Radium Girls

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Adapted by ORISE

Target Grade: 6th-12th cross curricular math, science, English, and history

Time Required: 5 days with 60-minute lessons

Standards

Next Generation Science Standards:

- MS-LS3-1- Heredity: Inheritance and Variation of Traits:
  Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.
- HS-LS3-2 Heredity: Inheritance and Variation of Traits:
  Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- HS-PS1-5 Matter and its Interactions:
  Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Common Core Math Standards:

- CCSS.MATH.CONTENT.6.SP.A.1: Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers. For example, "How old am I?" is not a statistical question, but "How old are the students in my school?" is a statistical question because one anticipates variability in students' ages.
- CCSS.MATH.CONTENT.6.SP.B.4: Display numerical data in plots on a number line, including dot plots, histograms, and box plots.
- CCSS.MATH.CONTENT.6.SP.A.2: Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.
  CCSS.MATH.CONTENT.HSS.ID.A.2: Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.
- CCSS.MATH.CONTENT.HSS.ID.A.3: Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

- CCSS.MATH.CONTENT.HSS.ID.A.4: Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

Lesson Objectives

Students will be able to:

- Analyze a real-world data set to determine the effects of radium on the human body.
- Create plots and charts from information gathered from a data set.
- Formulate questions and possible outcomes to better understand and analyze real-world research.
- Better understand how real-life influences can affect personal genealogy.

Central Focus

This lesson will allow students to use career-related, real-world data from the DOE's Comprehensive Epidemiologic Database Resource (CEDR) to improve math skills. At the same time, students will investigate, research, and write about the effects of overexposure to radium, which can cause mutations in the human body. The data reviewed in this lesson come from a data set collected about women who came in continual contact with radioactive materials, which were used in Oak Ridge laboratories.

Background Information

Prior to the lesson, the students should be aware of the following terms and concepts:
- X-axis: the principal or horizontal axis of a 2D system of coordinates. Used to describe the horizontal placement of a point. In a 2D coordinate system, ordered pairs are written as (x,y). The first number in the pair corresponds to the horizontal position and is referred to as the x-coordinate. A point positioned on the x-axis has a y-coordinate that is zero.
- Y-axis: the vertical axis of a 2D system of coordinates. Used to describe the vertical placement of a point. In a 2D coordinate system, ordered pairs are written as (x,y). The second number in the pair corresponds to the vertical position and is referred to as the y-coordinate. Points on the y-axis have an x-coordinate that is zero.
- Plotting on a graph: using the x and y coordinates, one can plot a certain location on a graph.
- Scatterplot: a graph in which the values of two variables are plotted along two axes, with the pattern of the resulting points revealing any correlation present.

Prior to the lesson, the teacher should be aware of the following terms:
- Variable: Anything that can change or be changed
- Mutation: the changing of the structure of a gene, resulting in a variant form that may be transmitted to subsequent generations, caused by the alteration of single base units in DNA, or the deletion, insertion, or rearrangement of larger sections of genes or chromosomes.
- Genes: a basic unit of heredity and a sequence of nucleotides in DNA that encodes the synthesis of a gene product, either RNA or protein.

- Radium: chemical element with the symbol Ra and atomic number 88.
- Types of Mutations:
  - Substitution: a change in DNA that occurs when one base pair in the sequence is replaced by a different base pair
  - Insertion: a change in the DNA that occurs when a base pair is added to the sequence.
  - Deletion: a change in the DNA that occurs when a base pair is removed from the sequence.
    - Click the link for more information on each type of mutation: https://www.yourgenome.org/facts/what-types-of-mutation-are-there/

For the high school part of the lesson:

- Line of regression: In statistics, linear regression is a linear approach for modelling the relationship between a scalar response and one or more explanatory variables.
- R^2 value: In statistics, the coefficient of determination is the proportion of the variation in the dependent variable that is predictable from the independent variable.

Materials

- "Parking Lot" question chart*
- Sticky notes*
- The Shocking Story of the Radium Girls video: The Shocking Story of the Radium Girls | WHAT THE PAST?
- *The Radium Girls* Article from Atomic Heritage Foundation: https://www.atomicheritage.org/history/radium-girls
- Laptop per student
- Access to Google Sheets
- Mutation Activity materials: DNA strands, DNA sides, markers, mutation key, glue/tape, and mutation list
- CEDR data set: https://oriseapps.orau.gov/cedr/search_results.aspx?DataSet=RADPDW01

*Can be replaced with virtual option explained in Instruction Notes

Instructions

Day 1:

Introduction (10 minutes)

- Begin by showing students the Shocking Story of the Radium Girls video: https://youtu.be/PHLNJeBtnm4
    - The video is a brief introduction to the women that used radium-based paint to create glow-in-the-dark watches. The factory workers were poisoned by the radiation causing many health issues, which led to laws to improve work conditions.
- Next, provide each student with a sticky note to write any questions they have about the video.
- Instruct students to place their questions onto the "Parking Lot" written either on the board or Flipchart paper (Figure 1)
    - This can also be completed virtually using Padlet.

