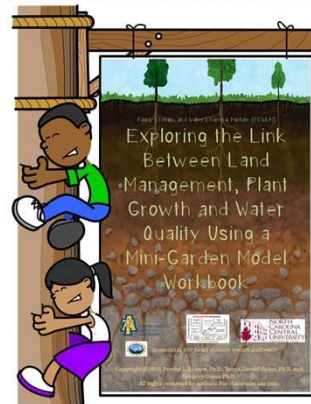
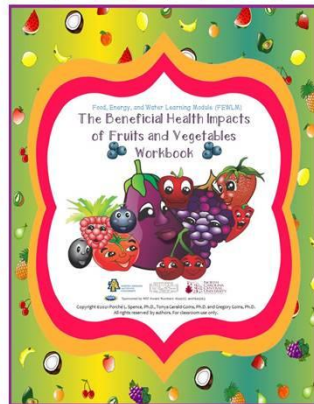
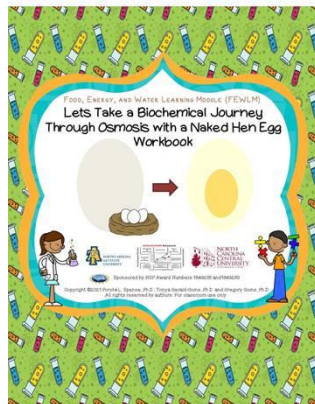
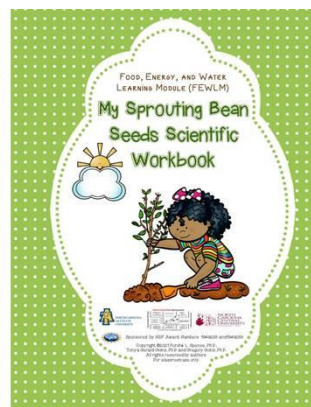
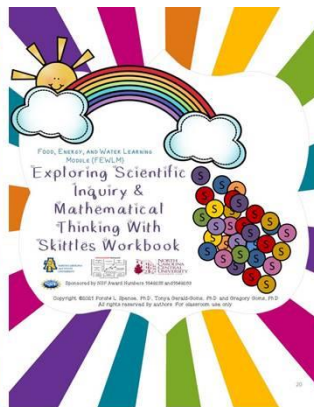
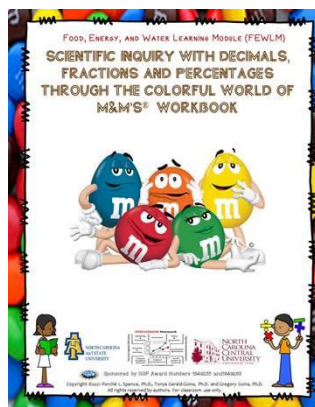


# Food, Energy, and Water Learning Module (FEWLM)

*A Low-Cost Affordable Science Inquiry-Based Curricula  
for Elementary and Middle School Youth*

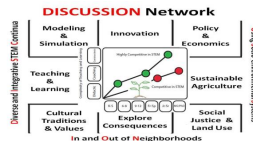


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# Overview for Educators

## FEWLM TERMS OF USE



FEWLM is a combination of pre-existing science activities modified to be self-driven and team-building workbooks emphasizing the application of scientific inquiry, quantitative literacy, conceptual understanding, and data analysis and interpretation. Through FEWLM, elementary and middle age youth are encouraged to act like a scientist by observing, recording, graphing, analyzing and interpreting data in order to test a hypothesis and formulate a conclusion. After completing the activity, the youth can self-reflect about what they learned from participating in the activity. These workbooks are designed for 3<sup>rd</sup> – 8<sup>th</sup> grade levels. Instructors have the liberty of assembling basic versions for elementary school age youth and advanced versions for middle school age youth by including the worksheets appropriate for a specific grade level.

FEWLM is designed to be taught sequentially to provide a scaffold curriculum for the elementary and middle school age youth to learn, practice, and apply their mathematical, analytical and graphing skills. However, instructors have the option to select workbooks that target specific topics or skills. The learning objectives align with the Next Generation Science Standards (NGSS) for elementary and middle school aged youth, which are provided on the instructor's page of each workbook. Depending on the activity, the time required to complete each workbook varies from 2 hours to 19 days. Instructions for teachers to effectively use these modules are provided with each individual activity.

FEWLM workbooks consist of:

1. Scientific inquiry with decimals and fractions through the colorful world of M&M's® workbook
2. Exploring scientific inquiry & mathematical thinking with skittles workbook
3. My sprouting bean seed workbook
4. Let's Journey through osmosis with a naked egg workbook
5. The health benefits of Fruits and vegetables workbook
6. Exploring the link between terrestrial ecosystems and water quality using a mini-garden model workbook

These workbooks are intended to be used in the classroom, outreach programs, summer camps, home schools, etc. to teach scientific inquiry. We hope that these workbooks provide an enjoyable learning experience for your inspiring scientist. We appreciate teachers, STEM outreach instructors, parents and grandparents for selecting FEWLM to teach scientific inquiry. We encourage researchers to use the FEWLM curriculum to conduct STEM education research.

All rights are reserved to the authors of these workbooks. Please do not copy, reproduce or redistribute this FEWLM workbook on the internet. These activities are intended for single classroom use only. Posting pictures of elementary and middle school age youth using FEWLM on social media website is allowed with proper credit. We encourage everyone to download your own free copy of FEWLM at the QUBES hub resources using this link: <https://qubeshub.org/publications/2287/1>





# Budget and Cost Savings



## FEWLM WORKBOOK IMPLEMENTATION COSTS

As educators, we understand teachers, schools and other educational programs operate on a limited and often fixed budget. Therefore, FEWLM was created with “*affordable programing*” as the focal point. **The suggested total cost to implement the complete series of FEWLM workbooks is less than \$300 for a class size of 30 students.** The cost for each individual module varies between \$26 and \$100. The items needed to conduct each activity can be purchased locally at a wholesale store, Dollar Tree, Walmart, pet store or grocery store, for a reasonable price. A budget and supply list containing the suggested price and vendor for each item is provided at the beginning of each module. After implementing FEWLM during year one, the cost is expected to decrease during the second and third year because several items can be reused. Moreover, instructors can save money if they purchase crayons, color pencils and Sharpie fine permanent markers during the “back to school sale.”

| Module Number | FEWLM Module   | Modeling Applications and STEM Features  | Real-World Environmental Applications | Bloom's Taxonomy | Activity Time          | Estimated Cost |
|---------------|--|--|---------------------------------------|------------------|------------------------|----------------|
| 1             | Scientific Inquiry with Decimals and Fractions through the Colorful World of m&m's Workbook          | Math Applications<br>Basic Statistics<br>Sample Replication<br>Data Collection | Scientific Inquiry                    | Understand       | Part I. 45 to 120 min  | \$46 USD       |
|               | OR<br>Exploring Scientific Inquiry and Mathematical Thinking with Skittles Workbook                  | Data Analysis  |                                       |                  | Part II. 60 to 120 min | \$6 USD        |
| 2             | My Sprouting Bean Seeds Scientific Workbook  | Seed Germination<br>Biological Organisms                                       | Food Insecurity                       | Apply            | 7-10 days              | \$26 USD       |
| 3             | Let's Take a Biochemical Journey Through Osmosis with a Naked Hen Egg Workbook                       | Cell Structure<br>Cell Membrane<br>Osmosis                                     | Health disparities                    | Analyze          | Up to 3 days           | \$53 USD       |
| 4             | The Beneficial Health Impacts of Fruits and Vegetables   | Cell Membrane<br>Biochemistry  | Health Antioxidants<br>pH             | Analyze          | 4 hours                | \$28 USD       |
| 5             | Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model | Plant Growth<br>Water Quality<br>Land Management                               | Water Pollution<br>Food Insecurity    | Synthesis        | Up to 19 days          | \$100 USD      |

Even though FEWLM can be implemented at an affordable price, here are a few suggestions for instructors to further reduce the total costs:

1. Instructors can purchase the school supplies at the beginning of the academic year when the school supply prices are significantly reduced.
2. Teachers could include the non-perishable items on the back to school classroom supply list so parents can purchase and donate the items.
3. Continue asking parents to donate seasonal or perishable items during the year.
4. Teachers can request items and/or funds to pay for items from the school's Parent Teacher Association (PTA).
5. Items not available in local stores, such as the Dollar Tree, can be purchased from the same vendor (Dollar Tree) online and shipped directly to the store to avoid shipping charges.

# Thank you for Choosing FEWLM to Teach Scientific Inquiry! 😊

**Credits:** The clipart, fonts, borders, and digital background paper used to design FEWLM were created by the following designers and artists listed below.



<https://www.teacherspayteachers.com/Store/The-Enlightened-Elephant>



<https://www.mycutegraphics.com/>



<https://www.teacherspayteachers.com/Store/Always-And-Forever>



<https://www.teacherspayteachers.com/Store/Monica-Abarca>



<https://www.teacherspayteachers.com/Store/Mrs-Fun>



<https://www.teacherspayteachers.com/Store/Glue-And-Ink>



<https://www.teacherspayteachers.com/Store/AmazingLessons4Friends>



<https://www.teacherspayteachers.com/Store/Educlips>



<https://www.teacherspayteachers.com/Store/Studio-Devanna>



<https://www.teacherspayteachers.com/Store/Vik-Clips>



<https://www.teacherspayteachers.com/Store/The-Chalkboard-Garden>



<https://www.teacherspayteachers.com/Store/The-Painted-Crow>



<https://www.teacherspayteachers.com/Store/Wendy-Finn>



<https://www.teacherspayteachers.com/Store/Mrs-Lovelace>



<https://www.teacherspayteachers.com/Store/Tracey-Orman>



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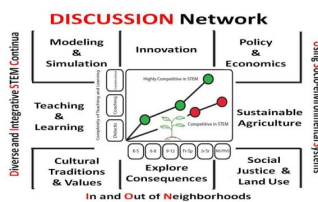


FOOD, ENERGY, AND WATER LEARNING MODULE (FEWLM)

# SCIENTIFIC INQUIRY WITH DECIMALS, FRACTIONS AND PERCENTAGES THROUGH THE COLORFUL WORLD OF M&M'S® WORKBOOK



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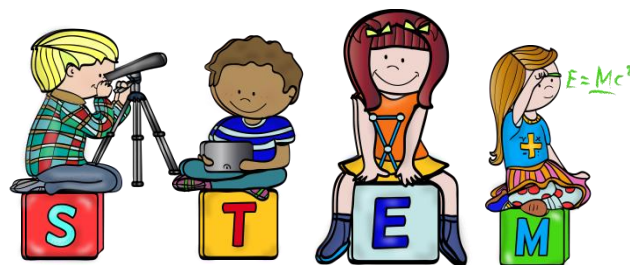
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# Scientific inquiry with decimals, fractions and percentages through the colorful world of m&m's® Workbook



## SUMMARY

This “Scientific inquiry with decimals & fractions through the colorful world of m&m's®” is a hands-on guide inquiry activity that allows students to engage in mathematical thinking while introducing the importance of data collection, sample replication and sample variability and enjoying an edible treat. Students will act like a scientist by recording, graphing, analyzing and interpreting data gathered from tallying and sorting plain chocolate m&m's® to determine if the percentage of colors in each bag are identical. Students also learn how to create bar graphs, which is a valuable tool for interpreting and communicating results and promotes mathematical thinking. Using m&m's® has been an effective technique for teaching the scientific inquiry and data analysis to elementary and middle school age youth. The mathematical, analytical and graphing skills learned during this activity will be practiced and applied while completing the other FEWLM activities. **Part I** focuses on using m&m's® to learn how to tally and sort into categories and calculate fractions, decimals and percentages, which aligns with the 3rd-5th graders next generation science standards (NGSS). **Part II**, a continuation of part I, includes basic statistics (6th-8th grade level NGSS) and the application of a statistical software program such as Microsoft Excel. Students work as a team of scientists and combine their individual data in a spreadsheet to calculate average, median, mode. Students evaluate differences in percentage of colors in their individual bag and a group bags to discover the importance of sample replication and variability. Students introduced to scientific inquiry learn to critically think through a research problem and mimic scientists. Worksheets too advance for a specific grade level can be removed prior to assembling each workbook.

## QUICK LOOK

**Grade Level:** 3<sup>rd</sup> – 8<sup>th</sup> grade

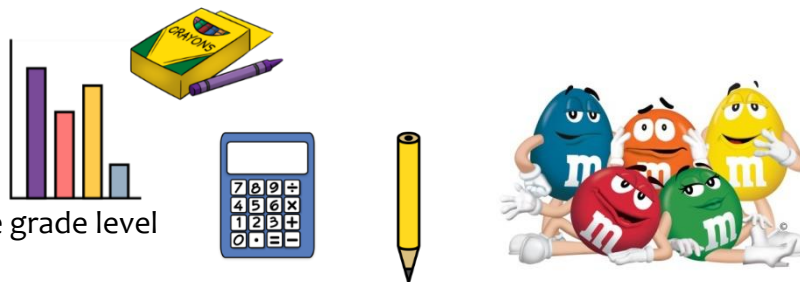
**Subjects:** Science, Math, and Writing

**Preparation:** Less than 30 minutes

**Time Required:** 45 to 120 minutes, depending on the grade level

**Group Size:** Should not exceed 5 students

**Estimated Total Cost:** The total cost to implement the this activity will be \$3.00 cheaper if the 24 count Crayola crayons are purchased for \$0.50 each during the “back to school” sale from Walmart, Target or Staples.



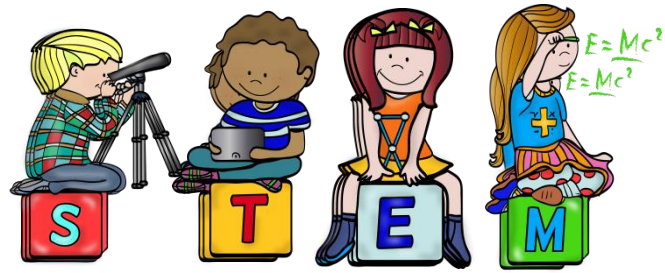
**FOCUS QUESTION:** Does a bag of milk chocolate m&ms® have the same percentage of each color?

**TABLE 1. SUPPLIES NEEDED TO BE PURCHASED** (\*supplies can be used in year 2 or other FEWLM activities)

| Item   | Recommended Vendor                           | Number of Item | Total Price                            |
|--|--|----------------|--|
| m&m's® Milk Chocolate (1.69 oz., 48 ct.)                 | Whole Sale Club                              | 1 box          | \$30.00                                |
| m&m's® Milk Chocolate Fun Size (0.75 oz., 24 ct.)        | Walmart                                      | 1 bag          | \$3.00                                 |
| Crayola 24 count Crayons*<br><i>Back to School Price</i> | Dollar Tree<br><i>Walmart/Target/Staples</i> | 6 boxes        | \$6.00<br><i>\$3.00</i>                |
| Jot 8-Digit Pocket Calculators*                          | Dollar Tree                                  | 6              | \$6.00                                 |
| Yellow Wooden #2 Pencils, 24-ct.*                        | Dollar Tree                                  | 2 boxes        | \$4.00                                 |
| <b>Total</b>   |  |                | \$46/ <i>\$43</i><br>\$19/ <i>\$16</i> |



# Scientific inquiry with decimals, fractions and percentages through the colorful world of m&m's® Workbook



## TEACHER PREPARATION AND INSTRUCTIONS

*Prior to beginning this activity:*

1. Teachers should purchase a box 48 count of m&m's® from a whole sale store, because each student will be given their own single bag of milk chocolate candy (1.69 oz., 48 ct.) to conduct the experiment.
2. A workbook should be printed and assembled for each student. Print only the pages appropriate for their grade level (i.e. part I – elementary students or parts I and II – middle school students)
3. Gather or purchase color pencils, crayons, pencils & calculators
4. The teacher should lead a discussion about the importance of the scientific process and the importance of sample size, collection, replication, analysis and interpretation.

*After completing the activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity. Their reflections should be written at the end of the workbook and expressed orally during the class discussion.
2. Teachers should lead a class discussion revisiting the scientific process, the connection between science and math for conducting scientific research and how science is applied to our everyday decisions.
3. Teachers can explain how the mathematical skills learned during this activity can be applied to other research projects such as the next activity – seed germination.

