share your commitment online on the Alliance for Climate Education website! https://acespace.org/dot
2. **Ask students, *"Why do you think we did these lessons?"* (Click through for different images as you discuss.)**
   a. To learn about a specific issue Michigan farmers are dealing with that impacts agriculture, tourism, and the economy in Michigan. How might this issue impact your life or that of people you know?
   b. To teach you about Citizen Science and how you can contribute to this field of study
   c. To learn how to graph and analyze data, and to use a model
   d. The bigger picture: Building these analytic skills is important whether you become a scientist or not. By being able to understand data and graphs when they are presented to you, you will be able to engage more with the news, scientists, politicians, etc. in your careers. Rather than just listening to someone tell you something is true or not, you will be able to analyze what they are saying and come to conclusions on your own.
3. **How can you contribute to phenology research?**
   a. Phenology data collected by citizens like you contributes to scientific research around the world.
   b. Students could visit Project BudBurst in class on their computers if they have time. Research how they are using phenology data to answer scientific questions.

Evaluating student learning

1. **Assign Homework #3:**
   a. Split students into three even groups; assign each group one of the following articles. They will read their article for homework and be prepared to discuss it and present it to the class for Lesson 4.
      i. "Why is phenology important?"

ii. "Climate change will leave Edith's checkerspot butterflies out of sync"

iii. "Walden warming"

2. **(Optional) Assign Homework #4:**

   a. Students write a letter, etc. to a cherry farmer about what they have learned.

      i. We suggest giving students more than one night to complete this assignment, to increase the quality of their work and their ability to access a computer/ internet to do their own research on pros/ cons of the different options farmers have.

OPTIONAL Exercises (Additional "Extend" and "Evaluate" exercises):

1. **Students practice graphing on graph paper or in Google Sheets, Excel, etc.**

   a. Provide the tables of the Year and Flowering Date and/or Year and temperature, students graph all the points on their own.

   b. Students graph all the data points for the Temperature vs. Bloom Date relationship on their own. Practice finding the equation for line of best fit.

2. **Work in groups to apply analysis/ modeling skills to other cherry data (graph it, find the line of best fit, use line/equation to make predictions).**

   a. D.C. cherry data (discuss importance of Washington D.C.'s cherry trees/ festival to tourism industry), a different plant species, or different plant-animal relationship. Fun video about D.C. cherry tree blooming by "Nature Boom Time."