PARKING LOT

🚧 PLACE YOUR QUESTIONS HERE 🚧
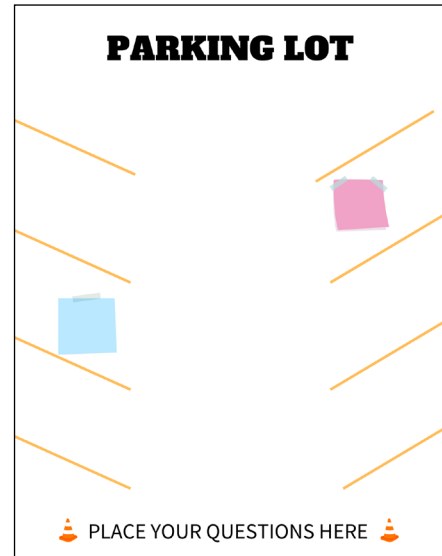
Figure 1: Parking Lot

Article (20 minutes)

- Provide each student with a copy of *The Radium Girls* article: https://www.atomicheritage.org/history/radium-girls
    - This article goes into the brief history of radium used by Marie and Pierre Curie, and the how and why the corporation the Radium Girls worked for began making products. It concludes by explaining the effects radium has on the human body and a brief overview of the legal compensation battle with U.S. Radium and the effects it has on the current workforce.
- Instruct each student to read through the article and annotate it using the resources in Figure 2.
- Next, as a class, read the article aloud with the students and pause at various spots and ask students things they annotated.
- Provide each student with a sticky note and instruct them to add an additional question to the "Parking Lot" based on the article.
    - See Instruction Notes for virtual option.

ANNOTATING AN ARTICLE

1. Circle new and important words and their context clues that help show their meaning.
2. Underline information or evidence that will help you answer the essential questions or objectives on the back of your plan of action.
3. Highlight examples and add them to your notes.
4. Draw a star or arrow next to images, charts, graphs, or diagrams that are important. ➡️ ⭐
5. Look up the meanings for new words and write them next to the words you circled. ✏️
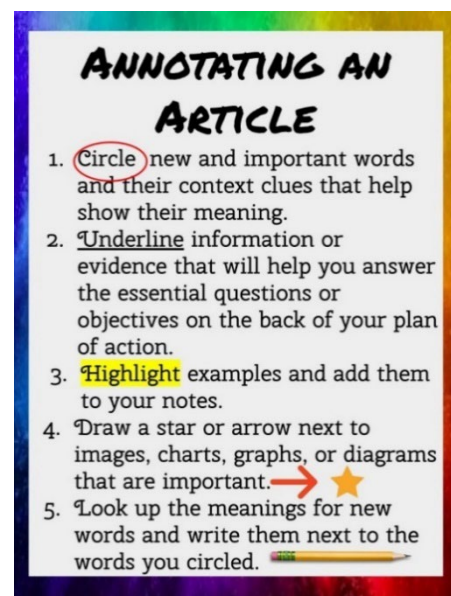
Figure 2: Annotating an Article

Graph Exploration (15 minutes)

- Show students the graph (Figure 3) and do a class discussion using the following questions:
    - What is a variable?
        - Anything that can change or be changed
    - What are the variables that were used to make this graph?
        - Number of tumors and amount of radiation
    - What is the x-axis measuring? Y-axis?
        - X-axis: amount of radiation, y-axis: amount of tumors
    - What is this graph telling you?
        - As radiation increases, so does the number of tumors. Tumors are dependent on the amount of radiation.
    - What can we conclude from this graph?
        - Radiation can cause tumors, or radiation can be harmful.
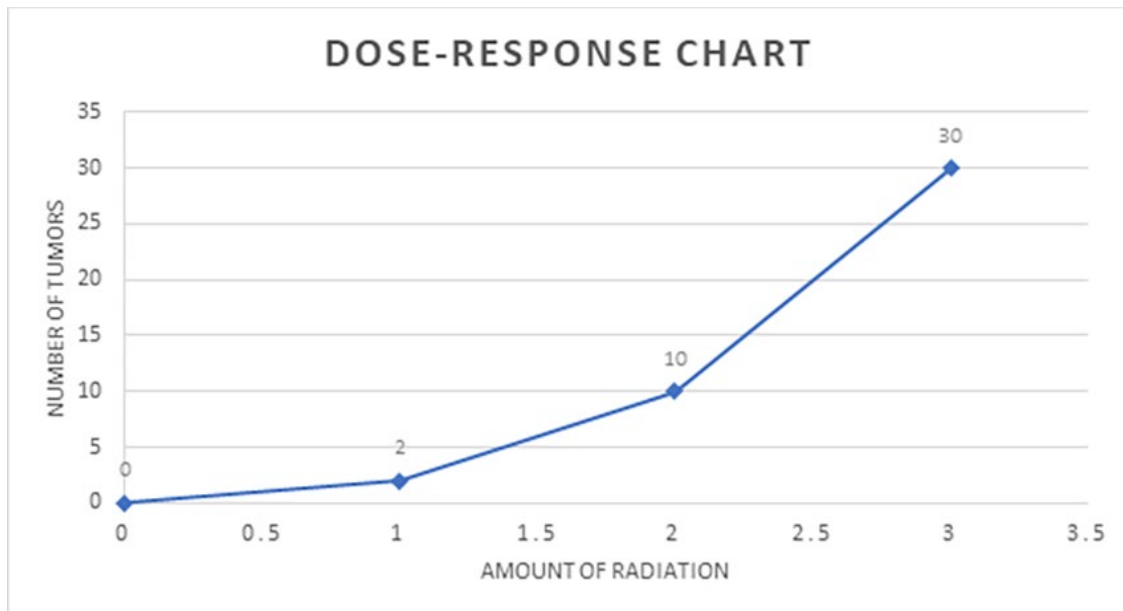
Figure 3: Radiation graph (source: https://www.acsh.org/news/2021/08/11/do-53-billion-cell-phone-users-need-worry-15724)

- Return to the "Parking Lot," and instruct students to add one additional question based on the graph.
    - See Instruction Notes for virtual option.

Closure

Middle School

- Tell students over the next few days they will create a research paper with a partner to answer the essential question: What effect did radium have on the Radium Girls' health?