## LEARNING OBJECTIVES *Based on Next Generation Science Standards\**

### **3<sup>rd</sup>-5<sup>th</sup> grade (Part I. Worksheet pages 1-7)**

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2), (4-ESS2-1), (4-PS3-2)
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)
- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2), (3-LS4-2)
- Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships. (3-ESS2-1)
- Most scientists and engineers work in teams. (4-PS3-4)
- Science affects everyday life. (3-ESS3-1), (4-PS3-4)

### **6<sup>rd</sup>-8<sup>th</sup> grade (Part II. Worksheet pages 1-13)**

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)

\*NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Name \_\_\_\_\_

Grade Level \_\_\_\_\_



# Scientific Inquiry with Decimals & Fractions through the Colorful World of m&m's



| Criterion                                 | Exemplary = 4  | Proficient = 3   | Approaching Proficiency = 2   | Non-Proficient = 1                                | Score      |
|---|--|--|---|---|------------|
| <b>APPEARANCE</b>                         | Neat and easy to read  | Somewhat neat and easy to read   | Neat and difficult to read  | Not neat and very difficult to read               |            |
| <b>HYPOTHESIS</b>                         | Hypothesis stated and explained well   | Hypothesis stated and vaguely explained  | Hypothesis stated and inadequately explained  | Hypothesis stated but not explained               |            |
| <b>DATA COLLECTION</b>                    | Collected all data correctly   | Collected most data correctly  | Collected some data correctly   | Collected few data correctly                      |            |
| <b>DATA ANALYSIS</b>                      | Calculated all data correctly  | Calculated most data correctly   | Calculated some data correctly  | Calculated few data correctly                     |            |
| <b>GRAPHS</b>                             | Correctly matches all the data analysis tables   | Correctly matches most of the data analysis  | Correctly matches some of the data analysis   | Correctly matches few data correctly              |            |
| <b>USE OF COLOR IN GRAPHS</b>             | Attractive with appropriate use of all color   | Attractive with appropriate use of most of the colors  | Attractive with appropriate use of some of the colors   | Attractive with appropriate use of a few colors   |            |
| <b>RESULTS &amp; GRAPH INTERPRETATION</b> | Answered all questions correctly   | Answered most of questions correctly   | Answered some of questions correctly  | Answered few questions correctly                  |            |
| <b>CONCLUSIONS</b>                        | Hypothesis accepted or rejected and clearly explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but vaguely explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but inadequately explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but not explained |            |
| <b>Additional Comments:</b>               |  |  |   | <b>TOTAL POINTS</b>                               | <b>/32</b> |

## OVERALL ACTIVITY PERFORMANCE

*Circle the Description that matches each student's score*

| Score      | Descriptive             |
|------------|-------------------------|
| 32-29      | Exemplary               |
| 28-26      | Proficiency             |
| 25-23      | Approaching Proficiency |
| 22 or less | Non-Proficient          |

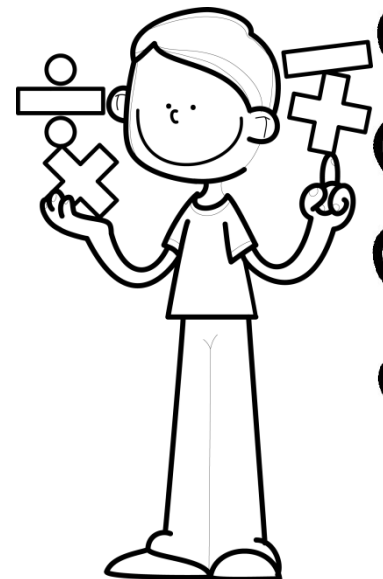
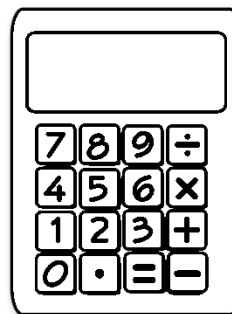
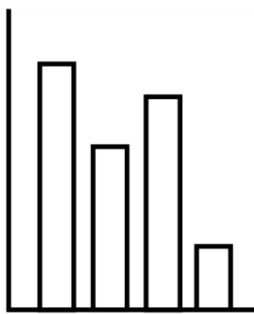




# Mathematics

## With m&m's

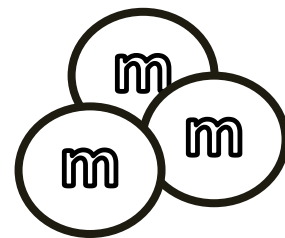
Scientific Inquiry with Decimals,  
Fractions and Percentages through the  
Colorful World of m&m's® Workbook



THIS M&M'S® WORKBOOK BELONGS TO:



# Background Information & Study Design



Do you like eating m&m's®? Circle **Yes** or **No**.

Which type of m&m's® will be used in this experiment? \_\_\_\_\_

What is the size of your bag of m&m's®? \_\_\_\_\_

Do you expect each bag of m&m's® to have the same amount of candies?  
Circle **Yes** or **No**. Explain Why?

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Do you expect each bag of m&m's® to have the same amount of each color?  
Circle **Yes** or **No**. Explain Why?

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---

What is the research problem?

---

---

List of Materials

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Hypothesis

I hypothesize that \_\_\_\_\_ is the most popular color in a bag of m&m's® because \_\_\_\_\_

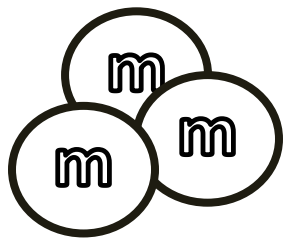
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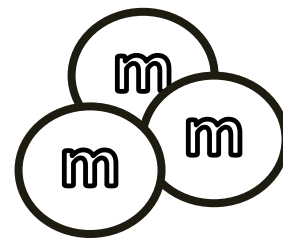
Name \_\_\_\_\_

Date \_\_\_\_\_





# Data Collection

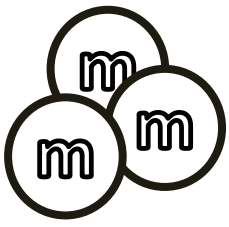


Open your Bag of m&m's® and empty the candies on the bottom of this page. Sort, tally and count the number of each color of m&m's®. Record your data in the table below.

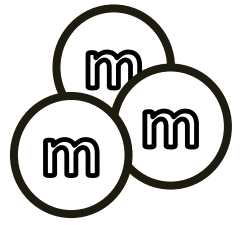
| Color | Tally | Total |
|-------|-------|-------|
|       |       |       |
|       |       |       |
|       |       |       |
|       |       |       |
|       |       |       |
|       |       |       |
|       |       |       |
| Total |       |       |

Name \_\_\_\_\_

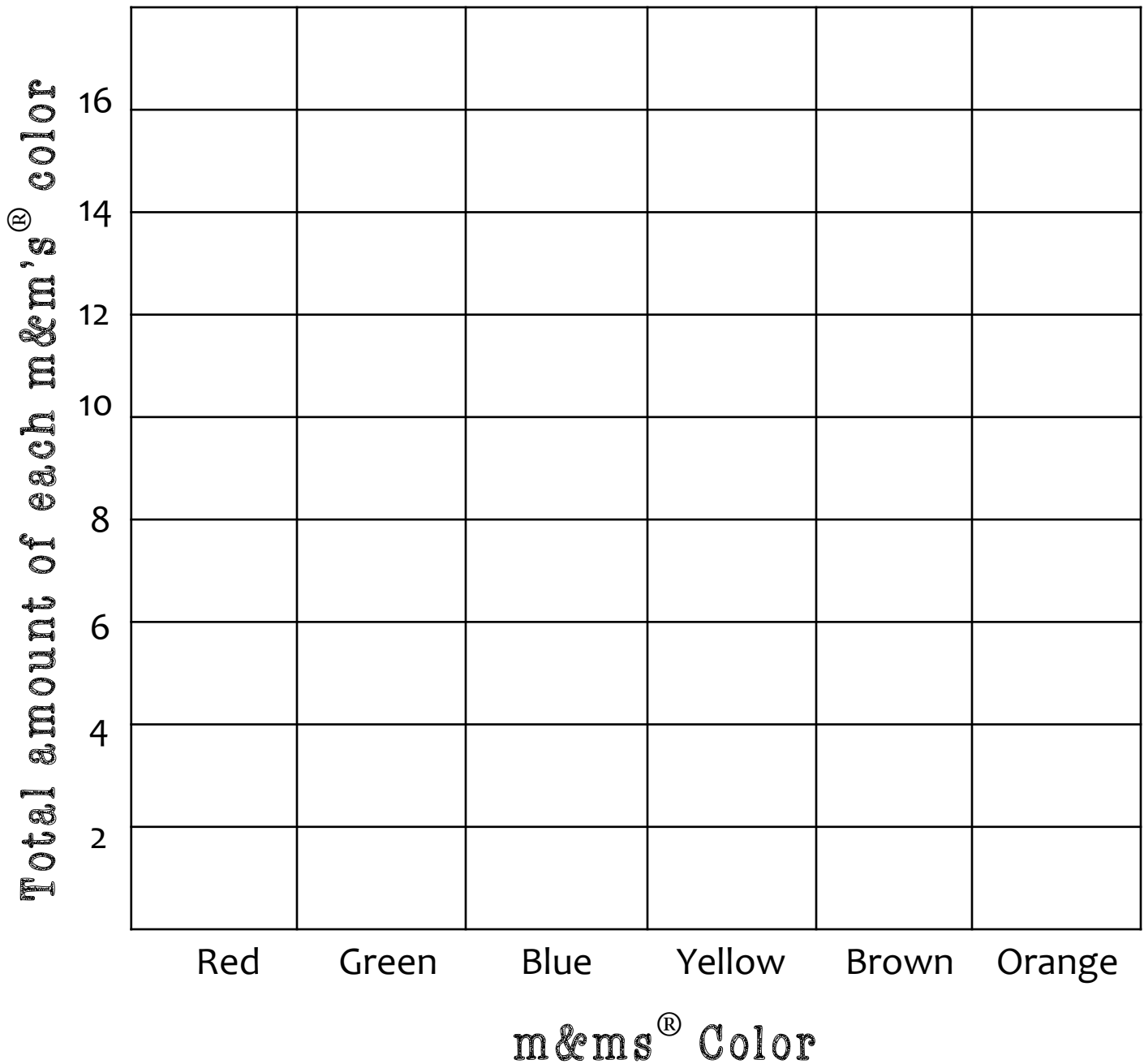
Date \_\_\_\_\_



# Total Amount Bar Graph



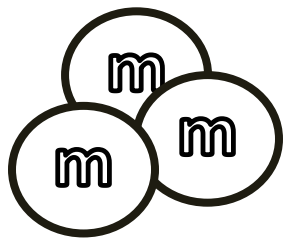
Create a **bar** graph illustrating the number of m&m's® for each color.  
Use the crayon or color pencil that matches the color of the m&m's®.



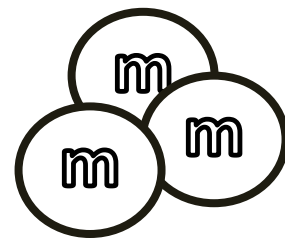
Name \_\_\_\_\_

Date \_\_\_\_\_





# Data Analysis



Write the total number for each color in the total column. Use the data (numbers) in the total column to write the fraction for each color. Use a calculator to find out the decimals and percentages for each color of m&m's®.

Use the decimal equation below to fill in the decimal column . Then use the percentage equation to calculate the percentages. Fill in the table below.

| Color | Total | Fractions | Decimals | Percentage |
|-------|-------|-----------|----------|------------|
|       |       |           |          |            |
|       |       |           |          |            |
|       |       |           |          |            |
|       |       |           |          |            |
|       |       |           |          |            |
|       |       |           |          |            |
|       |       |           |          |            |
| Total |       |           |          |            |

## Equations:

**Decimals** = number of m&m's® by color/total number of m&m's® in the bag

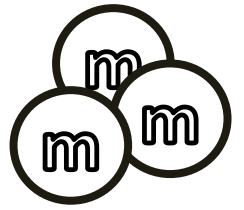
**Percentage** = decimals\*100

Name \_\_\_\_\_

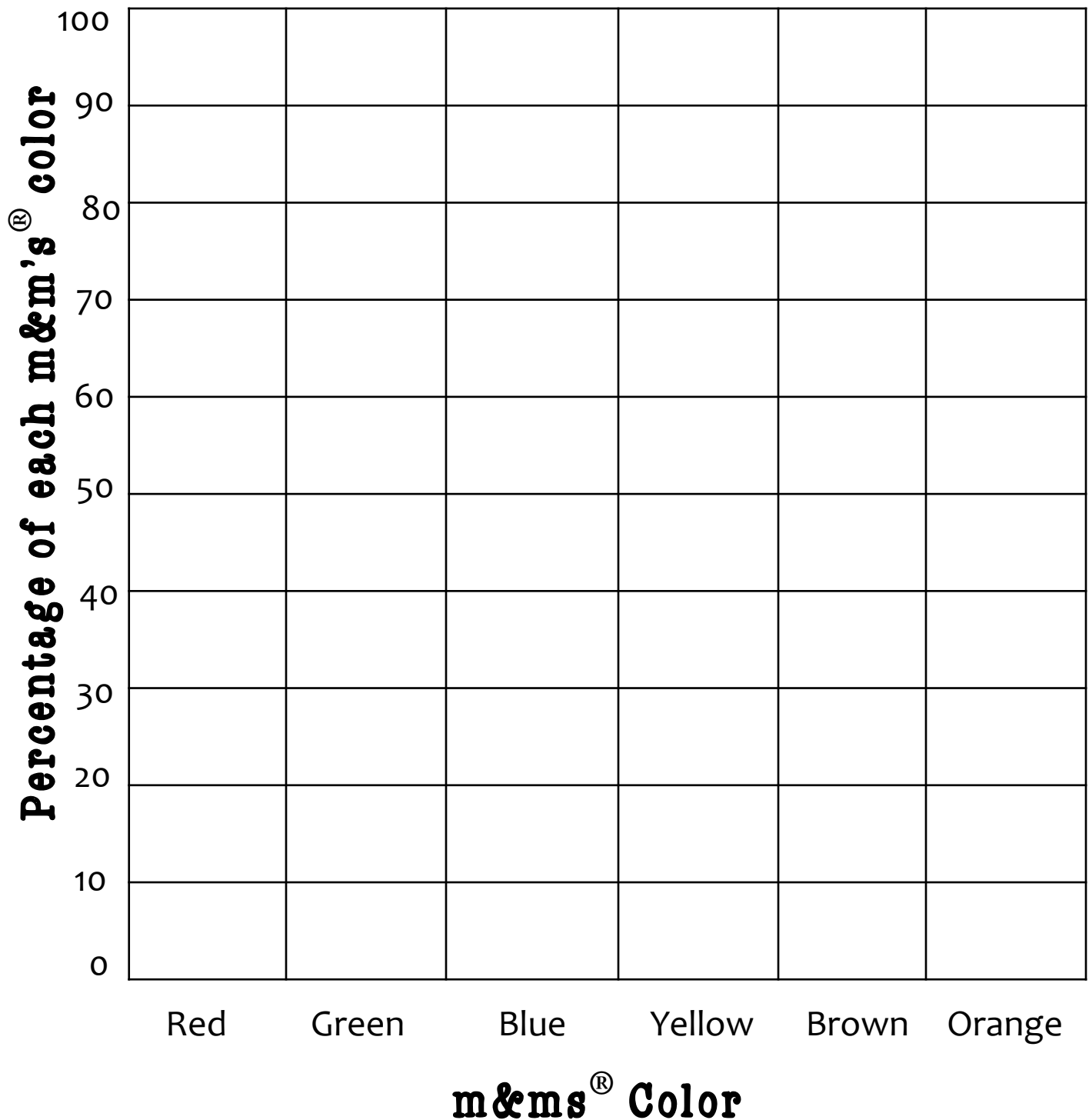
Date \_\_\_\_\_



# Percentages Bar Graph

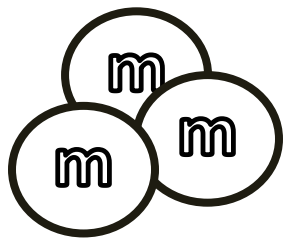


Create a **bar** graph illustrating the percentage (%) of m&m's® for each color.  
Use the crayon or color pencil that matches the color of the m&m's®.



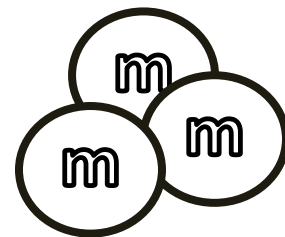
Name \_\_\_\_\_

Date \_\_\_\_\_



Part I

# Results & Conclusions



How many m&m's® did your bag contain? \_\_\_\_\_

Were the colors in your bag of m&m's® equal? \_\_\_\_\_

## Based on your bar graphs...

Which color had the highest number? \_\_\_\_\_

Which color had the second to highest number? \_\_\_\_\_

Which color had the lowest percentage? \_\_\_\_\_

Which color had the second to lowest percentage? \_\_\_\_\_

Are the patterns the two bar graphs the **same** or **different**? Explain your answer.

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Was your prediction correct? Circle **Yes** or **No**. Explain your answer.

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What can you conclude about total and percentage of each color in a bag of m&m's®?

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## SELF REFLECTION

What did you learn from participating in the decimals & percentage m&m's® activity?

