Lesson 2 - Intro to Modeling: Graphing and analyzing phenology data

Time Needed	50 minutes
Materials/Prep	1. Teacher Slides (slide 21) 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 2 Student Worksheet & Homework (printed, hand out at slide 30) - have Lesson 1 worksheet available for reference. 4. Graph Choice Chart (printed, optional: to help students figure out what kind of graph to use) 5. Julian Day Calendar Handout 6. Extra graph paper 7. Calculators 8. Pencils and Rulers 9. Have students sit in groups
Student Learning Outcomes	Students will be able to: 1. Analyze and explain temperature and cherry phenology graphs and their implications. 2. Analyze a model of blooming date as a function of average March temperature by calculating line of best fit. 3. Use graphical model to predict timing of phenology events based on various average March temperature scenarios.
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-ESS3-1.** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Review:

1. **Lesson 1 Review:** *"What happened in 2012 to Michigan cherries? What did we discover through our data sets?*

2. **Review:** *"What story do these graphs tell? What years stand out? What conclusions can we draw from the graphs? Do these graphs support our hypothesis that warmer temperatures lead to earlier bloom dates?"*
    a. "So it does seem like there might be a relationship between average March temperature and bloom date. Looks like perhaps when average March temperatures are warmer, the cherries bloom earlier, and when average March temperatures are cooler, the cherries bloom later."

Introducing the concept and study of phenology

1. **Introduce and define concept of phenology: *"The timing of when the cherry trees blossom and all of these other events you described are examples of "phenology. What do you think phenology means?"*** (Help students come to understanding/ definition, writing the definition up on the board as needed.)
    a. Literal meaning: "The science of appearance."
    b. Roots: Pheno: "to show or appear" and Logos: "to study"
    c. Definition: Phenology refers to recurring plant and animal life cycle stages. It is also the study of these recurring plant and animal life cycle stages, especially their timing and relationships with weather and climate. (Cite: National Phenology Network)
    d. Definition of "Phenophase": An observable stage or phase in the annual life cycle of a plant or animal. (The actual stage, "flower bloom" for example, is called a "phenophase.")

2. **Show TedEd video: Phenology and Nature's Shifting Rhythms to reinforce concepts of phenology.** (Watch full video, 3 min 40 seconds). *"This general topic of how temperature and other climate and weather patterns can influence plants or animals is called "phenology." Let's learn more about the study of phenology and why it is so important."*
    a. After the video: *"What did you learn from this video? Why is phenology an important field of study?"*

3. **Students Brainstorm: *"How can we use phenology to help cherry farmers?"***

How can we graph the relationship between Bloom Date and Avg. March Temperature?

1. **Homework Review: *"How could we graph the information differently to make it even more clear whether or not there is a direct relationship between March temperature and blooming date?"***
    a. **Students brainstorm with each other in groups, then with teacher guidance:** Farmers would want to be able to *PREDICT* the bloom date using temperature data. We want to see if there is a direct relationship between bloom date and March temperature, so we need to graph those two variables on the SAME graph, rather than on two separate graphs.

2. **Think- Pair- Share:** Students use graph choice chart (optional) and discuss with teacher help to come to the realization that plotting bloom date as a function of March temperature on a scatterplot would help them to see the relationship more clearly:
    a. **Students in groups (or with teacher on board as necessary) work through steps of graphing these as one graph. Graph as any points as possible (before showing slide 29 of the full graph/model.)** Students do the work on graph paper:
        i. *What would be the y axis?* (Date of Full Bloom)
        ii. *X axis?* Temperature
    b. How to plot the data (for example):
        i. 1983: Plot a point at 32 degrees and Date of Year 141 = May 21.
        2012: Plot a point at 47 degrees and Date of Year 110 = April 19.

Analyzing our graph of Bloom Date as a function of Avg. March Temp.