- For the rest of class, they will work on their introduction paragraphs.
- Instruct students to write 3 paragraphs using all the resources reviewed today (article, graph, and video).
- Tell students to format their paragraphs with the following prompts:
  - Paragraph 1: Give a brief history (5-6 sentences) about radium by answering the question, "What is the history of Radium?"
  - Paragraph 2: Answer the question, "How did the "Radium Girls'" project positively affect the community and the future of workers' rights?"
  - Paragraph 3: Answer the question, "How did this project negatively affect the close community and families where these workers lived?"

High School

- Tell students over the next few days they will create a research paper, and for the rest of class, they will work on their introduction paragraphs.
- Provide each student with the scoring rubric and explain that they will be provided with experimental data on radium exposure with Radium Dial Painter workers in the coming days.
  - https://oriseapps.orau.gov/cedr/search_results.aspx?DataSet=RADPDW01
- Explain to students their research paper will be answering the essential question, "How does radiation effect the human body?"
- Provide each student with the data set background information:
  - https://oriseapps.orau.gov/cedr/search_results.aspx?DataSet=RADPDW01
- Instruct students to write the introduction paragraphs using the data set background information, the Radium Girls article, and any other supportive resource to complete the following criteria:
  - Write 2-3 paragraphs.
  - Explain why this experiment was conducted.
  - Include applicable background information.
  - State the purpose and object of the study.
  - State your hypothesis.
  - Outline how the data was collected.
  - Write the section in present tense.
  - Include in-text citations using ACS format.
  - Do not include any results or conclusions.

Day 2

Introduction (10 minutes)

- Have students spend 7 minutes recording any questions they have about the essential question: "How does radiation effect the human body?"
  - Remind students to use the questions in the "parking lot" based on the video, article, and graph.

Research (30 minutes)

- Tell students that today they will begin their investigation.
- Provide students with the resources below (Table 1) and instruct students to begin researching the answer to their questions.
  - If students are unable to find an answer, allow them to search online to find it.
  - The teacher can choose which materials they would like to provide to their students depending on their ability level.
  - Recommendation: If you would like to provide more direct instruction to your students, you can create a video of your teaching to also share with the students.

Table 1: Research Resources

| Name	Ability Level	Link
Videos		
CDC Biological Effects of Radiation	Beginner	https://www.youtube.com/watch?v=EuKzI3g5ra4
How Radiation Changes your DNA	Beginner	https://www.youtube.com/watch?v=PQjL4ZDuq2o
Is radiation dangerous? - Matt Anticole	Intermediate	https://www.youtube.com/watch?v=zI2vRwFKnHQ
Mutations	Beginner	https://www.youtube.com/watch?v=Jl1Aa7Iq4tc
Cancer is caused by mutations	Beginner	https://www.youtube.com/watch?v=6QHBxH5EmRg
The animals of Chernobyl	Beginner	https://www.youtube.com/watch?v=TG-nwQBBfmc
Mutations | Genetics | Biology | FuseSchool	Beginner	https://www.youtube.com/watch?v=Izhp5NuXo-k
The different types of mutations | Biomolecules	Advanced	https://www.youtube.com/watch?v=xYOK-yzUWSI
Mutations	Intermediate	https://www.youtube.com/watch?v=vl6Vlf2thvI&t=61s
Articles		
Ionizing radiation-induced DNA injury and damage detection in patients with breast cancer	Advanced	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4763322/#:~:text=Ionizing%20radiation%20directly%20affects%20DNA,single%20strand%20breaks%20(SSB).
Genetic Effects of Radiation	Advanced	https://www.ncbi.nlm.nih.gov/books/NBK218706/
Radium Girls NPR	Intermediate	https://www.npr.org/2014/12/28/373510029/saved-by-a-bad-taste-one-of-the-last-radium-girls-dies-at-107
What are Mutations	Intermediate	https://www.livescience.com/53369-mutation.html
How radiation effects genes	Intermediate	https://www.britannica.com/science/radiation/Damage-to-genes-mutations
Mutations	Beginner	https://www.genome.gov/genetics-glossary/Mutation
What is a mutation	Beginner	https://www.yourgenome.org/facts/what-is-a-mutation/

Types of mutations	Beginner	https://www.yourgenome.org/facts/what-types-of-mutation-are-there/
Games		
Gene Mutations	Beginner	https://app.legendsoflearning.com/teachers/dashboard?q=mutation
Genetic Zoo Nursery	Beginner	https://app.legendsoflearning.com/teachers/dashboard?q=mutation
DNA Mutation Simulation	Advanced	https://www.biologycorner.com/worksheets/DNA-sim.html
BrainPOP		
Genetic Mutations	Beginner	https://www.brainpop.com/health/geneticsgrowthanddevelopment/geneticmutations/

Closure (20 minutes)

- Provide each student with DNA strands, DNA sides, markers, mutation key, glue/tape, and DNA Chain Instruction Sheet.
- Place students in groups of four and instruct students they will practice manipulating a DNA strand with a mutation.
- Using the DNA Chain Instruction Sheet, students will complete the following steps:
  1. Cut out the boxes and sides.
  2. Glue/tape 4 letters to one side.
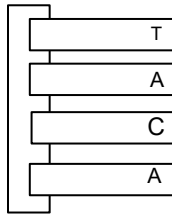
  3. Next, glue/tape the other side of your DNA strand to the first so that T and A match together and G and C match together
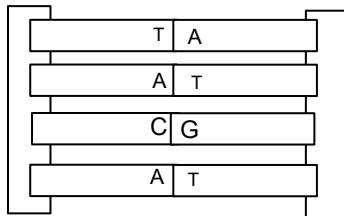
  4. Once everyone in your group has created your DNA strand, pass your strand to your right.
  5. Using the mutation list, create a mutation on your partner's DNA strand.
     - Mutation List: https://www.yourgenome.org/facts/what-types-of-mutation-are-there/
  6. Once finished, pass the DNA strand to your right.
  7. Using a marker, write on the DNA strand where the mutation appeared and which kind.
     - For example, you could write, "Mutation: Insertion"
  8. Turn in DNA strands to the teacher.