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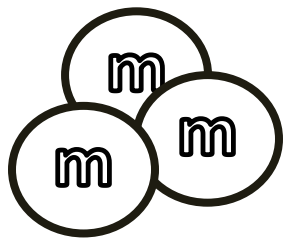
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Name \_\_\_\_\_

Date \_\_\_\_\_





# Group Data Collection



After completing part I, discuss your data with five of your friends and record their percentage data for each color in the table below. Use the data table below to calculate the basic statistics for each color of m&ms® in your bag and your friends.

| <b>Bags of m&amp;ms</b> | <b>Red</b> | <b>Green</b> | <b>Blue</b> | <b>Yellow</b> | <b>Brown</b> | <b>Orange</b> |
|-------------------------|------------|--------------|-------------|---------------|--------------|---------------|
| Your Data               |            |              |             |               |              |               |
| Friend 1                |            |              |             |               |              |               |
| Friend 2                |            |              |             |               |              |               |
| Friend 3                |            |              |             |               |              |               |
| Friend 4                |            |              |             |               |              |               |
| Friend 5                |            |              |             |               |              |               |
| Sample Size             |            |              |             |               |              |               |
| Average                 |            |              |             |               |              |               |
| Median                  |            |              |             |               |              |               |
| Mode                    |            |              |             |               |              |               |

## Equations:

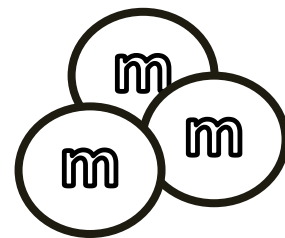
**Average (%)** = Total Percentage of m&ms® Color/ total number of bags of m&ms®

Name \_\_\_\_\_

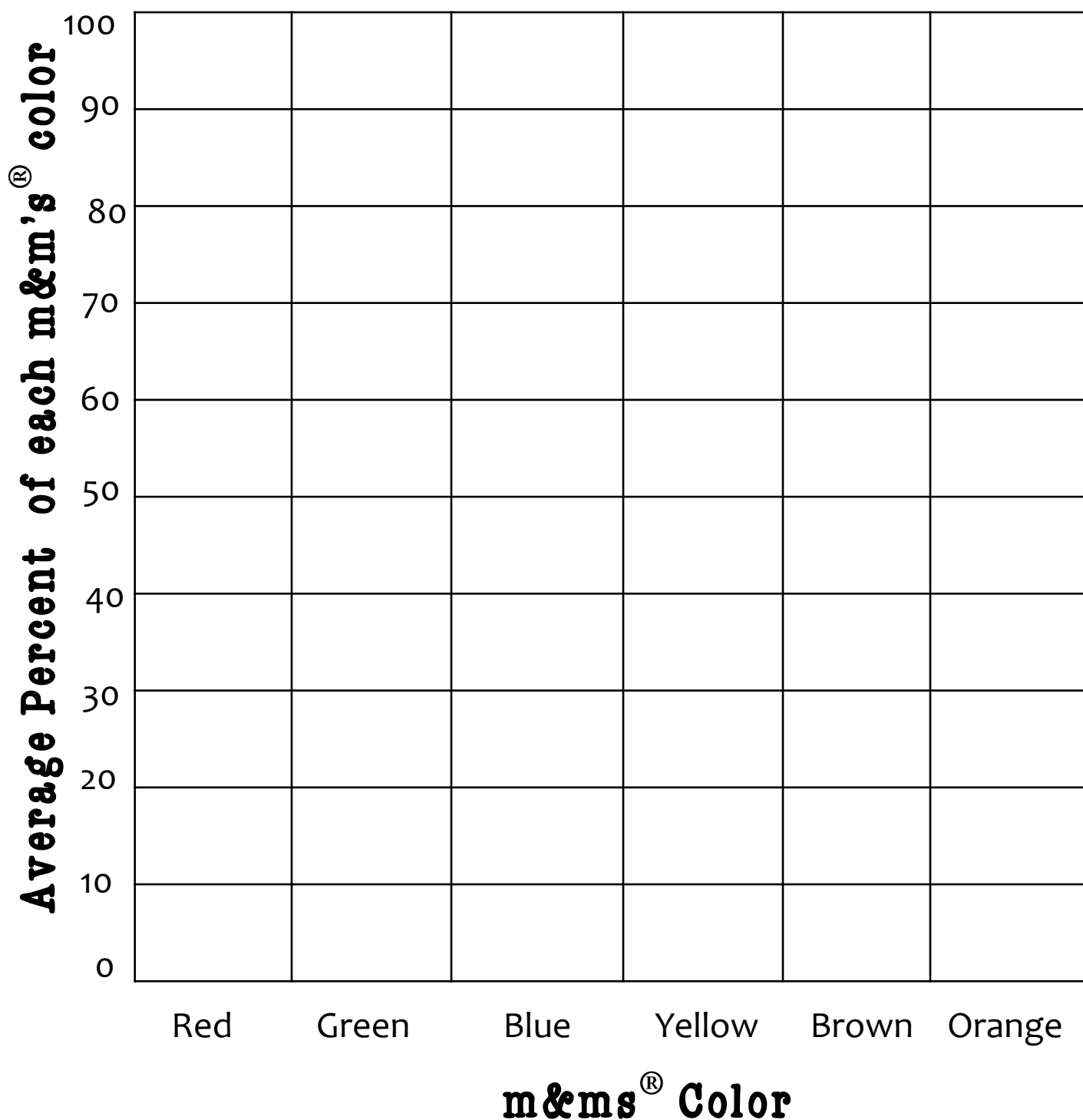
Date \_\_\_\_\_



# Group Percentages Bar Graph

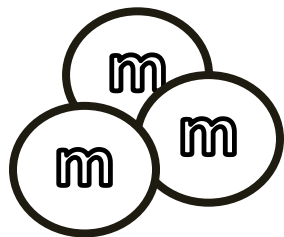


Create a **bar** graph illustrating the average percent (%) of m&m's® for each color in several bags of m&m's®. Use the crayon or color pencil that matches the m&m's® color.

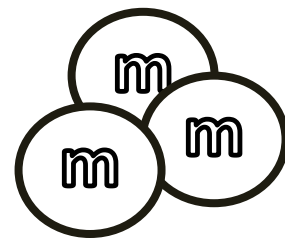


Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II



# Results & Conclusions

Were the number of m&ms® the same for each bag? Circle **YES** or **NO**

Were the percentages of each color of m&ms® the same for each bag? Circle **YES** or **NO**

On average, which color had the highest number? \_\_\_\_\_

On average, which color had the second to highest number? \_\_\_\_\_

On average, which color had the lowest percentage? \_\_\_\_\_

On average, which color had the second to lowest percentage? \_\_\_\_\_

Are your individual and group bar graphs the **identical** or **different**? Explain your answer.

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Was your hypothesis correct? Circle **Yes** or **No**. Explain your answer.

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What can you conclude about sample variability & percentage of each color per bag of m&m's?

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## SELF REFLECTION

What did you learn from participating in the basic statistics m&m's® activity?

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Name \_\_\_\_\_

Date \_\_\_\_\_



Thank you for choosing FEWLM to teach scientific inquiry!



We hope that this workbook provided an enjoyable learning experience for your aspiring scientist. We appreciate teachers, STEM outreach instructors, parents and grandparents for selecting FEWLM to teach scientific inquiry.

All rights are reserved to the authors of this workbook. Please do not copy, reproduce or redistribute this FEWLM workbook on the internet. This activity is intended for a single classroom use only. Posting pictures of elementary and middle school age youth using FEWLM on social media website is allowed with proper credit. We encourage everyone to download your own free copy of FEWLM at the QUBES hub resources using this link: <https://qubeshub.org/publications/2287/1>



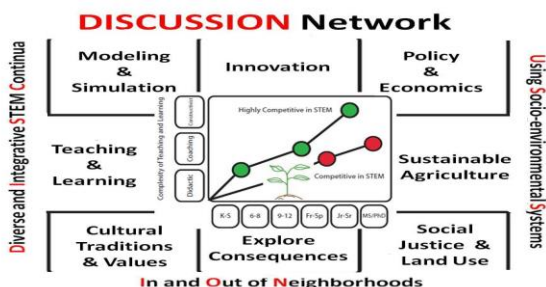
Sponsored by NSF Award Numbers 1649255 and 1649263



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<https://www.teacherspayteachers.com/Store/A-Sketchy-Guy>



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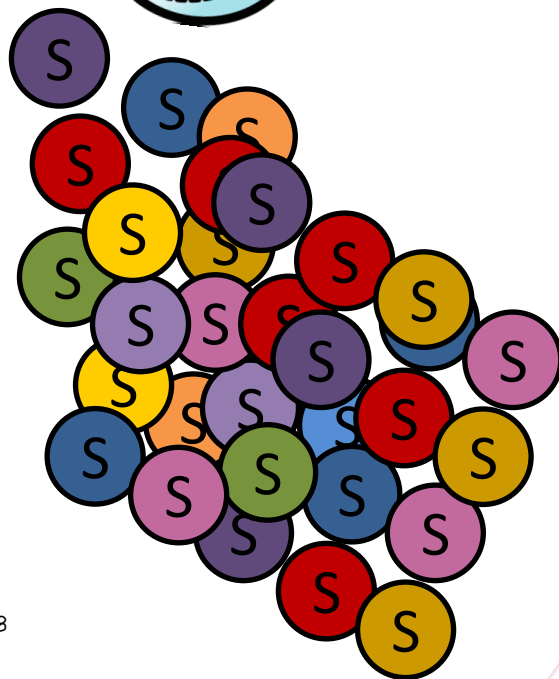


<https://www.teacherspayteachers.com/Store/Teachesthirdingeorgia>



FOOD, ENERGY, AND WATER LEARNING  
MODULE (FEWLM)

# Exploring Scientific Inquiry & Mathematical Thinking With Skittles Workbook



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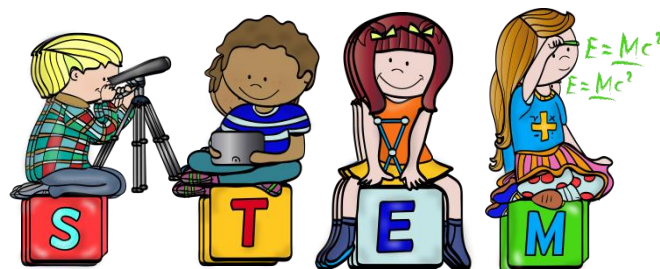
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# Exploring Scientific Inquiry & Mathematical Thinking With Skittles Workbook



## SUMMARY

The “Exploring Scientific Inquiry & Mathematical Thinking With Skittles” is a hands-on guide inquiry activity that allows students to engage in mathematical thinking while introducing the importance of data collection, sample replication and sample variability and enjoying an edible treat. Students will act like a scientist by recording, graphing, analyzing and interpreting data gathered from tallying and sorting skittles to determine if the percentage of colors in each bag are identical. Students also learn how to create bar graphs, which is a valuable tool for interpreting and communicating results and promotes mathematical thinking. Using skittles has been an effective technique for teaching the scientific inquiry and data analysis to elementary and middle school age youth. The mathematical, analytical and graphing skills learned during this activity will be practiced and applied while completing the other FEWLM activities. **Part I** focuses on using skittles to learn how to tally and sort into categories and calculate fractions, decimals and percentages, which aligns with the 3rd-5th graders next generation science standards (NGSS) . **Part II**, a continuation of part I, includes basic statistics (6th- 8th grade level NGSS) and the application of a statistical software program such as Microsoft Excel. Students work as a team of scientists and combine their individual data in a spreadsheet to calculate average, median, mode. Students evaluate differences in percentage of colors in their individual bag and a group bags to discover the importance of sample replication and variability. Students introduced to scientific inquiry learn to critically think through a research problem and mimic scientists. Worksheets too advance for a specific grade level can be removed prior to assembling each workbook.

## QUICK LOOK

**Grade Level:** 3<sup>rd</sup> – 8<sup>th</sup> grade

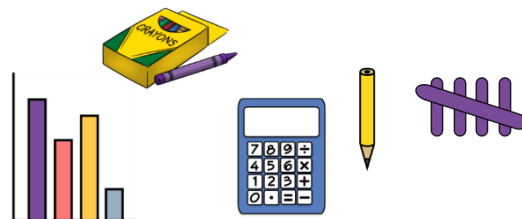
**Subjects:** Science, Math, Graphing and Writing

**Preparation:** Less than 30 minutes

**Time Required:** 45 to 120 minutes, depending on the grade level

**Group Size :** Should not exceed 5 students

**Estimated Total Cost:** The total cost to implement the this activity will be \$3.00 cheaper if the 24 count Crayola crayons are purchased for \$0.50 each during the “back to school” sale from Walmart, Target or Staples.



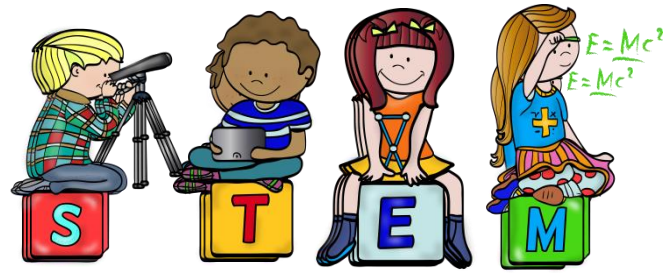
**FOCUS QUESTION:** Does a bag of Skittles® have the same percentage of each flavor?

**TABLE 1. SUPPLIES NEEDED TO BE PURCHASED** (\*supplies can be used in year 2 or other FEWLM activities)

| Item  | Recommended Vendor                           | Number of Item | Total Price  |
|---|--|----------------|--|
| Skittles Original Candy (2.17 oz., 36 ct.)                    | Whole Sale Club                              | 1 box          | \$30.00  |
| Skittles Original Fun Pack (0.65 oz., 21 ct.)                 | Walmart                                      | 1 bag          | \$2.00   |
| Crayola 24 count Crayons*<br><i>Back to School Sale Price</i> | Dollar Tree<br><i>Walmart/Target/Staples</i> | 6 boxes        | \$6.00<br><i>\$3.00</i>                            |
| Calculators*  | Dollar Tree                                  | 6 bag          | \$6.00   |
| Yellow Wooden #2 Pencils, 24-ct.*                             | Dollar Tree                                  | 2 boxes        | \$4.00   |
| <b>Total</b>  |  |                | \$46.00/ <i>\$43.00</i><br>\$18.00/ <i>\$15.00</i> |



# Exploring Scientific Inquiry & Mathematical Thinking With Skittles Workbook



## TEACHER PREPARATION AND INSTRUCTIONS

*Prior to beginning this activity:*

1. Teachers should purchase a box 48 count of m&m's® from a whole sale store, because each student will be given their own single bag of Skittles original candy (2.17 oz., 36 ct.) to conduct the experiment.
2. A workbook should be printed and assembled for each student. Print only the pages appropriate for their grade level (i.e. part I – elementary students or parts I and II – middle school students)
3. Gather or purchase color pencils, crayons, pencils & calculators
4. The instructor should lead a discussion about the importance of the scientific process and the importance of sample size, collection, replication, analysis and interpretation.

*After completing the activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity. Their reflections should be written at the end of the workbook and expressed orally during the class discussion.
2. Teachers should lead a class discussion revisiting the scientific process, the connection between science and math for conducting scientific research and how science is applied to our everyday decisions.
3. Teachers can explain how the mathematical skills learned during this activity can be applied to other research projects such as the next activity – seed germination.

## LEARNING OBJECTIVES *Based on Next Generation Science Standards\**

### **3<sup>rd</sup>-5<sup>th</sup> grade (Part I. Worksheet pages 1-7)**

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2), (4-ESS2-1), (4-PS3-2)
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)
- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2), (3-LS4-2)
- Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships. (3-ESS2-1)
- Most scientists and engineers work in teams. (4-PS3-4)
- Science affects everyday life. (3-ESS3-1), (4-PS3-4)

### **6<sup>rd</sup>-8<sup>th</sup> grade (Part II. Worksheet pages 1-13)**

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)

\*NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Name \_\_\_\_\_

Grade Level \_\_\_\_\_



# Exploring Scientific Inquiry & Mathematical Thinking With Skittles

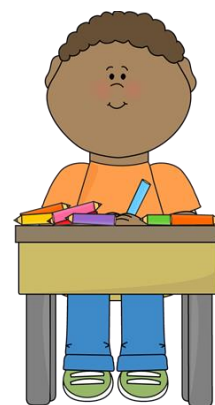


| Criterion                                 | Exemplary = 4  | Proficient = 3   | Approaching Proficiency = 2   | Non-Proficient = 1                                | Score      |
|---|--|--|---|---|------------|
| <b>APPEARANCE</b>                         | Neat and easy to read  | Somewhat neat and easy to read   | Neat and difficult to read  | Not neat and very difficult to read               |            |
| <b>HYPOTHESIS</b>                         | Hypothesis stated and explained well   | Hypothesis stated and vaguely explained  | Hypothesis stated and inadequately explained  | Hypothesis stated but not explained               |            |
| <b>DATA COLLECTION</b>                    | Collected all data correctly   | Collected most data correctly  | Collected some data correctly   | Collected few data correctly                      |            |
| <b>DATA ANALYSIS</b>                      | Calculated all data correctly  | Calculated most data correctly   | Calculated some data correctly  | Calculated few data correctly                     |            |
| <b>GRAPHS</b>                             | Correctly matches all the data analysis tables   | Correctly matches most of the data analysis  | Correctly matches some of the data analysis   | Correctly matches few data correctly              |            |
| <b>USE OF COLOR IN GRAPHS</b>             | Attractive with appropriate use of all color   | Attractive with appropriate use of most of the colors  | Attractive with appropriate use of some of the colors   | Attractive with appropriate use of a few colors   |            |
| <b>RESULTS &amp; GRAPH INTERPRETATION</b> | Answered all questions correctly   | Answered most of questions correctly   | Answered some of questions correctly  | Answered few questions correctly                  |            |
| <b>CONCLUSIONS</b>                        | Hypothesis accepted or rejected and clearly explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but vaguely explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but inadequately explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but not explained |            |
| <b>Additional Comments:</b>               |  |  |   | <b>TOTAL POINTS</b>                               | <b>/32</b> |