1. **After students/teacher work through the steps of starting to graph this (as many points as possible) on the board/ graph paper, show and analyze the full graph (slide 29) of Blooming Date as a function of March temperature. Students answer:**
    a. *What is this graph telling us?*
    b. *What is the dependent variable? Independent?*
    c. *Looking at the points on this graph, describe the relationship between average March temperature and Blooming Date.*
    d. *What about the point all the way to the right? What do you think that dot is? (2012)*
2. ***"What can you add to this graph to help make the relationship more clear and to better predict bloom date?"***
    a. *"We could add a l**ine-of-best-fit**: a linear average of all data points. This means the line is as close as possible to all data points. The line-of-best-fit can be used to identify any patterns in your data because it summarizes the relationship between the independent and dependent variable. It is also called the **trend line** or **linear regression**."*
3. **Hand out Lesson 2 Worksheet.**

Adding and understanding line of best fit on our graph of Bloom Date as a function of Avg. March Temp.

1. ***"We determined we should add the line of best fit. How do we find that?"*** **(Get student ideas)**
    a. Have students estimate the line of best fit on their graphs on Lesson 2 Worksheet (using a rule or other straight edge like the edge of a book). Share/compare their line of best fit with their groups and with the with other students around the class. Students could also use rulers or string to show others their estimates on the projected image.
    b. *"The line you added to your graphs is called a line-of-best-fit, or a trend line. A line-of-best-fit is a linear average of all data points. This means the line is as close as possible to all data points. The line-of-best-fit can be used to identify any patterns in your data because it summarizes the relationship between the independent and dependent variable."*

2. **Show students line-of-best-fit on slide.** *"The line-of-best-fit can be used to identify any patterns in your data because it summarizes the relationship between the independent and dependent variable. What does this line tell us about the relationship between our variables?"*
    a. *"We visually estimated the line of best fit, but we can be even more sure if we mathematically calculated the line of best fit. This is the actual line of best fit that has been mathematically calculated to minimize the distance between the line and all the points. How close were your estimates?"*

3. **Discussing and analyzing our line of best fit and equation.** *"Why would we want the equation for the line?" (Would it make it easier to estimate the bloom date, rather than just eyeing it on the graph?) "What would that look like?"* (Get student ideas.)

4. **What does the equation mean?** *"The general equation is y = mx + b. This equation is a way of describing the line-of-best-fit mathematically! The variables in the equation are y, m, x, and b. They represent different pieces of information shown on the graph. In the next few slides, we will go over what each means.* ***With these four pieces of information you can summarize the relationship between the two variables in your graph****."*

5. **Review slope-intercept form:** What does each part of the equation y = mx+b represent in general and in this context? (Questions are on Lesson 2 worksheet)
    a. What is x?
        i. X= x value of a point on the line
        ii. The temperature in degrees Fahrenheit
        iii. This is the independent variable
    b. What is y?
        i. Y= y value of a point on the line
        ii. The date of full bloom
        iii. This is the dependent variable
    c. What is m?
        i. M= slope (rise over run; the change in y over the change in x)
        ii. Point to the m= y2-y1/ x2-x1 equation. "Slope is calculated by dividing a change in y by a change in x. Did bloom date get earlier or later as temperature increased/got warmer?"
        iii. "It decreased, it got earlier. This makes sense because the slope here is a negative number. Remember a negative slope means a line-of-best-fit that slants downwards, while a positive slope means a line that slants upwards."
        iv. Interpreting the slope: "For every degree warmer, how many days earlier do the cherries bloom?"
    d. What is b?
        i. B = y-intercept (where the line crosses the y-axis). The Y value when X= 0.
        ii. The blooming date if the average March temperature was zero degrees Fahrenheit.
        iii. NOTE: The Y intercept represents the Bloom Date if the average March temperature were 0 degrees. We can't see zero on our graph, but we can estimate where the line might hit zero. This would be somewhere around 170.
        iv. Date of year (DOY) 173.2

corresponds with June 21st. This very cool average March temperature would correspond to a very late Bloom Date. (Compare 173/June 21 to the average date of bloom - 133/May 12)

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

1. **Student Practice:** Using the Lesson 2 worksheet, have students practice predicting bloom date based on given temperatures (25, 30, 45 degrees).

2. **HOMEWORK (Listed on Lesson 2 Worksheet):**
   a. What impact may very early or late bloom dates have on cherry farmers and the larger population?
   b. Reflect on the strengths and limitations of your graph. What can it help farmers with? What doesn't the graph do? How could you make it more accurate?