- At the end of class, collect the DNA strands and look through the students' responses to check for any class misconceptions.

Day 3:

Introduction (10 minutes)

- Spend the first 10 minutes of the class reviewing any misconceptions determined from the end of class exercise from the previous day.
- If students showed proficiency, allow time for them to update their lab report introduction with information collected from the previous day.

Teacher note: For this day, this lesson plan is divided into two sections after the introduction, one for middle school *and one for* high school*. Click the hyperlinked word to skip to the section you would like.*

High School

Discussion (10 minutes)

- Tell students that over the next two days, they will work to organize and understand data to communicate scientific reasoning.
- As a math warmup, begin a discussion by asking students the following questions (note: it might be helpful to write students' responses on the board):
  - Think back on the resources you have looked at over the past few days. What are the mathematical methods scientists use to organize their data and communicate information?
  - What are mathematical ways to communicate that two variables have a relationship?
  - What are possible mathematical models you could use in your research paper to answer the question, "How does radium affect the human body?"
- Instruct students that today they will explore one method of communicating scientific reasoning by showing relationships through scatterplots, line of regression, and R^2 values.

Mathematical exploration (40 minutes)

- Place students into groups of two and provide each student with the Data Plotting worksheet.
- On the worksheet, students will first practice plotting points and answering questions about the plot with the following questions:
  - What do you notice about the data points?
  - Draw a straight line that best connects the data points. Is that line decreasing or increasing? How do you know?
  - What can we predict will happen if we add a new X value of 3? What do you think its Y value would be and why?

- Next, students will work through the Understanding a Line of Regression sections. For this section, students will be allowed to research and record their answers to each of the following prompts:
    - What is a line of regression?
    - What equation is associated with the line of regression?
    - How do you find a line of regression by hand and on Google Sheets?
    - What does a line of regression tell you about a data set?
    - When do you use a line of regression? When do you NOT use a line of regression on a graph?
    - Draw an example of a line of regression. Is it increasing or decreasing?
    - Using the data set from before, calculate the line of regression equation. How did you find your answer?
- Students will use the same pattern to answer the following questions about an R^2 value:
    - What is an R^2 value?
    - What does the R^2 value tell you about your data set?
    - How do you find an R^2 value on Google Sheets?
    - When do you use an R^2 value?
    - What are the limitations of an R^2 value?
    - How do you interpret an R^2 value?
- Finally, students will be given a data set of age vs. height to work through the following prompt on Google Sheets:
    - Place the following data set into Google Sheets.
    - Create a scatterplot of the data points. How did you do this?
    - Label your axes and provide a title to your graph. How did you do this?
    - Find the line of regression. What was the line of regression and how did you find it?
    - Find the R^2 value. What was the R^2 value and how did you find it?
    - What does this graph tell you about your data?
    - Draw or insert a screenshot of your final graph.
- The teacher can choose to either pause the lesson at each section or wait until all students are finished to go over the answers.

Closure (10 minutes)

- Tell students that over the next two days, they will use their background information to analyze and interpret the radium data for their results and discussion section.
- Instruct students to go to the following CEDR link: https://oriseapps.orau.gov/cedr/DataFile.aspx?DataSet=RADPDW01&DFile=RADPDW01_4
- Have students explore the contents of the data set.
- Have students discuss in their groups the question, "What variables would best show the relationship between human health and radium exposure?"

Middle School

Discussion (10 minutes)

- Tell students that over the next two days, they will work to organize and understand data to communicate scientific reasoning.
- As a math warmup, begin a discussion by asking students the following questions (note: it might be helpful to write student responses on the board):
  - Think back on the resources you have looked at over the past few days. What are the mathematical methods or models that scientists use to show their findings and communicate information?
  - Recall from the previous days, what is a variable?
  - What are ways you think we could compare two variables?
  - What are possible mathematical models you could use in your paper to answer the question, "What effect did radium have on the Radium Girls' health?"
- At this point, students most likely will not have complete answers and that is okay. This discussion is used to spark their thinking.

Mathematical exploration (40 minutes)

- Place students into groups of two and provide each student with the Data Plotting worksheet and the recommended resources.

Name	Link
Videos	
Understanding Scatter Plots	https://www.youtube.com/watch?v=hKNFn2E2biw
Statistics Scatter Plots & Correlations Part 1 - Scatter Plots	https://www.youtube.com/watch?v=qscgK78No70
Scatter Plots and Equations of Lines by Shmoop	https://www.youtube.com/watch?v=r7zsYcxgWEA
Articles	
A Complete Guide to Scatter Plots	https://chartio.com/learn/charts/what-is-a-scatter-plot/
Scatter Plot	https://www.mathsisfun.com/data/scatter-xy-plots.html
What is a Scatter Plot?	https://corporatefinanceinstitute.com/resources/knowledge/other/scatter-plot/

- On the worksheet, students will first practice plotting points and answering questions about the plot with the following questions:
  - Label the axes on the graph. Why did you label them the way you did?
  - Number the lines on the graph in a way that best fits the data. Why did you number the graph the way you did?
  - Plot the data points in the table on the graph.
  - What do you notice about the data points?