## OVERALL ACTIVITY PERFORMANCE

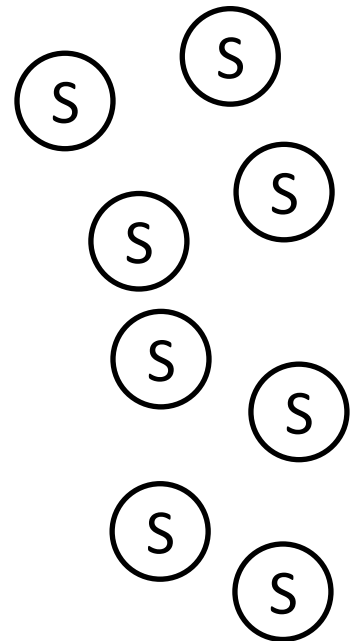
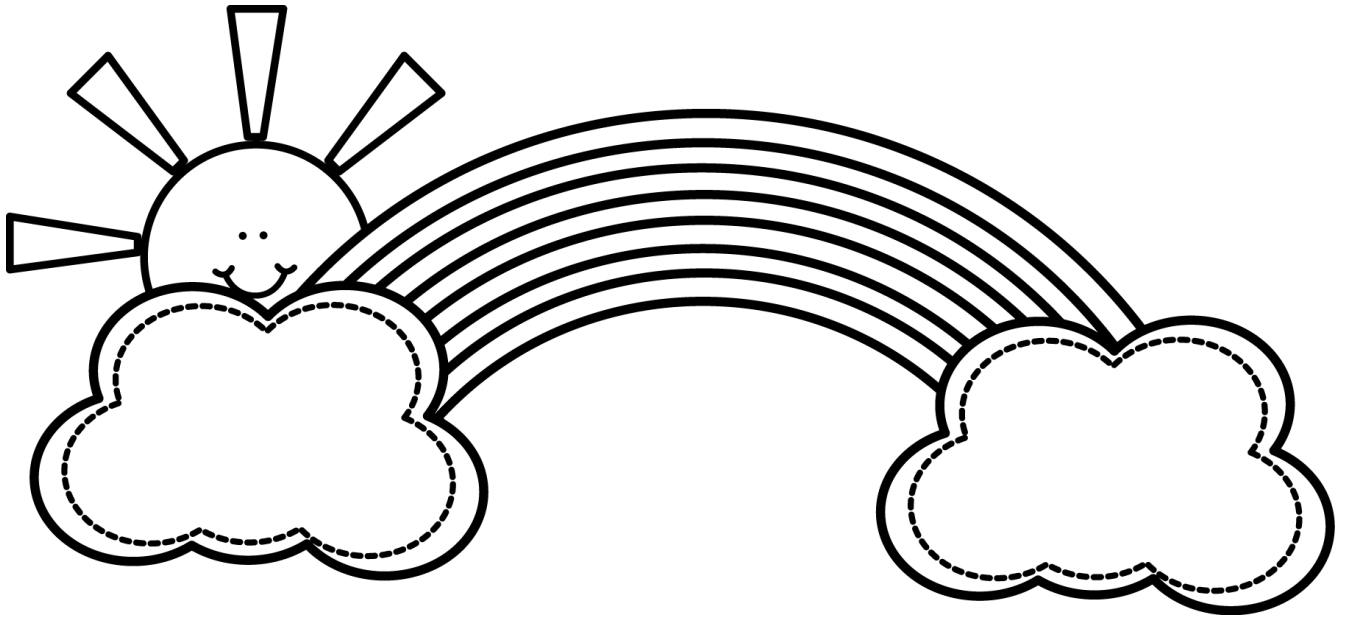
*Circle the Description that matches each student's score*

| Score      | Descriptive             |
|------------|-------------------------|
| 32-29      | Exemplary               |
| 28-26      | Proficient              |
| 25-23      | Approaching Proficiency |
| 22 or less | Non-Proficient          |



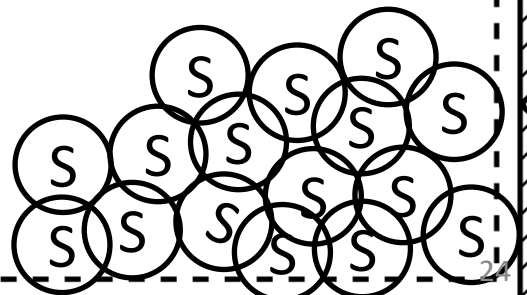
Food, Energy, and Water Learning Module (FEWLM)

# Exploring Scientific Inquiry & Mathematical Thinking With Skittles

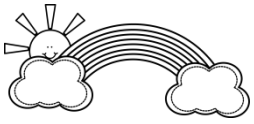


This workbook belongs to:

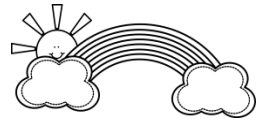
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# Background Information & Experimental Design



Do you enjoy eating Skittles? Circle **Yes** or **No**.

Which type of Skittles will be used in this experiment? \_\_\_\_\_

What is the size of your bag of Skittles? \_\_\_\_\_

Look on the back of your bag of skittles and list the different flavors in your bag.

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Do you expect each bag of Skittles® to have the same amount of each flavor of candies? Circle **Yes** or **No**. Explain Why?

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Which flavor to you think is most common in each bag of Skittles? Why?

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Research Problem

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List of Materials

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Hypothesis

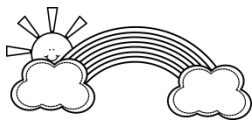
I hypothesis that \_\_\_\_\_ is the most popular flavor in my bag of Skittles because \_\_\_\_\_

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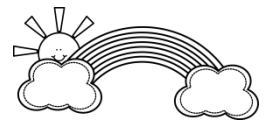
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Name \_\_\_\_\_

Date \_\_\_\_\_



# Data Collection

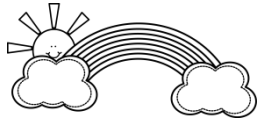


Open your bag of Skittles and empty the candies on the bottom of this page.  
Sort, tally and count the number of each flavor of Skittles.  
Record your data in the table below.

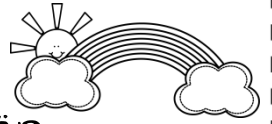
| Flavors | Tally | Total |
|---------|-------|-------|
|         |       |       |
|         |       |       |
|         |       |       |
|         |       |       |
|         |       |       |
|         |       |       |
|         |       |       |
|         |       |       |
| Total   |       |       |

Name \_\_\_\_\_

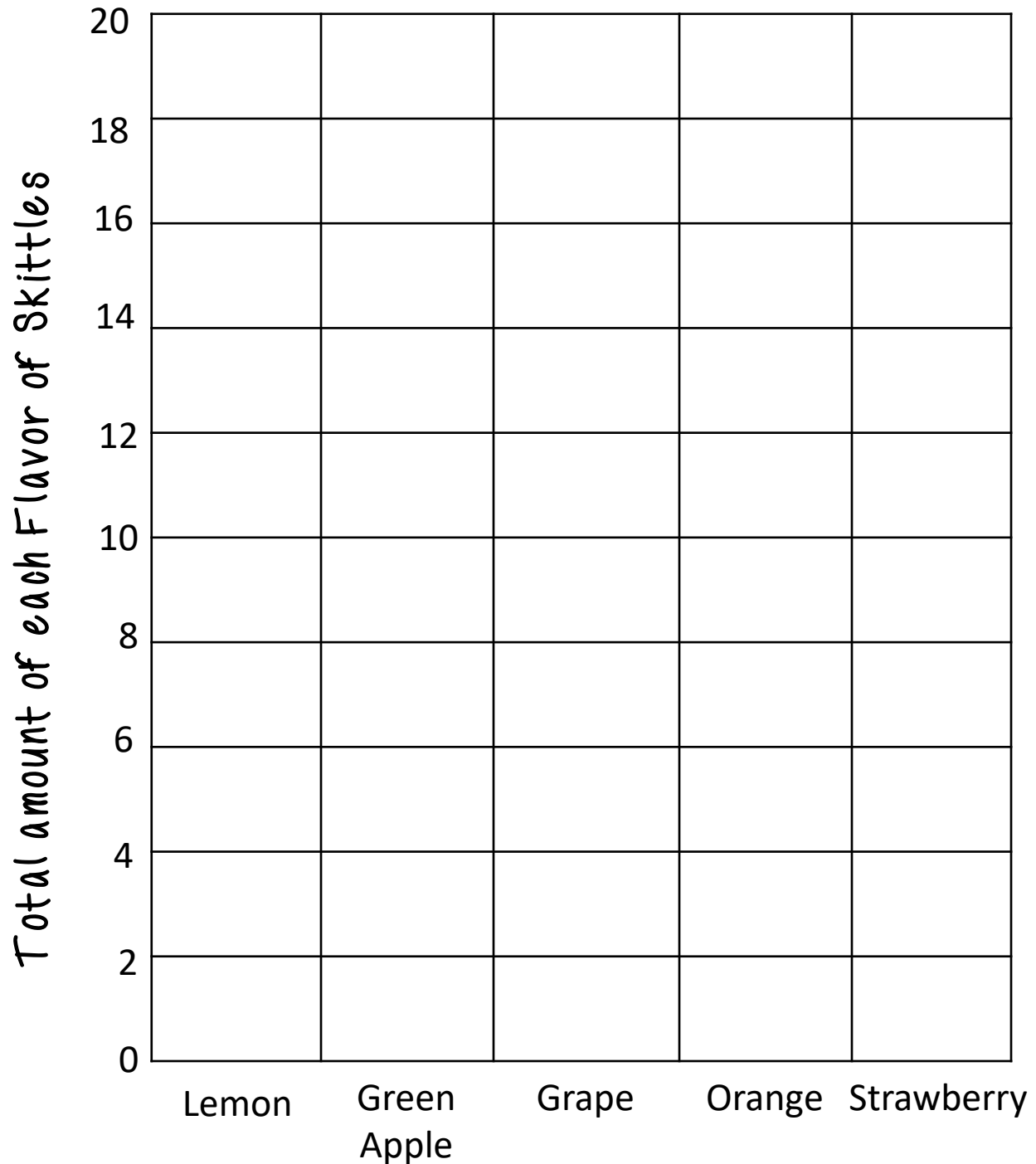
Date \_\_\_\_\_

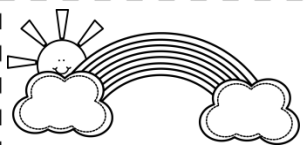


# Total Amount of Each Flavor in a Bag of Skittles

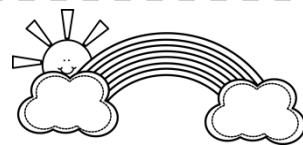


Create a bar graph illustrating the number of each flavor in a bag of skittles.  
Use the crayon or color pencil that matches the flavor of the skittles.





# Data Calculations and Analysis



Write the total number for each flavor in the total column. Use the data (numbers) in the total column to write the fraction for each flavor. Use a calculator to find out the decimals and percentages for each color of Skittles.

Use the decimal equation below to fill in the decimal column. Then use the percentage equation to calculate the percentages. Fill in the table below.

| Flavor | Total | Fractions | Decimals | Percentage |
|--------|-------|-----------|----------|------------|
|        |       |           |          |            |
|        |       |           |          |            |
|        |       |           |          |            |
|        |       |           |          |            |
|        |       |           |          |            |
|        |       |           |          |            |
|        |       |           |          |            |
| Total  |       |           |          |            |

## Equations:

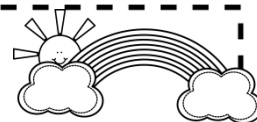
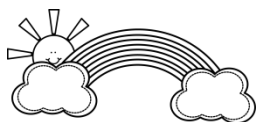
**Decimals** = number of Skittles by color/total number of Skittles in the bag

**Percentage** = decimals\*100

Name \_\_\_\_\_

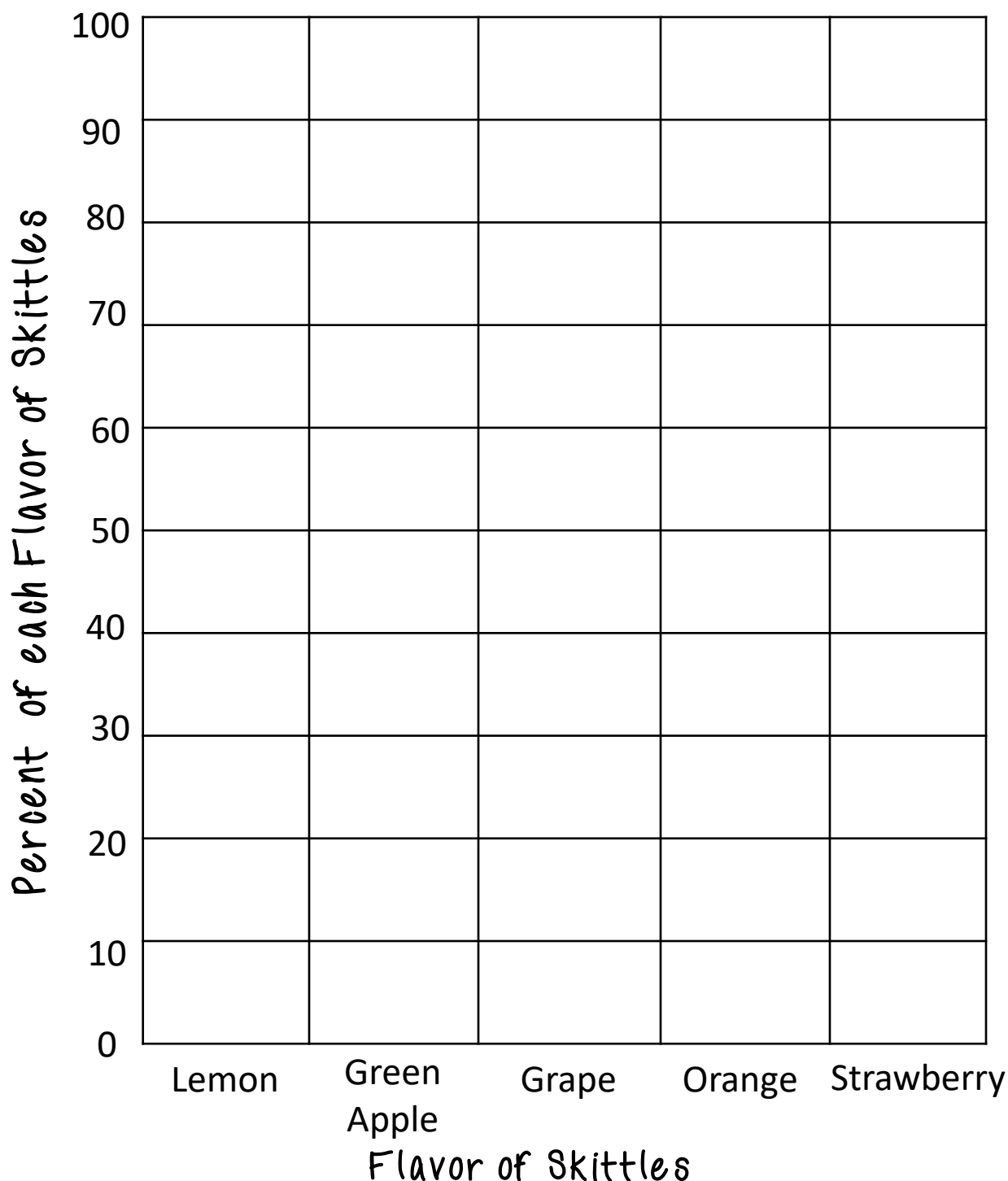
Date \_\_\_\_\_

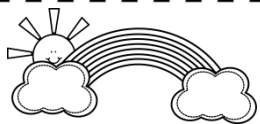




# Percentages of Each of Flavor of Skittles in YOUR Bag

Create a bar graph illustrating the percent (%) of each flavor in your bag of Skittles. Use the crayon or color pencil that matches the Skittles flavor.





Part I



# Results & Conclusions

How many skittles did your bag contain? \_\_\_\_\_

Were the flavors in your bag of skittles equal? YES or No \_\_\_\_\_

**Based on your bar graphs...**

Which flavor was most common (highest number)? \_\_\_\_\_

Which flavor was the least common (lowest number)? \_\_\_\_\_

Which color had the second highest percentage? \_\_\_\_\_

Which color had the second to lowest percentage? \_\_\_\_\_

Are the patterns the two bar graphs the **same** or **different**? Explain your answer.

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Was your hypothesis correct? Circle Yes or No. Explain your answer.

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What can you conclude about percentage of each flavor in a bag of Skittles?

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## SELF REFLECTION

What did you learn from participating in this Skittles activity?

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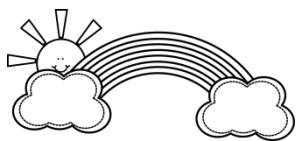
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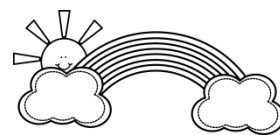
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Name \_\_\_\_\_

Date \_\_\_\_\_



## Group (Replicate) Data Collection



After completing part 1, discuss your data with five of your friends and record their percentage data for each flavor in the table below.

Use the data table below to calculate the basic statistics for each flavor of Skittles in your bag and your friends' bag.