- o Draw a straight line that best connects all the data points. What do you notice about the line?
  - o What do you think the line tells us about the data points?
  - o What can we predict will happen if we add a new X value of 3? What do you think its Y value would be and why?
- Next, students can use the resources to record their answers to the following questions:
  - o What does increasing mean? Is it positive or negative?
  - o What does decreasing mean? Is it positive or negative?
  - o Look at the arrow on the graph. Is that arrow increasing or decreasing? How do you know?
  - o Look at the arrow on the graph. Is it becoming more positive or more negative? How do you know?
  - o What is a scatter plot?
  - o What is a line of best fit?
  - o Draw a picture of a scatter plot.
  - o What does a scatter plot tell you about data?
  - o Draw examples of scatterplots that show a strong positive linear correlation, moderate negative linear correlation, and no correlation. You should have one plot for each positive, negative, and no correlation.
  - o Draw a line of best fit. Is it increasing or decreasing?
- Finally, following the same pattern, students will practice putting data into Google Sheets with the following prompts:
  - o Place the following data set into Google Sheets.
  - o Create a scatter plot of the data points. How did you do this?
  - o Label your axes and provide a title to your graph. How did you do this?
  - o Find the line of best fit. Was the line increasing or decreasing and how did you find it?
  - o What does this graph tell you about your data?
  - o What can we predict will happen to the height at age 19?
  - o Draw or insert a screenshot of your final graph.
- The teacher can choose to either pause the lesson at each section or wait until all students are finished to go over the answers.

Closure (10 minutes)

- Tell students that over the next two days, they will use their background information to analyze and interpret the radium data for their paper.
- In small groups and then as a class, ask students to discuss the question, "What variables would best show the effect radium had on the Radium Girl's health?"
  - o Probe students' responses by asking why-based questions.

Day 4

Introduction (5 minutes)

- Begin class by discussing the data analysis plan for the day with a partner.
- Select student groups to share a summary of their discussion.

Exploration (50 minutes)

- Provide groups with the data set that correlates to their ability level.
  - HS: https://docs.google.com/spreadsheets/d/1OeYGsKReYtl2CvwL_8y8vKSvZF3wqmGat-nTJ20HBPE/copy
  - MS: https://docs.google.com/spreadsheets/d/1KGSQCqdqr3-Jrn_xWCO_sMx7c-A1nvM9MQ2CzijqX2Q/copy
  - Teacher note: The teacher can use their discretion to filter the data down even more for selected students. The datasheets included in this lesson plan are set to the highest ability level to allow the teacher to filter down when needed.
- For groups that finish early, allow them time to begin working on their paper.

Closure (5 minutes)

- Provide each student with the prompts for the rest of their paper.

High School

- Use the following criteria to finish your paper:
  - Write 3-5 paragraphs.
  - Provide graphs and equations of your analysis.
  - Explain your procedure to analyze your data.
  - Report your findings by explaining your data and justifying what it means.
  - Explain possible errors in your method.
  - Explain future studies to further this research.

Middle School

- Write three paragraphs using the following prompts:
  - Paragraph 1: Write 4-5 sentences that answer the question: What does your data tell you about the effects of radium on the Radium Girls?
  - Paragraph 2: Write 4-5 sentences that answer the question: How did you analyze your data?
  - Paragraph 3: Write 4-5 sentences that answer the question: What should future companies/governments do to prevent this from happening again?

Day 5

Introduction (5 minutes)

- Explain to students that today will be a workday to finish their papers.
- Instruct students to develop a work plan and share it with the teacher.

Exploration (50 minutes)

- Have students collaborate to finish their paper.
- Halfway through the work time, instruct students to share their work with a peer for feedback on what they have completed. After receiving feedback, tell groups to write their "to do next" plan on a sticky note and share it with the teacher.
- Allow students to finish their work for the remainder of class.

Closure (5 minutes)

- Instruct students to turn in their paper.

Differentiation

- The teacher can read any articles to the students by either placing a voice recording on their learning platform or reading to the class.
- For the research paper, allow students to use other sources of media instead of writing. Examples would be creating a video, podcast, or comic strip.

Instruction Notes

This lesson plan is written for the highest difficulty level to allow the teacher to cut down information for students who may need alternate or modified activities.

CEDR: The Comprehensive Epidemiologic Data Resource (CEDR) is the U.S. Department of Energy (DOE) electronic database comprised of health studies of DOE contract workers and environmental studies of areas surrounding DOE facilities. DOE recognizes the benefits of data sharing and supports the public's right to know about worker and community health risks. CEDR provides independent researchers and educators with access to de-identified data collected since the Department's early production years. Current CEDR holding include more than 79 studies of over 1.5 million workers at 34 DOE sites. Access to these data is at no cost to the user.

Most of CEDR's holdings are derived from epidemiologic studies of DOE workers at many large nuclear weapons plants, such as Hanford, Los Alamos, the Oak Ridge reservation, Savannah River Site, and Rocky Flats. These studies have primarily used death certificate information to identify excess deaths and patterns of disease among workers to determine what factors contribute to the risk of developing cancer and other illnesses. In addition, many of these studies have radiation exposure measurements on individual workers. CEDR is supported by the Oak Ridge Institute for Science and Education (ORISE) in Oak Ridge, Tennessee. Now a mature system in routine operational use, CEDR's modern internet-based systems respond to thousands of requests to its web server daily. With about 1,500 internet sites pointing to CEDR's web site, CEDR is a national online digital repository, with a large audience for data that are not available elsewhere.

Padlet: Padlet is a free service that allows instructors to make discussion boards for students to post on and interact with. This is a good resource if students do not have time to verbally discuss their thoughts. Students can quickly upload a post to the board and comment on others. The instructor will need to set up the board prior to the meeting and share the link with the students.

- Link to website: Padlet.com
- Link to a "how to use" video: https://www.youtube.com/watch?v=dC69Sr-OQik

High School Data Plotting Worksheet

Name: _____

Date: _____

Class: _____

Plotting Data

1. On the graph, plot the x and y values given the table and label the axis.

X Value	Y Value
7	85
63	50
79	42
51	63
30	74
42	70
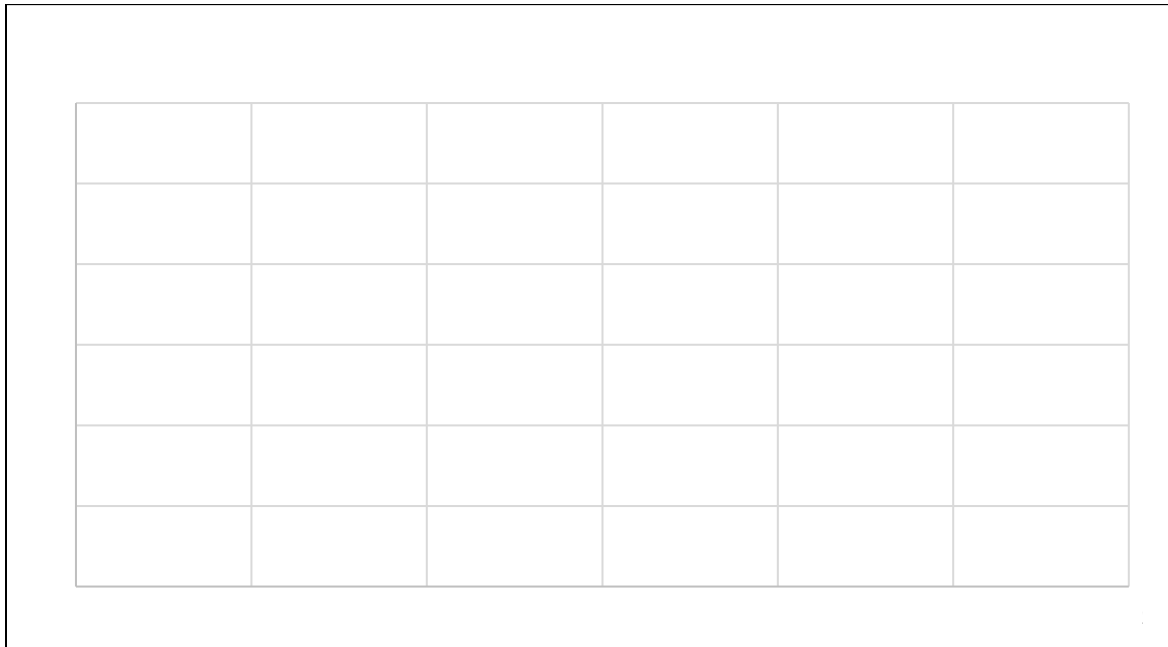
What do you notice about the data points?

Draw a straight line that best connects the data points. Is that line decreasing or increasing? How do you know?

What do you think this line tells us about the data points?

What can we predicts will happen if we added a new X value of 3? What do thing its Y value would be and why?

Understanding a line of regression

2. Using whatever resources you would like, research and record your answer the questions in your own words.

What is a line of regression?

What equation is associated with the line of regression?

How do you find a line of regression by hand and on Google Sheets?

What does a line of regression tell you about a data set?

When do you use a line of regression? When do you NOT use a line of regression on a graph?

Draw an example of a line of regression. Is it increasing or decreasing?
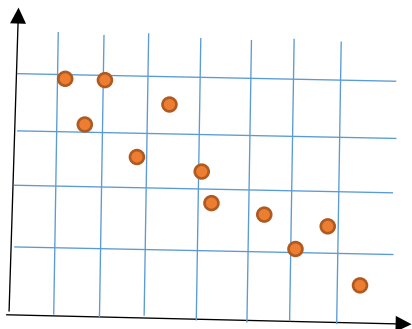
Using the data set from before, calculate the line of regression equation. How did you find your answer?

X Value	Y Value
7	85
63	50
79	42
51	63
30	74
42	70

Understanding an R^2 value

3. Using whatever resources you would like, research and record your answer the questions in your own words.

What is an R^2 value?

What does the R^2 value tell you about your data set?

How do you find an R^2 value on Google Sheets?

When do you use an R^2 value?

What are the limitations of an R^2 value?

How do you interpret an R^2 value?

How do you interpret an R^2 value?

X Value	Y Value
7	85
63	50
79	42
51	63
30	74
42	70

Plotting with Google Sheets

4. Work through the prompts on Google Sheets. Use whatever resources you need to solve each prompt.

Place the following data set into Google Sheets.

Age (years)	Height (inches)
5	38
6	40.2
7	41.3
8	49
9	50.2
10	50.8
11	54
12	55.8
13	58
14	58.9
15	60.2
16	62.5
17	68
18	68.1

Create a scatterplot of the data points. How did you do this?

Label your axis and provide a title to your graph. How did you do this?

Find the line of regression. What was the line of regression and how did you find it?

Find the R^2 value. What was the R^2 value and how did you find it?

What does this graph tell you about your data?

Draw or insert a screenshot of your final graph.