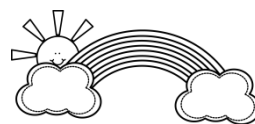
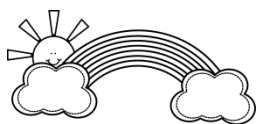
| Group Data  | Lemon | Green Apple | Grape | Orange | Strawberry |
|-------------|-------|-------------|-------|--------|------------|
| Your Data   |       |             |       |        |            |
| Friend 1    |       |             |       |        |            |
| Friend 2    |       |             |       |        |            |
| Friend 3    |       |             |       |        |            |
| Friend 4    |       |             |       |        |            |
| Friend 5    |       |             |       |        |            |
| Sample Size |       |             |       |        |            |
| Average     |       |             |       |        |            |
| Median      |       |             |       |        |            |
| Mode        |       |             |       |        |            |

### Equations:

**Average (%)** = Total Percentage of Skittles Color / total number of bags of Skittles

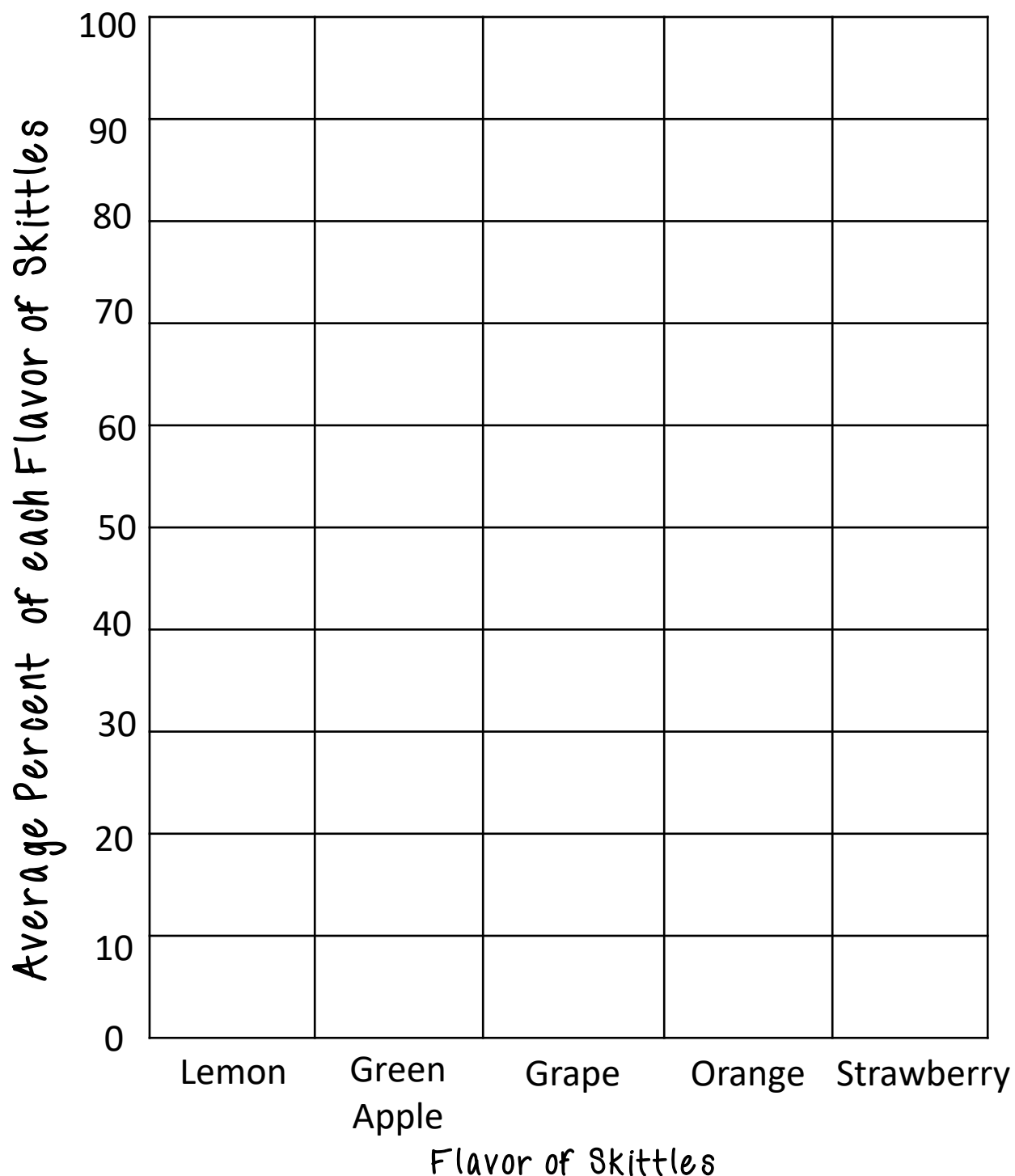
Name \_\_\_\_\_

Date \_\_\_\_\_

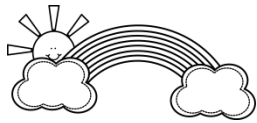


# Percentage of Each Flavor of Skittles in Multiple Bags

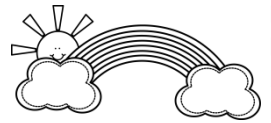
Create a bar graph illustrating the average percent (%) of flavor in multiple bags of skittles. Use the crayon or color pencil that matches the Skittles flavor.







Part II



## Results & Conclusions

Were the number of Skittles the same for each bag? Circle **YES** or **NO**

Were the percentages of each color of Skittles the same for each bag?  
Circle **YES** or **NO**

On average, which color was the most common? \_\_\_\_\_

On average, which color had the second to highest number? \_\_\_\_\_

On average, which color had the lowest percentage? \_\_\_\_\_

On average, which color had the second to lowest percentage? \_\_\_\_\_

Are your individual and group bar graphs the **identical** or **different**? Explain your answer.

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Was your original hypothesis correct? Circle **Yes** or **No**. Explain your answer.

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What can you conclude about variability of the percentage of each flavor in bag of Skittles?

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### SELF REFLECTION

What did you learn from participating in this Skittles activity?

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Name \_\_\_\_\_

Date \_\_\_\_\_

Thank you for choosing FEWLM to teach scientific inquiry! 😊

We hope that this workbook provided an enjoyable learning experience for your aspiring scientist. We appreciate teachers, STEM outreach instructors, parents and grandparents for selecting FEWLM to teach scientific inquiry.

All rights are reserved to the authors of this workbook. Please do not copy, reproduce or redistribute this FEWLM workbook on the internet. This activity is intended for a single classroom use only. Posting pictures of elementary and middle school age youth using FEWLM on social media website is allowed with proper credit. We encourage everyone to download your own free copy of FEWLM at the QUBES hub resources using this link: <https://qubeshub.org/publications/2287/1>



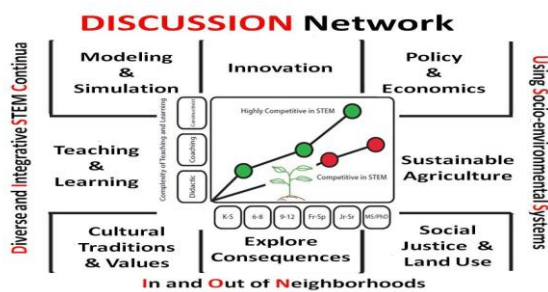
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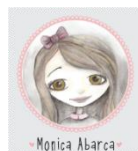
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FOOD, ENERGY, AND WATER  
LEARNING MODULE (FEWLM)

# My Sprouting Bean Seeds Scientific Workbook



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# My Sprouting Bean Seeds

## Scientific Workbook Lesson Plan



### SUMMARY

The “**My Sprouting Bean Seed**” activity is an adaptation of the “Pocket Seed Viewer” experiment” provided by ask a biologist (<https://askabiologist.asu.edu/content/pocket-seed-viewer>) that is designed to allow students to continue applying scientific inquiry while learning the importance of beans and seed germination. Part I of this activity is designed for 3rd- 8th graders. Students will act like a scientist by observing and comparing the root and shoot growth rate of black, pinto and lima beans in a pocket seed viewer over a 7-day period. The data collected will illustrate using a line graph, analyze and interpret to test a hypothesis and formulate a conclusion. At the end of part I, the instructor can lead a class discussion about their results and the importance of seed germination. **MIDDLE SCHOOL STUDENTS:** Part II is a continuation of the activity for 6th-8th graders only. Students work as a team of scientists and combine their individual data in an excel spreadsheet to calculate average, median, mode for the root and shoot growth for each bean. Each group of students create line graphs to illustrate the average root and shoot growth rate over the seven day period for each bean. Students evaluate the growth rate of their individual pocket seed viewer and the growth group bags to discover the importance of sample replication and variability. Worksheets too advance for a specific grade level can be removed prior to assembling each workbook.

### QUICK LOOK

**Grade Level:** 3<sup>rd</sup> – 8<sup>th</sup> grade

**Subjects:** Science, Math, Writing and Statistics

**Preparation:** Seed Soaking 12 to 24 hours; other preparation is less than 30 minutes

**Duration:** 7 days

**Group Size :** Should not exceed 5 students

**Initial Estimated Total Cost:** US \$26.00 for 30 students - based recommended vendors

**Year 2 Estimated Cost:** US \$8.00 for 30 students



**FOCUS QUESTION:** Which bean will have the longest shoot and root growth over a 7-day growing period?

**TABLE 1. SUPPLIES NEEDED TO BE PURCHASED** (\*supplies can be used in year 2 experiments or other FEWLM activities/ Items highlighted in green represent the “back to school” price )

| Item  | Recommended Vendor                           | Number of Item | Total Price             |
|---|--|----------------|-------------------------|
| Bag of Black Beans (16oz)*  | Walmart                                      | 1 bag          | \$2.00                  |
| Bag of Lima Beans (16oz)*   | Walmart                                      | 1 bag          | \$2.00                  |
| Bag of Pinto Beans (16oz)*  | Walmart                                      | 1 bag          | \$2.00                  |
| Light Blue Luncheon Napkins – 20 per pack   | Dollar Tree                                  | 4 packs        | \$4.00                  |
| Quart –Sized Storage Bags   | Dollar Tree                                  | 2 boxes        | \$2.00                  |
| Jot 12 inch Translucent Plastic Rulers 3-ct pack*                                   | Dollar Tree                                  | 5 packs        | \$5.00                  |
| Teaching Tree Plastic Test Tubes with Holders<br>Set 2 count pack*                  | Dollar Tree                                  | 16 sets        | \$8.00                  |
| Sure fresh Plastic Dry-Food storage containers<br>with lids 5 piece set (16.6 oz.)* | Dollar Tree                                  | 1 set          | \$1.00                  |
| Crayola Short Colored Pencils, 8-ct.*<br><i>Crayola Colored Pencils, 12-ct.*</i>    | Dollar Tree<br><i>Walmart/Target/Staples</i> | 6 boxes        | \$6.00<br><i>\$6.00</i> |
| <b>TOTAL</b>  |  |                | <b>\$26.00</b>          |



# My Sprouting Bean Seeds Scientific Workbook Lesson Plan



## TEACHER PREPARATION AND INSTRUCTIONS

*Prior to beginning this activity:*

1. Teachers should purchase the black, lima and pinto beans from the local grocery store and gather or purchase the other required supplies.
2. Place at least 100 of each type of beans in a separate plastic container. Add enough tap or deionized water to each container to cover the top of the beans. Allow the beans to soak in the water for 12 to 24 hours. *Soaking the beans will activate the enzymes within the seeds to jumpstart germination process prior to placing them in the plastic bags.*
3. A workbook should be printed and assembled for each student. Print only the pages appropriate for their grade level (i.e. part I – elementary students or parts I and II – middle school students)
4. The teacher should lead a discussion about the history of beans in past cultures, importance of biodiversity, the connection between seed germination and food security while revisiting the scientific process.
5. **OPTIONAL:** Print the “**Little Sprout House**” Worksheet for students to color and cut out. After student assemble their sprout houses (seeds in bags), they can tape their cut out sprout house to the front of the bag. The “**Little Sprout House**” can be found here: <https://www.teacherspayteachers.com/Product/My-Little-Sprout-House-Printable-1218023>

*After completing the activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity.
2. Teachers should lead a class discussion focusing the on variability of germination rates for each type of seed, the need for planting several seeds to ensure plant growth, the importance for biodiversity as it relates to food options and how science is applied to our everyday decisions.
3. Teachers can explain changes in the environment can impact our food supply, which can be a lead into discussing the next activity – the impact of pH difference on seed germination.

## LEARNING OBJECTIVES Based on Next Generation Science Standards\*

### 3<sup>rd</sup>-5<sup>th</sup> grade (Part I)

- Plants acquire their material for growth chiefly from air and water. (5-LS1-1)
- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. (4-LS1-1)
- The food of almost any kind of animal can be traced back to plants. (5-LS2-1)
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2), (4-ESS2-1), (4-PS3-2)
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)
- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2), (3-LS4-2)
- Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships. (3-ESS2-1)
- Most scientists and engineers work in teams. (4-PS3-4)
- Science affects everyday life. (3-ESS3-1), (4-PS3-4)
- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Science findings are limited to questions that can be answered with empirical evidence. (5-ESS3-1)

### 6<sup>th</sup>-8<sup>th</sup> grade (Part I & II)

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)
- Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2)
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)
- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena. (MS-LS2-2)

\*NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

# My Sprouting Bean Seeds

## Scientific Workbook Lesson Plan



### BACKGROUND INFORMATION

Seeds are baby plants with stored food and seed leaves inside a thick hard protective coat. Seeds are normally dry and dormant “sleeping.” When favorable moisture, oxygen and temperature conditions occur, germination begins and the seed “wakes up.” The ideal conditions for seed germination varies based on the plant. Some seeds germinate in the spring when the temperatures are cooler while other seeds germinate in warmer temperatures during the summer. During the germination process, a dry seed re-hydrates by soaking up water and the seed coat cracks exposes the plant embryo to oxygen in the air. The roots begin to emerge from the seed coat followed by the seed leaves (shoots). The stored food in the seed breaks down to usable energy for the growing plant until photosynthesis occurs.

Early Native American cultures were the first to grow a variety of beans throughout North, Central and South America<sup>1</sup>. Beans are rich in nutrients, low in calories, and an inexpensive protein substitute for fish, chicken, beef and pork<sup>2,3</sup>. Black, pinto and lima beans were selected for this activity because they are native to the Americans. Black and pinto beans are indigenous to Peru. Black beans are common in Latin American cuisine<sup>2</sup> while pinto beans are more popular in Mexican cuisine. Lima beans originated in Guatemala<sup>4</sup>; however they are popular in the diets of many cultures around the world.

Eating beans on a regular basis potentially lowers the risk of cancer, heart disease, diabetes, and obesity while promoting long-term health<sup>2</sup>. Despite the health benefits, the consumption of beans has declined substantially in recent years as a result of people embracing non-conservative diets<sup>3</sup>. Now, about 8% of the overall United States’ population report eating beans on a daily basis. When comparing the ethnic groups within the United States, Hispanics eat beans more frequently<sup>5</sup>. If people decide to change their diets and eat beans instead of beef, greenhouse gas emissions are expected to decline significantly<sup>6</sup> and other environmental problems related to intensive agriculture practices<sup>7</sup>.

Now, let’s begin this activity by gathering more background information about black, pinto and lima beans and establish an experimental design to conduct our seed germination study. The **“My Sprouting Bean Seeds Scientific Workbook”** will be a fun and exciting activity for a young scientist in training.

### REFERENCES

1. Park S, Hongu N, Daily JW. 2016. Native American foods: History, culture, and influence on modern diets. *Journal of Ethnic Foods* 3:171-177.
2. Garden-Robinson J, McNeal K. 2013. All about beans: nutrition, health benefits, preparation and use in menus. The Bean Institute, North Dakota State University Extension Service, Service NDSUE, Fargo, ND.
3. Messina V. 2014. Nutritional and health benefits of dried beans. *American Journal of Clinical Nutrition* 100 437S-442S.
4. Mackie WW. 1943. Origin, dispersal, and variability of the lima bean, *Phaseolus lunatus*. *Hilgardia* 15:1-29.
5. Mitchell DC, Lawrence FR, Hartman TJ, Curran JM. 2009. Consumption of Dry Beans, Peas, and Lentils Could Improve Diet Quality in the US Population. *Journal of the American Dietetic Association* 109:909-913.
6. Harwatt H, Sabate J, Eshel G, Soret S, Ripple W. 2017. Substituting beans for beef as a contribution toward US climate change targets. *Climate Change* 143:261.
7. Schneider C. 2014. The cancer prevention properties of beans, vol 59, p 4-9. CSA-SSSA-ASA, Madison, WI.
8. Dr. Biology. 2009 October 07. "Dr. Biology's Virtual Pocket Seed Experiment." ASU - Ask A Biologist. Retrieved December 16, 2017 from <https://askabiologist.asu.edu/content/pocket-seed-viewer>
9. Hoefnagels, Mariëlle. 2019. *Biology: The Essentials*. McGraw Hill. New York, NY. p621.