Middle School Data Plotting Worksheet

Name: _____

Date: _____

Class: _____

Plotting Data

1. Use the data table and graph below to answer the questions.

X Value	Y Value
7	85
63	50
79	42
51	63
30	74
42	70
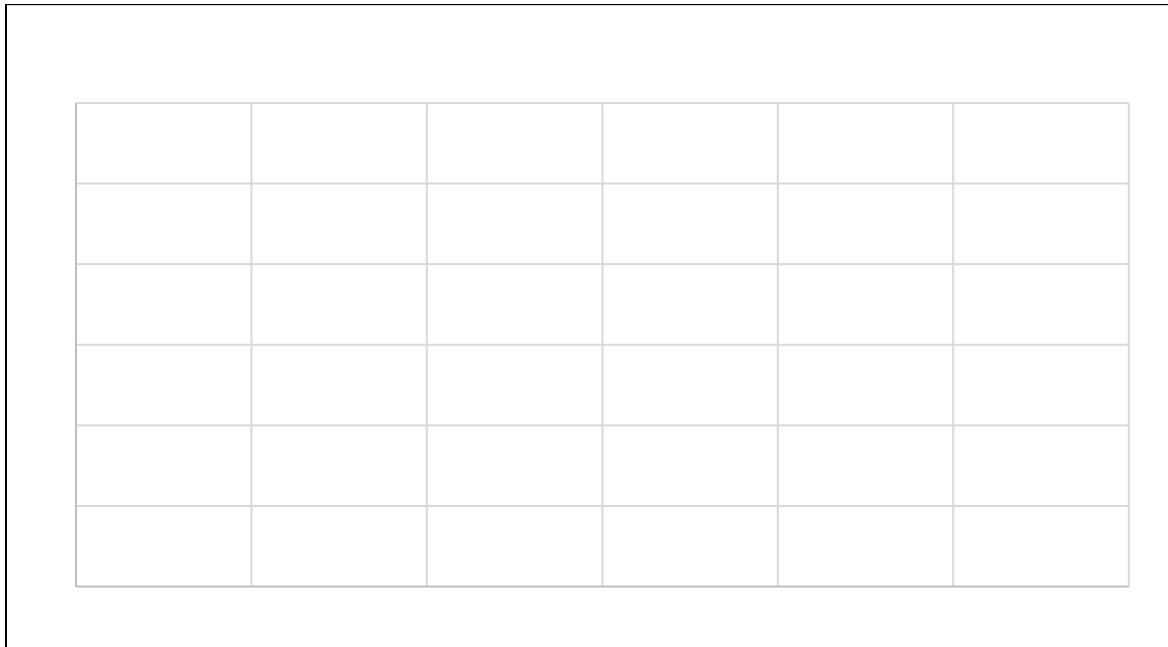
Label the axis on the graph. Why did you label them the way you did?

Number the lines on the graph in a way that best fits the data. Why did you number the graph the way you did?

Plot the data points in the table on the graph.

Middle School Data Plotting Worksheet

What do you notice about the data points?

Draw a straight line that best connects all the data points. What do you notice about the line?

What do you think the line tells us about the data points?

What can we predicts will happen if we added a new X value of 3? What do thing its Y value would be and why?

Understanding Scatter plots

2. Using whatever resources you would like, research and record your answer the questions in your own words.

What does increasing mean? Is it positive or negative?

What does decreasing mean? Is it positive or negative?

Look at the arrow on the graph is that arrow increasing or decreasing? How do you know?
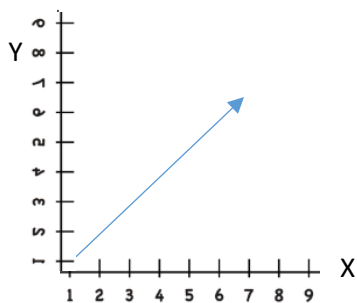
Middle School Data Plotting Worksheet

Look at the arrow on the graph is becoming more positive or more negative? How do you know?
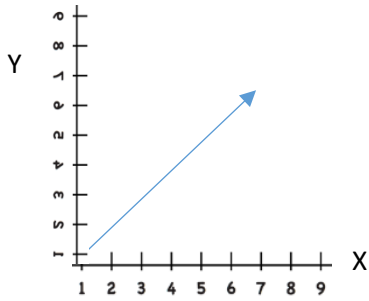
What is a scatter plot?

What is a line of best fit?

Draw a picture of a scatter plot.

What does a scatter plot tell you about data?

Draw examples of scatterplots that show a strong positive liner, moderate negative liner, and no correlation. You should have one plot for each positive, negative, and no correlation.

Middle School Data Plotting Worksheet

Draw a line of best fit. Is it increasing or decreasing?
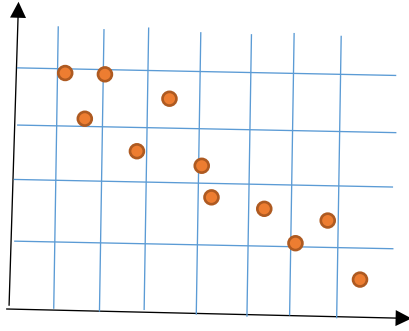
Plotting with Google Sheets

3. Work through the prompts on Google Sheets. Use whatever resources you need to solve each prompt.

Place the following data set into Google Sheets.

Age (years)	Height (inches)
5	38
6	40.2
7	41.3
8	49
9	50.2
10	50.8
11	54
12	55.8
13	58
14	58.9
15	60.2
16	62.5
17	68
18	68.1

Create a scatter plot of the data points. How did you do this?

Label your axis and provide a title to your graph. How did you do this?

Find the line of best fit. What was the line increasing or decreasing and how did you find it?

Middle School Data Plotting Worksheet

What does this graph tell you about your data?

What can we predict will have to the height at age 19?

Draw or insert a screenshot of your final graph.

Creating a DNA Strand and a Mutation

1. Color the boxes with the letters
   a. T- Red
   b. A- Blue
   c. G- Purple
   d. C- Green
2. Cut out each box including the "Sides"
3. Attach-(Tape, Glue, or Staple) 2 different letters to the "Sides" long boxes with no letters you can place them in any order you would like but (T-A)(A-T) and (G-C)(C-G) must always be with one another.