# My Sprouting Bean Seed Scientific Workbook Grading Rubric



| Criterion                                 | Exemplary = 4  | Proficient = 3   | Approaching Proficiency = 2   | Non-Proficient = 1                                | Score      |
|---|--|--|---|---|------------|
| <b>APPEARANCE</b>                         | Neat and easy to read  | Somewhat neat and easy to read   | Neat and difficult to read  | Not neat and very difficult to read               |            |
| <b>HYPOTHESIS</b>                         | Hypothesis stated and explained well   | Hypothesis stated and vaguely explained  | Hypothesis stated and inadequately explained  | Hypothesis stated but not explained               |            |
| <b>DATA COLLECTION</b>                    | Collected all data correctly   | Collected most data correctly  | Collected some data correctly   | Collected few data correctly                      |            |
| <b>DATA ANALYSIS</b>                      | Calculated all data correctly  | Calculated most data correctly   | Calculated some data correctly  | Calculated few data correctly                     |            |
| <b>GRAPHS</b>                             | Correctly matches all the data analysis tables   | Correctly matches most of the data analysis  | Correctly matches some of the data analysis   | Correctly matches few data correctly              |            |
| <b>USE OF COLOR IN GRAPHS</b>             | Attractive with appropriate use of all color   | Attractive with appropriate use of most of the colors  | Attractive with appropriate use of some of the colors   | Attractive with appropriate use of a few colors   |            |
| <b>RESULTS &amp; GRAPH INTERPRETATION</b> | Answered all questions correctly   | Answered most of questions correctly   | Answered some of questions correctly  | Answered few questions correctly                  |            |
| <b>CONCLUSIONS</b>                        | Hypothesis accepted or rejected and clearly explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but vaguely explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but inadequately explained using the STEM concepts associated with the activity | Hypothesis accepted or rejected but not explained |            |
| <b>Additional Comments:</b>               |  |  |   | <b>TOTAL POINTS</b>                               | <b>/32</b> |

## OVERALL ACTIVITY PERFORMANCE

*Circle the Description that matches each student's score*

| Score      | Descriptive             |
|------------|-------------------------|
| 32-29      | Exemplary               |
| 28-26      | Proficient              |
| 25-23      | Approaching Proficiency |
| 22 or less | Non-Proficient          |



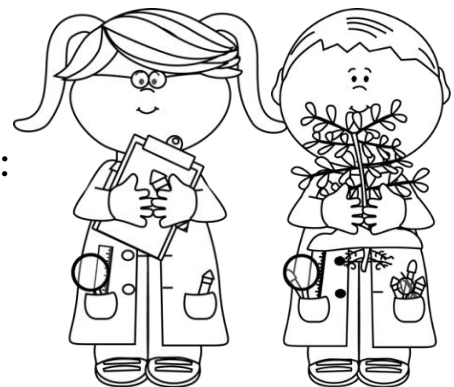
Food, Energy, and Water Learning Module (FEWLM)

# My Sprouting Bean Seeds Scientific Workbook

*In the blank space below, draw yourself as a scientist working with plants (Botanist)*

This Sprouting Bean Workbook Belongs to:

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# Background Information

Seeds are plant embryos “baby plants” with stored food and a seed leaf or seed leaves inside a thick hard protective seed coat. Seeds are normally dry and dormant “sleeping.” When favorable moisture, oxygen and temperature conditions occur, germination begins and the seed “wakes up.” The ideal conditions for seed germination varies based on the plant. Some seeds germinate in the spring when the temperatures are cooler while other seeds germinate in warmer temperatures during the summer. During the germination process, a dry seed re-hydrates by soaking up water and the seed coat cracks exposes the plant embryo to oxygen in the air. The roots begin to emerge from the seed coat followed by the seed leaves (shoots). The stored food in the seed breaks down to usable energy for the growing plant until photosynthesis occurs.

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Eating beans on a regular basis potentially lowers the risk of cancer, heart disease, diabetes, and obesity while promoting long-term health (2). Despite the health benefits, the consumption of beans has declined substantially in recent years as a result of people embracing non-conservative diets (3). Now, about 8% of the overall United States’ population report eating beans on a daily basis. When comparing the ethnic groups within the United States, Hispanics eat beans more frequently (5). If people decide to change their diets and eat beans instead of beef, greenhouse gas emissions are expected to decline significantly (6) and other environmental problems related to intensive agriculture practices (7).

Now, let’s begin this activity by gathering more background information about black, pinto and lima beans and establish an experimental design to conduct our seed germination study. The “My Sprouting Bean Seeds Scientific Workbook” will be a fun and exciting activity for a young scientist in training.

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4. Mackie WW. 1943. Origin, dispersal, and variability of the lima bean, *Phaseolus lunatus*. *Hilgardia* 15:1-29.
5. Mitchell DC, Lawrence FR, Hartman TJ, Curran JM. 2009. Consumption of Dry Beans, Peas, and Lentils Could Improve Diet Quality in the US Population. *Journal of the American Dietetic Association* 109:909-913.
6. Harwatt H, Sabate J, Eshel G, Soret S, Ripple W. 2017. Substituting beans for beef as a contribution toward US climate change targets. *Climate Change* 143:261.
7. Schneider C. 2014. The cancer prevention properties of beans, vol 59, p 4-9. CSA-SSSA-ASA, Madison, WI.



# Definitions

**Autotroph:** organisms that make their own food

**Cotyledon:** "seed leaf" that emerges from the ground as the first leaf or leaves to carry out photosynthesis during germination. Cotyledons are not true leaves.

**Dicot:** seeds containing two seed leaves

**Germination:** growth of a seedling into a small plant

**Hypocotyl:** "stem" of a germinating seedling

**Monocots:** seeds containing one seed leaf

**Photosynthesis:** plants, algae and some microorganisms use carbon dioxide and water in the presence of sunlight to make sugars. Oxygen is released as a waste product.

**Roots:** the part of the plant below ground

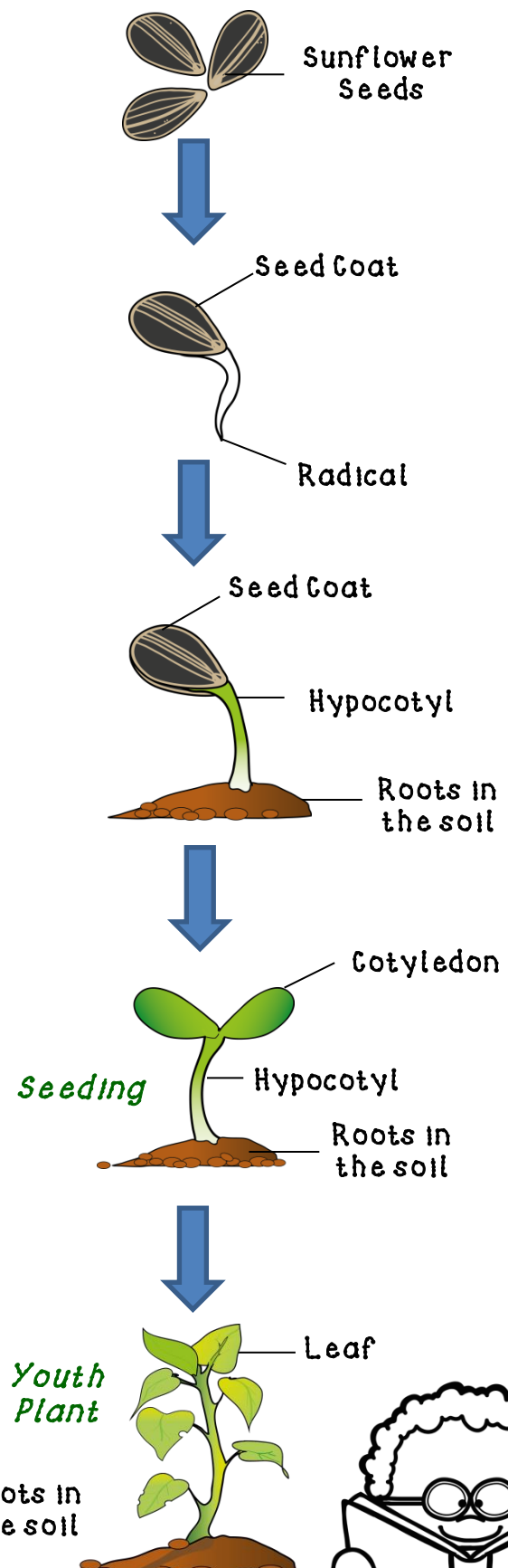
**Shoots:** the part of the plant above ground; stem and leaves

**Seed:** plant embryo "baby plant" with stored food and seed leaves inside a thick hard protective seed coat.

**Seed coat:** hard protective coat

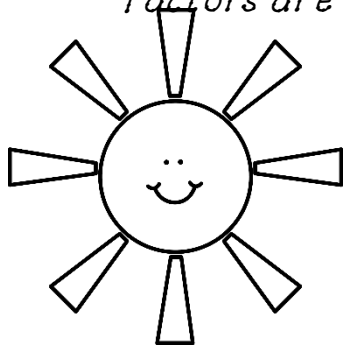
**Seedling:** a young plant that developed from a plant embryo

## Stages of a Germinating Dicot Seed



# Background Information

*Explain why seeds need these non-living items to germinate. Use reliable scientific sources to find evidence to support why these factors are necessary for plant germination and growth.*



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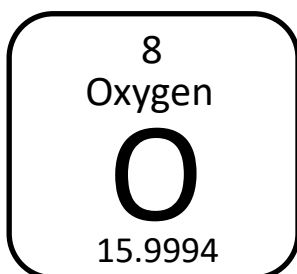
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# Observations

*Draw a picture of each seed, then search the scientific literature and write important facts about each seed.*

Black Bean



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Pinto Bean



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Lima Bean



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# Lab Procedure

1. Prior to beginning the activity, soak the dry seeds overnight in tap water.
2. Color and cut out your little sprout house. (Optional)  
<https://www.teacherspayteachers.com/Store/The-Chalkboard-Garden> 
3. Fold 2 lightly colored paper towels and place them inside a sandwich size re-sealable plastic bag.
4. Add 30 ml of water to each bag, which soaks the paper towel, but prevents any standing water from accumulating in the bag.
5. Place one pre-soaked black, pinto and lima bean seed an inch apart in the middle of the napkin in each re-sealable plastic bag.
6. Seal the bag and write your name on it in the upper right hand corner.
7. Tape the pocket seed viewer<sup>1</sup> to the back of little sprout house so you can view the seed germination from the front. Tape the experiment to a wall, box or window. Make sure your germination samples in an area with ample sunlight. Keep the bags sealed during the entire activity.
8. Record your measurements and draw your observations for each bean in your workbook everyday for the next seven days. Use a string to trace the length of the shoot and root growth on the outside of the bag. Then use a ruler to measure the length of each string in centimeters.
9. At the end of the activity, use the data recorded in your workbook to create a line graph to show the length of the shoots and roots for each bean. After creating the line graphs, students should answer the results and conclusions follow-up questions.
10. Middle school students should continue with Part II.
11. Have fun!

## Source

1. Dr. Biology. "Dr. Biology's Virtual Pocket Seed Experiment." ASU - Ask A Biologist. 15 Dec 2009. <http://askabiologist.asu.edu/experiments/vpocketseeds>





# Experimental Design

Why is seed germination important?

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Why do we soak the seeds overnight before starting the experiments?

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What is your research question?

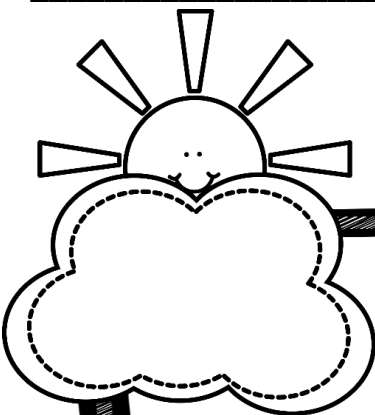
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What is your hypothesis ?

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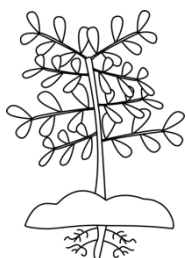
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Draw what you think will happen at the end of your experiment:

Name \_\_\_\_\_

Date \_\_\_\_\_



# Experimental Design

## The Scientific Procedure



|        |  |
|--------|--|
| Step 1 |  |
| Step 2 |  |
| Step 3 |  |
| Step 4 |  |
| Step 5 |  |
| Step 6 |  |

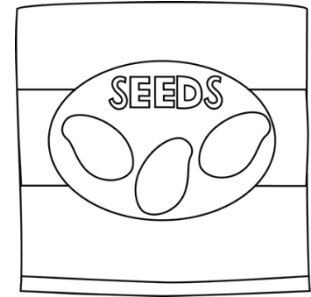
Name \_\_\_\_\_

Date \_\_\_\_\_

Day 1 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



### Black Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Pinto Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Lima Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

Lima Bean

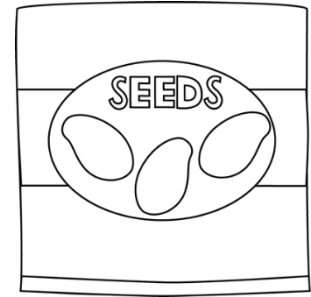
Name \_\_\_\_\_

Date \_\_\_\_\_

Day 2 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



### Black Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Pinto Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Lima Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

Lima Bean

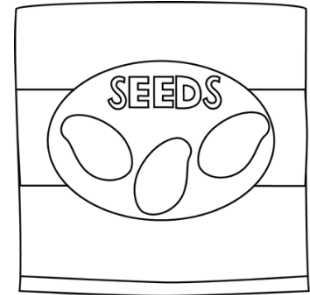
Name \_\_\_\_\_

Date \_\_\_\_\_

Day 3 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



**Black Bean**  
Shoot Length \_\_\_\_\_ cm  
Root Length \_\_\_\_\_ cm

**Pinto Bean**  
Shoot Length \_\_\_\_\_ cm  
Root Length \_\_\_\_\_ cm

**Lima Bean**  
Shoot Length \_\_\_\_\_ cm  
Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

Lima Bean

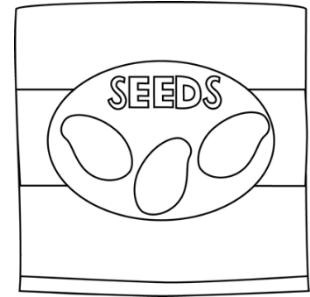
Name \_\_\_\_\_ Date \_\_\_\_\_



Day 4 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



### Black Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Pinto Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Lima Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

Lima Bean

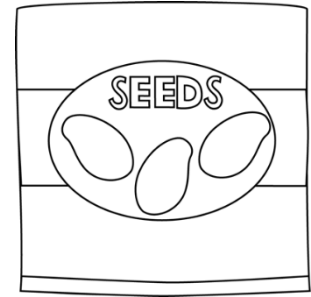
Name \_\_\_\_\_

Date \_\_\_\_\_

Day 5 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



### Black Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Pinto Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Lima Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

Lima Bean

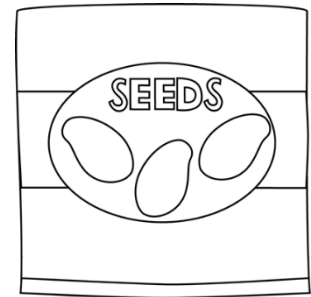
Name \_\_\_\_\_

Date \_\_\_\_\_

Day 6 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



### Black Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Pinto Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Lima Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

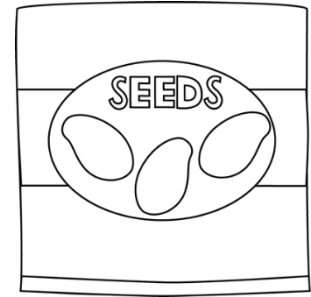
Lima Bean

Name \_\_\_\_\_ Date \_\_\_\_\_

Day 7 Date: \_\_\_\_\_

## Data Collection

*What do I see... & What is different...*



### Black Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Pinto Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

### Lima Bean

Shoot Length \_\_\_\_\_ cm

Root Length \_\_\_\_\_ cm

*Draw your observations below.*

Black Bean

Pinto Bean

Lima Bean

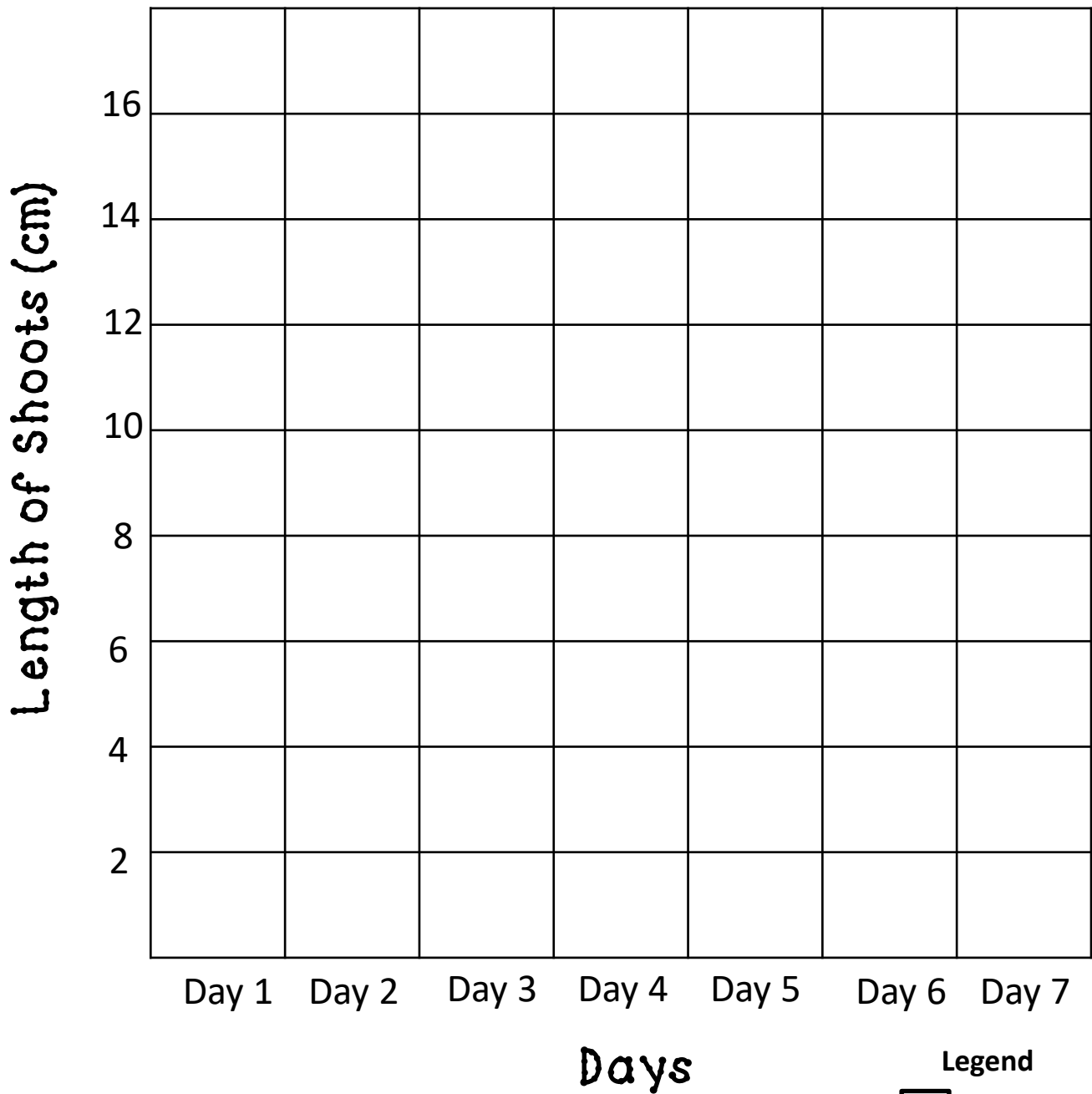
Name \_\_\_\_\_

Date \_\_\_\_\_

Part I. Individual Data Collection

# Bean Shoot Growth

Create a line graph showing the number of seeds that germinated over a 7-day sample collection period. Use a different color pencil or crayon to illustrate the different beans.



Name \_\_\_\_\_

Date \_\_\_\_\_

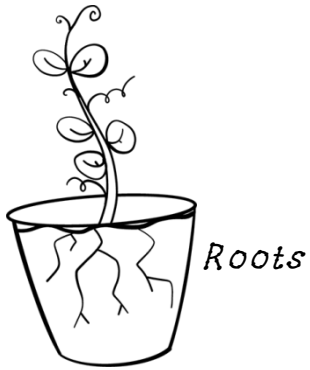
**Legend**

- ☐ Black Bean
- ☐ Pinto Bean
- ☐ Lima Bean

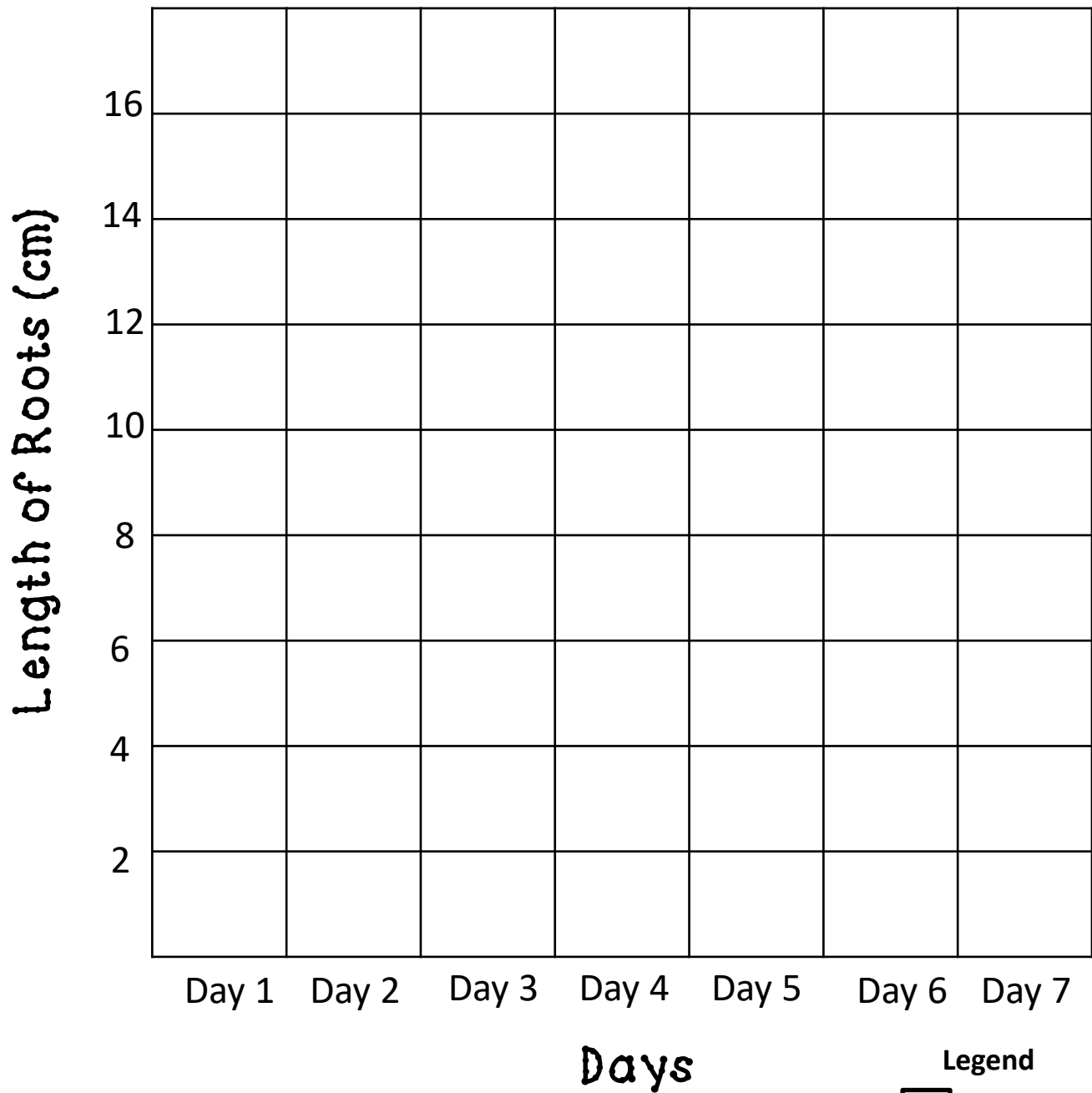


Part I. Individual Data Collection

## Bean Root Growth



Create a line graph showing the number of seeds that germinated over a 7-day sample collection period. Use a different color pencil or crayon to illustrate the different beans.



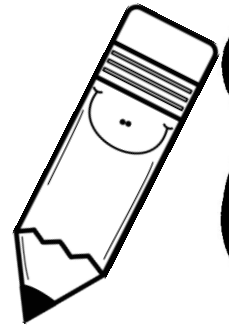
Name \_\_\_\_\_

Date \_\_\_\_\_

### Legend

- ☐ Black Bean
- ☐ Pinto Bean
- ☐ Lima Bean

## Conclusions



How many beans were in your study? \_\_\_\_\_

Which beans were used in this study? \_\_\_\_\_

### Based on your line graphs...

Which bean germinated first? \_\_\_\_\_

How many days passed before one of beans germinated? \_\_\_\_\_

Which bean had the longest root? \_\_\_\_\_

Which bean had the shortest shoot? \_\_\_\_\_

Overall what does your line graph tell you about the germination of each bean?

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Was your hypothesis correct? Circle **Yes** or **No**. Explain your answer.

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What did you learn while participating in the my sprouting bean seeds activity?

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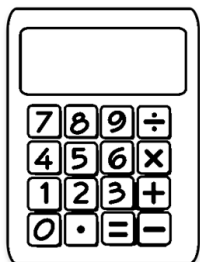
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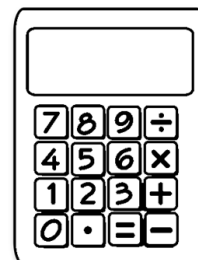
Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II. Group Data Collection

# Black Bean Shoot Growth



After completing part I, discuss your data with five of your friends and record their shoot growth data for the black bean seeds in the table below. Use the data in the table to calculate the basic statistics.

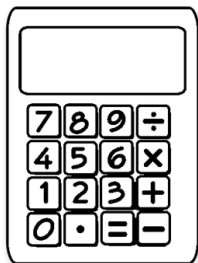
|                      | Black Bean Shoot Growth (cm) |       |       |       |       |       |       |
|----------------------|------------------------------|-------|-------|-------|-------|-------|-------|
| Group Members        | Day 1                        | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| Your Data            |                              |       |       |       |       |       |       |
| Friend 1             |                              |       |       |       |       |       |       |
| Friend 2             |                              |       |       |       |       |       |       |
| Friend 3             |                              |       |       |       |       |       |       |
| Friend 4             |                              |       |       |       |       |       |       |
| Friend 5             |                              |       |       |       |       |       |       |
| Total Shoot Growth   |                              |       |       |       |       |       |       |
| Average Shoot Growth |                              |       |       |       |       |       |       |
| Median Shoot Growth  |                              |       |       |       |       |       |       |
| Mode Shoot Growth    |                              |       |       |       |       |       |       |

### Equations:

Average Shoot Growth (cm) = The total of each day/ number of group members

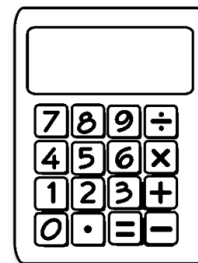
Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II. Group Data Collection

# Pinto Bean Shoot Growth



After completing part I, discuss your data with five of your friends and record their shoot growth data for the pinto bean seeds in the table below. Use the data in the table to calculate the basic statistics.

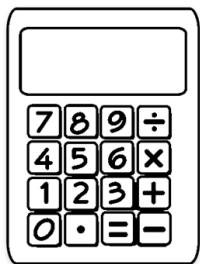
|                      | Pinto Bean Shoot Growth (cm) |       |       |       |       |       |       |
|----------------------|------------------------------|-------|-------|-------|-------|-------|-------|
| Group Members        | Day 1                        | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| Your Data            |                              |       |       |       |       |       |       |
| Friend 1             |                              |       |       |       |       |       |       |
| Friend 2             |                              |       |       |       |       |       |       |
| Friend 3             |                              |       |       |       |       |       |       |
| Friend 4             |                              |       |       |       |       |       |       |
| Friend 5             |                              |       |       |       |       |       |       |
| Total Shoot Growth   |                              |       |       |       |       |       |       |
| Average Shoot Growth |                              |       |       |       |       |       |       |
| Median Shoot Growth  |                              |       |       |       |       |       |       |
| Mode Shoot Growth    |                              |       |       |       |       |       |       |

### Equations:

Average Shoot Growth (cm) = The total of each day/ number of group members

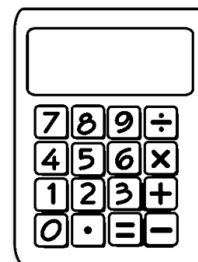
Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II. Group Data Collection

# Lima Bean Shoot Growth



After completing part I, discuss your data with five of your friends and record their shoot growth data for the lima bean seeds in the table below. Use the data in the table to calculate the basic statistics.

|                      | Lima Bean Shoot Growth (cm) |       |       |       |       |       |       |
|----------------------|-----------------------------|-------|-------|-------|-------|-------|-------|
| Group Members        | Day 1                       | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| Your Data            |                             |       |       |       |       |       |       |
| Friend 1             |                             |       |       |       |       |       |       |
| Friend 2             |                             |       |       |       |       |       |       |
| Friend 3             |                             |       |       |       |       |       |       |
| Friend 4             |                             |       |       |       |       |       |       |
| Friend 5             |                             |       |       |       |       |       |       |
| Total Shoot Growth   |                             |       |       |       |       |       |       |
| Average Shoot Growth |                             |       |       |       |       |       |       |
| Median Shoot Growth  |                             |       |       |       |       |       |       |
| Mode Shoot Growth    |                             |       |       |       |       |       |       |

### Equations:

Average Shoot Growth (cm) = The total of each day/ number of group members

Name \_\_\_\_\_

Date \_\_\_\_\_



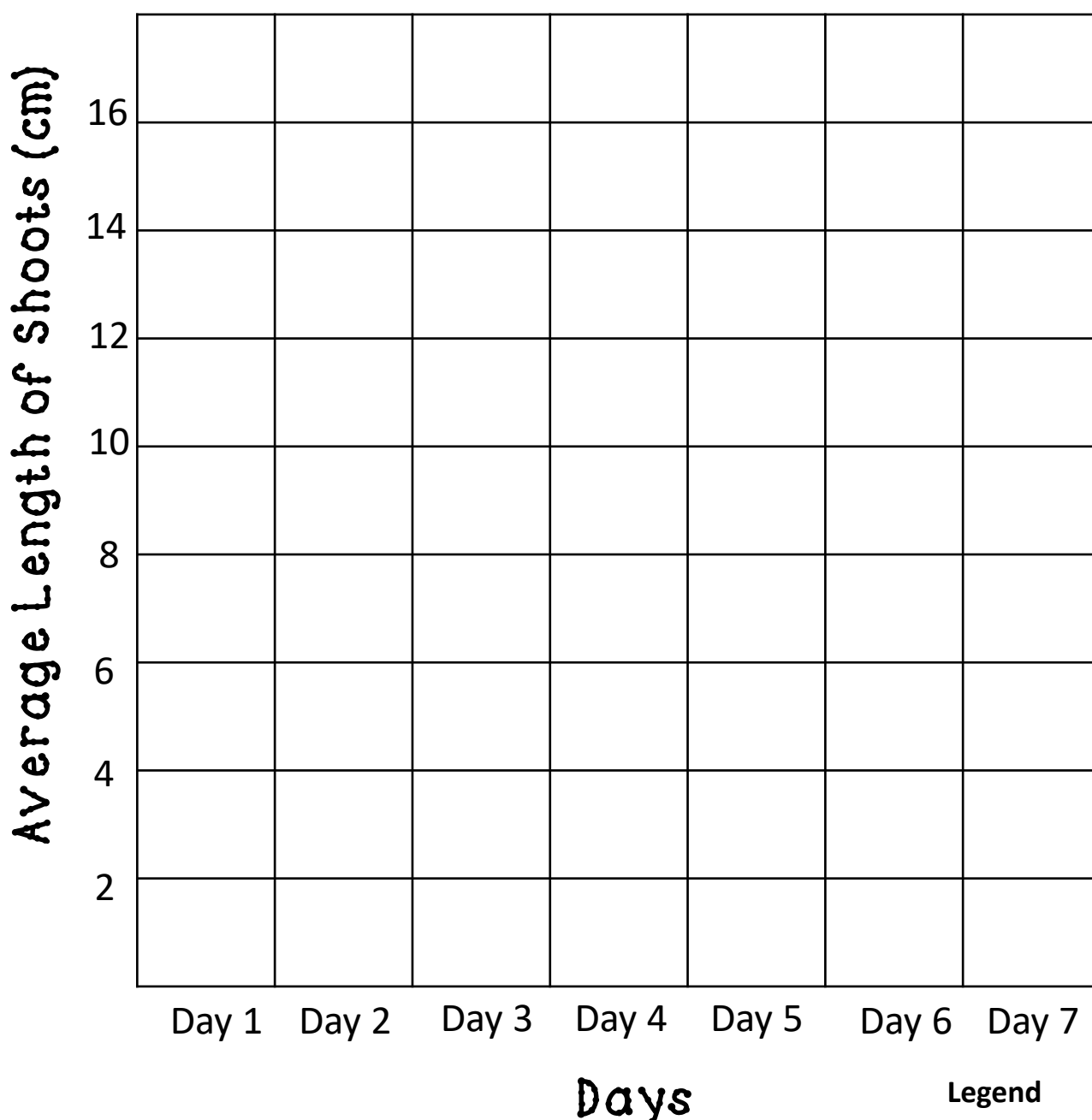


Shoots

Group Data Analysis

# Shoot Growth

Create a line graph to show the average shoot growth over a 7-day germination period. Use a different color pencil or crayon to illustrate the different beans.

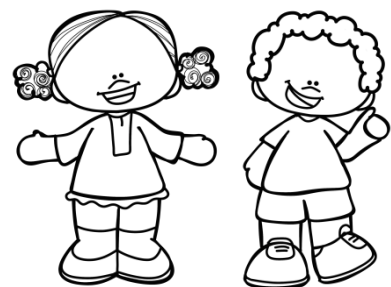


**Legend**

- ☐ Black Bean
- ☐ Pinto Bean
- ☐ Lima Bean

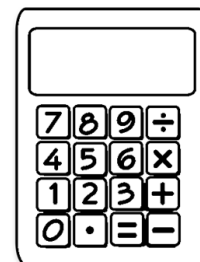
Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II. Group Data Collection

# Black Bean Root Growth



After completing part I, discuss your data with five of your friends and record their root growth data for the black bean seeds in the table below. Use the data in the table to calculate the basic statistics.

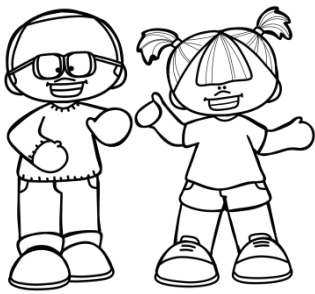
|                     | Black Bean Root Growth (cm) |       |       |       |       |       |       |
|---------------------|-----------------------------|-------|-------|-------|-------|-------|-------|
| Group Members       | Day 1                       | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| Your Data           |                             |       |       |       |       |       |       |
| Friend 1            |                             |       |       |       |       |       |       |
| Friend 2            |                             |       |       |       |       |       |       |
| Friend 3            |                             |       |       |       |       |       |       |
| Friend 4            |                             |       |       |       |       |       |       |
| Friend 5            |                             |       |       |       |       |       |       |
| Total Growth        |                             |       |       |       |       |       |       |
| Average Root Growth |                             |       |       |       |       |       |       |
| Median Root Growth  |                             |       |       |       |       |       |       |
| Mode Root Growth    |                             |       |       |       |       |       |       |

### Equations:

Average Root Growth (cm) = The total of each day/ number of group members

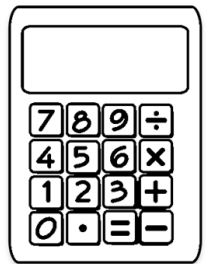
Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II. Group Data Collection

# Pinto Bean Root Growth



After completing part I, discuss your data with five of your friends and record their germination data for the pinto bean seeds in the table below. Use the data in the table to calculate the basic statistics.