T	A
G	C
A	T
C	G
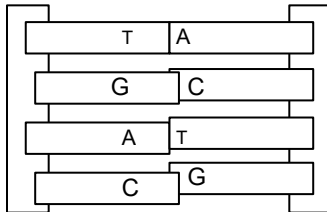
   a. T and A will be attached together and to the "sides"
   b. G and C will be attached together and to the "sides"
   c. The 3rd set of letters will be used if you decided to make a specific mutation later

▲ T   G ●

▲ T   G ●

▲ T   G ●

▲ A   C ●

▲ A   C ●

▲ A   C ●
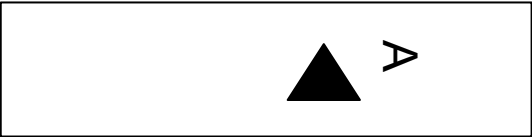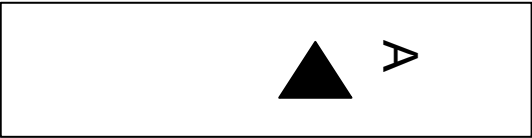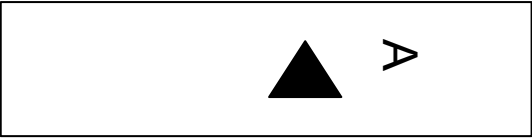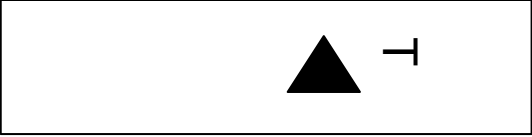
"Sides" of DNA Strands

The Radium Girls

In 1898, Marie and Pierre Curie, two of the most prominent pioneers in researching radioactivity, discovered the element radium. Radium was particularly intriguing because it glowed in the dark, and as Marie noted, "These gleamings seemed suspended in the darkness [and] stirred us with ever-new emotion and enchantment" (Moore).

Soon enough, the radium craze was on. After it was observed that radium could treat cancer, many people mistakenly thought it could also be used to treat other diseases as well. Before long, radium was widely considered a "miracle" substance, sold in pharmacies for all kinds of ailments. It was also widely believed that radium could prevent aging, and companies sold radium toothpaste, radium cosmetics, and even radium water.

The Radium Dials

Around this time, American inventor William J. Hammer went to Paris and obtained a sample of radium salt crystals from the Curies. Hammer discovered that by mixing the radium with glue and zinc sulfide, he could make glow-in-the-dark paint. His discovery would soon be used by the U.S. Radium Corporation to manufacture wristwatches with radium-painted dials. Advertisements for the product, which they called *Undark*, boasted of how it was all "made possible by the magic of radium!" U.S. Radium would also receive government contracts during World War I to produce watches and airplane instruments for American soldiers.

The corporation set up its factories in New Jersey and recruited dozens of young women to paint the watch dials. No safety precautions were taken, and the women were even encouraged to lick their brushes to keep the tip pointed and prevent the paint from drying. By the end of the day, the women themselves would be glowing from the radioactive paint on their clothes and skin. Harvard physiologist Cecil Drinker, who later investigated the factories, reported, "Dust samples collected in the workroom from various locations and from chairs not used by the workers were all luminous in the dark room. Their hair, faces, hands, arms, necks, the dresses, the underclothes, even the corsets of the dial painters were luminous. One of the girls showed luminous spots on her legs and thighs. The back of another was luminous almost to the waist."

All along, the company assured the women that their work was perfectly safe. Within a few years, however, dozens of the women began showing signs of illness. The human body mistakes radium for calcium, so it filled their bones as calcium would, irradiating them from within. The victims had their bones break, teeth fall out, and spines collapse, and by 1927 more than 50 had died.

Initial attempts to receive compensation from U.S. Radium were futile. Medical and legal costs were enormous, and U.S. Radium was well defended by a team of lawyers and held a prominent position as government contractor. Nevertheless, the story of the so-called "radium girls" poisoning soon became a national sensation. Eventually, dial painter Grace Fryer filed a lawsuit along with four other women for damages of $250,000. In desperate need of money, they would eventually settle for $10,000 each and a $600 annual payment, although none of them would survive more than two years after the settlement.

Impact on the Manhattan Project

While the development of *Undark* was a catastrophe for the women who worked on it, it also served to disclose the dangers of radiation exposure. This was true even prior to the creation of the Manhattan Project. During his time working at Berkeley, nuclear chemist Glenn Seaborg noted in his diary, "As I was making the rounds of the laboratory rooms this morning, I was suddenly struck by a disturbing vision [of] the workers in the radium dial-painting industry" (Moore). Seaborg insisted that his scientific team further research the properties of plutonium and take appropriate safety precautions, regulations which would later extend to the Manhattan Project as well.

Louis Hempelmann, a doctor at Los Alamos, recalled how Manhattan Project safety regulations were also based on those of the radium dial factories, which were much improved by this time. Hempelmann recalled, "All of the doctors of the Manhattan Project went up to the radium dial painting plant up in Boston to see how they handle their—plutonium and radium are quite similar. They give off the same radiation… They had a hood or they worked under hoods, or something like that. They would clean it up and test the contaminated area for actual contamination. So our procedures were patterned after that."

As one official from the Atomic Energy Commission would later note, "If it hadn't been for those dial-painters, the [Manhattan] project's management could have reasonably rejected the extreme precautions that were urged on it and thousands of workers might well have been, and might still be, in great danger" (Moore).

Legacy

Although U.S. Radium factory in New Jersey was the most infamous case of radium dial painting, it was far from the only one. It is estimated that by the 1920s as many as 4,000 workers were hired at companies across the United States and Canada to paint radium dials. Radium watches would continue to be manufactured until 1968, although the safety regulations were drastically improved.

The case of the radium girls would also have an impact on establishing strict guidelines for worker safety and compensation beyond the Manhattan Project. In 1949, the United States Congress passed a law which gave workers the right to receive compensation for occupational illnesses.

More Historical Resources:

Moore, Kate. *The Radium Girls: The Dark Story of America's Shining Women.* Naperville, IL: Sourcebooks, 2017.