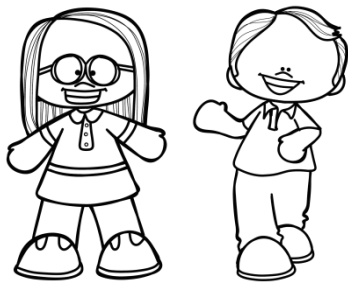
|                     | Pinto Bean Root Growth (cm) |       |       |       |       |       |       |
|---------------------|-----------------------------|-------|-------|-------|-------|-------|-------|
| Group Members       | Day 1                       | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| Your Data           |                             |       |       |       |       |       |       |
| Friend 1            |                             |       |       |       |       |       |       |
| Friend 2            |                             |       |       |       |       |       |       |
| Friend 3            |                             |       |       |       |       |       |       |
| Friend 4            |                             |       |       |       |       |       |       |
| Friend 5            |                             |       |       |       |       |       |       |
| Total Growth        |                             |       |       |       |       |       |       |
| Average Root Growth |                             |       |       |       |       |       |       |
| Median Root Growth  |                             |       |       |       |       |       |       |
| Mode Root Growth    |                             |       |       |       |       |       |       |

### Equations:

Average Root Growth (cm) = The total of each day/ number of group members

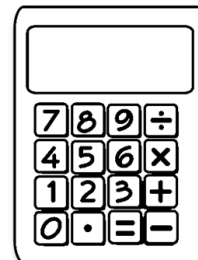
Name \_\_\_\_\_

Date \_\_\_\_\_



## Part II. Group Data Collection

# Lima Bean Root Growth



After completing part I, discuss your data with five of your friends and record their germination data for the lima bean seeds in the table below. Use the data in the table to calculate the basic statistics.

|                     | Lima Bean Root Growth (cm) |       |       |       |       |       |       |
|---------------------|----------------------------|-------|-------|-------|-------|-------|-------|
| Group Members       | Day 1                      | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| Your Data           |                            |       |       |       |       |       |       |
| Friend 1            |                            |       |       |       |       |       |       |
| Friend 2            |                            |       |       |       |       |       |       |
| Friend 3            |                            |       |       |       |       |       |       |
| Friend 4            |                            |       |       |       |       |       |       |
| Friend 5            |                            |       |       |       |       |       |       |
| Total Growth        |                            |       |       |       |       |       |       |
| Average Root Growth |                            |       |       |       |       |       |       |
| Median Root Growth  |                            |       |       |       |       |       |       |
| Mode Root Growth    |                            |       |       |       |       |       |       |

### Equations:

Average Root Growth (cm) = The total of each day/ number of group members

Name \_\_\_\_\_

Date \_\_\_\_\_

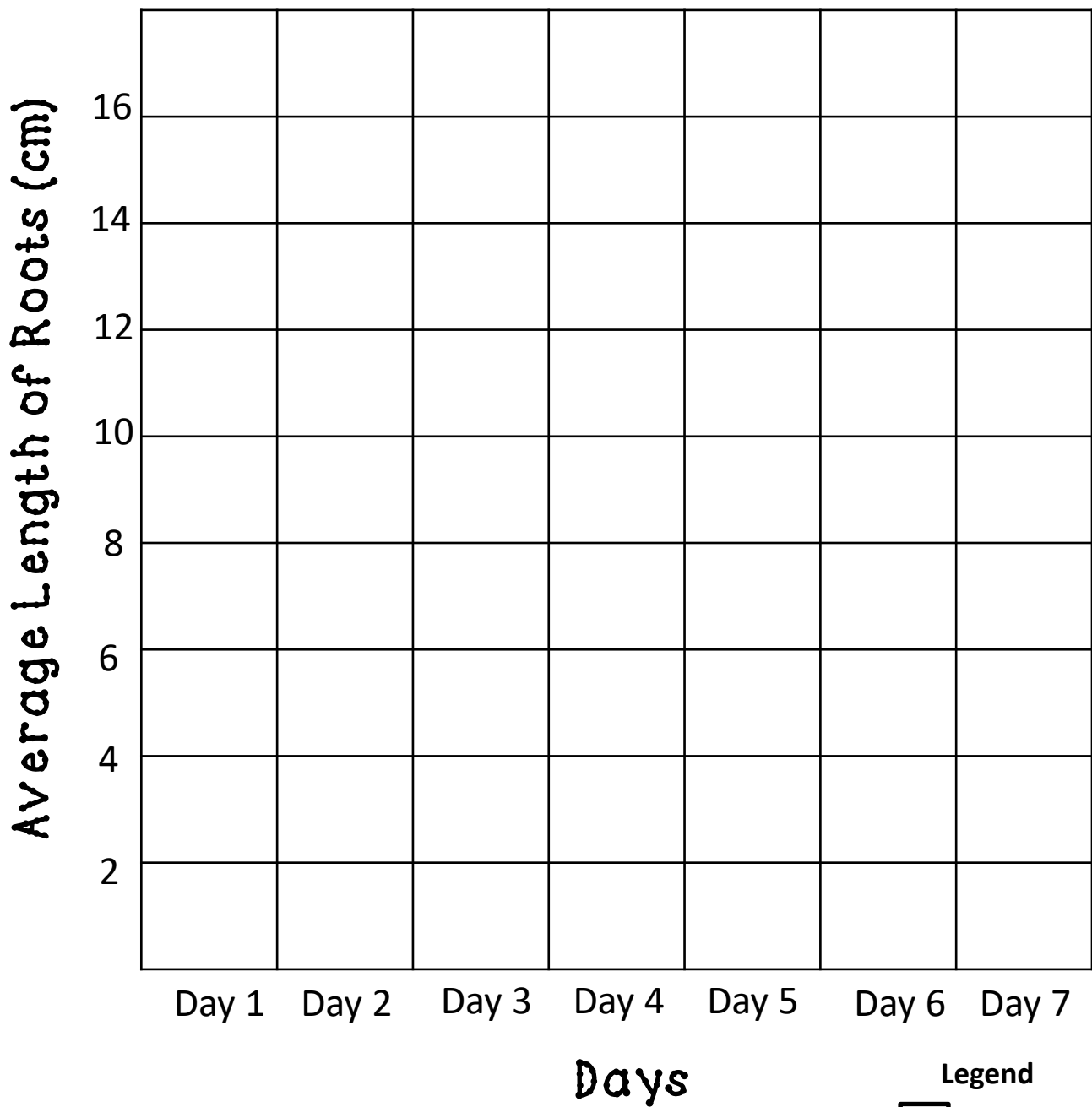


*Roots*

## Part II. Group Data Analysis

# Root Growth

Create a line graph to show average root growth over a 7-day germination period. Use a different color pencil or crayon to illustrate the different beans.



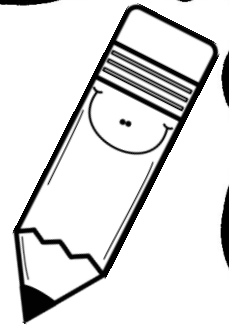
Name \_\_\_\_\_

Date \_\_\_\_\_

### Legend

- ☐ Black Bean
- ☐ Pinto Bean
- ☐ Lima Bean

## Conclusions



How many beans were in the group's study? \_\_\_\_\_  
Which beans were used in this study? \_\_\_\_\_

### Based on group's line graphs...

On average, which bean germinated first? \_\_\_\_\_  
On average, how many days passed before one of beans germinated? \_\_\_\_\_  
On average, which bean had the longest root? \_\_\_\_\_  
On average, which bean had the shortest shoot? \_\_\_\_\_

Overall how does **YOUR** line graph compare to the **GROUP's** line graph?

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Based on the group's line graph, was your hypothesis correct? Circle **Yes** or **No**.  
Explain your answer.

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What can you conclude about this study?

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What did you learn while participating in the group sprouting bean seeds activity?

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Name \_\_\_\_\_ Date \_\_\_\_\_



Thank you for choosing FEWLM to teach scientific inquiry!



We hope that this workbook provided an enjoyable learning experience for your aspiring scientist. We appreciate teachers, STEM outreach instructors, parents and grandparents for selecting FEWLM to teach scientific inquiry.

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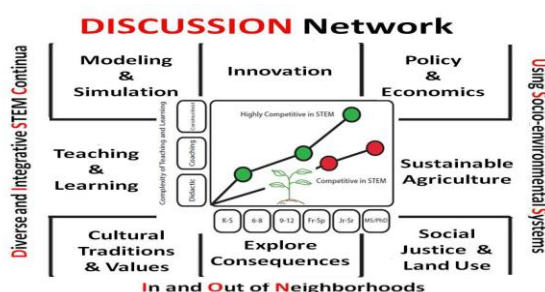
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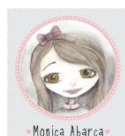
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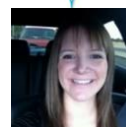
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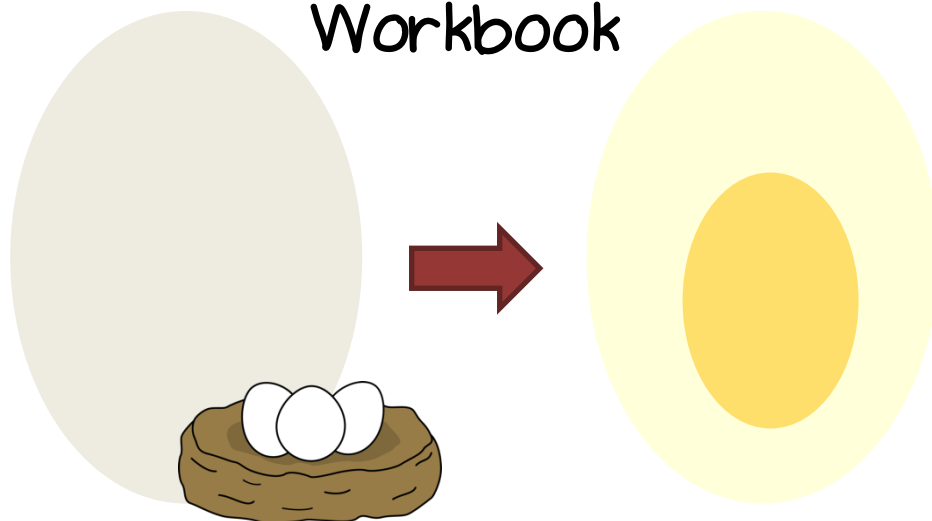
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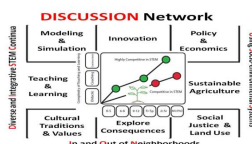
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FOOD, ENERGY, AND WATER LEARNING MODULE (FEWLM)  
Let's Take a Biochemical Journey  
Through Osmosis with a Naked Hen Egg  
Workbook

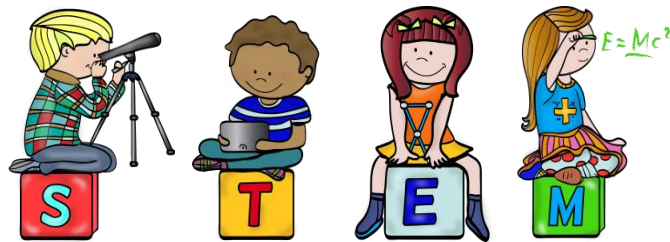


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# Lets Take a Biochemical Journey Through Osmosis with a Naked Hen Egg Workbook



## SUMMARY

The “**Lets Journey through Osmosis with a Naked Hen Egg**” activity is a classic experiment that introduces fundamental biological and chemical laws and theories through understanding osmosis and hypotonic, isotonic, and hypertonic conditions using naked hen eggs as a model specimen. Students learn the type of environment they are creating in their bodies by eating foods most people enjoy. They discover the negative impacts of unhealthy eating habits on their cellular function and the molecules that lead to human diseases such as diabetes, obesity and high-blood pressure. Students learn how naked eggs respond in different environments to demonstrate how cells in our bodies will respond after we eat foods high in salt, sugar, etc. During Part I of the activity, students observe osmosis in an animal cell using various salt concentrations while expanding their knowledge about scientific inquiry by identifying independent, dependent, experimental and standardized variables. They learn when to illustrate their data using a line and bar graph. Students mimic scientists by recording, graphing, analyzing and interpreting data to test a hypothesis and formulate a conclusion. Part I of the “**Lets Journey through Osmosis with a Naked Hen Egg**” activity can be assigned as an individual or team activity for 6th-8th graders and solely as a group demonstration activity for an entire class or large group of 3rd-5th graders. Part II of the activity, “Your Turn,” provides the middle school aged students the opportunity to apply the concepts learned during part one to design and implement their own experiment and investigate the effects of one independent variable (i.e. sugar, vinegar, corn syrup, rubbing alcohol, corn starch or baking soda) on a naked egg.

## QUICK LOOK

**Grade Level:** 3<sup>rd</sup> – 8<sup>th</sup> grade

**Subjects:** Science, Math, Statistics and Writing

**Preparation:** 10 eggs for a class demonstration or 8 eggs for each research team. Prior to beginning the experiment, place the eggs in white vinegar to dissolve the shell thus creating a naked egg.

**Duration:** 1 to 2 hours

**Group Size:** as a class demonstration activity or group 3 to 5 students

**Initial Estimated Cost:** US \$.54.00 for 8 groups of 4 students

**Year 2 Estimated Cost:** US \$6.00 for 8 groups of 4 students

**FOCUS QUESTION:** What is the effect of different salt solutions on the mass of a naked egg?

## TEACHER PREPARATION AND INSTRUCTIONS

*Prior to beginning this activity:*

1. Teachers should purchase hen eggs and soak the eggs in white vinegar for at least 24 hours or until the egg shell has been completely removed. **OPTIONAL:** This can be done in class as part of the activity prior to beginning the experiment.
2. The salt solutions should be prepared. Instructions provided on the next page.
3. A workbook should be printed and assembled for each student. Print only the pages appropriate for their grade level (i.e. part I – elementary students or parts I and II – middle school students)
4. The teacher should lead a discussion about eating healthy and how our food choices affect the cells in our body.

*After completing the activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity.
2. Teachers should lead a class discussion focusing the on how naked hen eggs respond to changes in salt concentrations and relate these concept to other living organisms such other animals and plants.



# Lets Take a Biochemical Journey Through Osmosis with a Naked Hen Egg



**TABLE 1. SUPPLIES NEEDED TO BE PURCHASED** (\*supplies can be used in year 2 or other FEWLM activities)

| Item   | Recommended Vendor             | Number of Item           | Total Price               |
|--|--------------------------------|--------------------------|---------------------------|
| Hen Eggs   | Dollar Tree                    | 2 dozen Eggs             | \$2.00                    |
| Sure Fresh Rectangular Deep Storage Container (216.5 oz)*  | Dollar Tree                    | 2 Containers             | \$3.00                    |
| Salt*  | Local Grocery Store            | 1 container              | \$1.00                    |
| Sharpie Fine Point Permanent Marker, Black, 12 ct*<br><i>Sharpie Fine Point Permanent Marker, Black, 5 ct*</i> | Walmart<br><i>Office Depot</i> | 1 pack<br><i>3 packs</i> | \$8.00<br><i>\$3.00</i>   |
| Cooking Concepts Digital Electronic Kitchen Timers*  | Dollar Tree                    | 8 Digital Timers         | \$8.00                    |
| Luncheon Napkins   | Dollar Tree                    | 3 packs of 20            | \$3.00                    |
| White Vinegar*   | Walmart                        | 1 gallon                 | \$3.00                    |
| Sure fresh Plastic Dry-Food storage containers with lids 5 piece set (16.6 oz.)*                               | Dollar Tree                    | 6 – 5 per pack           | \$6.00                    |
| Insten Digital Multifunction Kitchen Food Scale 1g to 5000g 5kg (units of measurements: gram or oz)*           | Walmart                        | 4                        | \$20.00                   |
| <b>Total</b>   |                                |                          | \$53.00<br><i>\$48.00</i> |

**TABLE 2. SUPPLIES USED DURING PREVIOUS FEWLM ACTIVITIES**

| Item                     | Previous Activity                     |
|--------------------------|---------------------------------------|
| Crayons or Color Pencils | m&m's® or Skittles / Seed Germination |

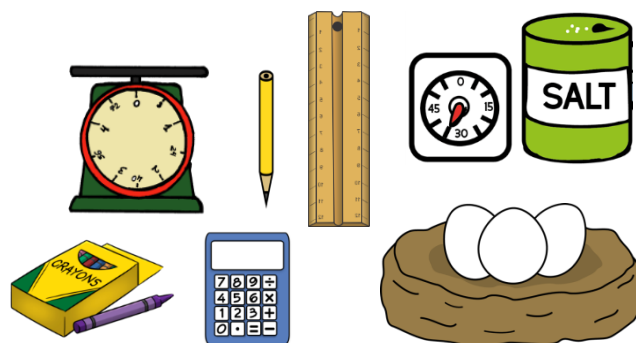
## SALT WATER SOLUTIONS INSTRUCTIONS

### 3.5% Salt Solution:

1. Add 3.5 mg or tsp to 1000 mL of water
2. Shake the container to completely dissolve the salt.

### 15% Salt Solution:

1. Add 15 mg or tsp to 1000 mL of water
2. Shake the container to completely dissolve the salt.



# Lets Take a Biochemical Journey Through Osmosis with a Naked Hen Egg



## LEARNING OBJECTIVES *Based on Next Generation Science Standards\**

### 3<sup>rd</sup>-5<sup>th</sup> grade (Part I)

- Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. (5-LS2-1)
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2), (4-ESS2-1), (4-PS3-2)
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)
- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2), (3-LS4-2)
- Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships. (3-ESS2-1)
- Most scientists and engineers work in teams. (4-PS3-4)
- Science affects everyday life. (3-ESS3-1), (4-PS3-4)

### 6<sup>rd</sup>-8<sup>th</sup> grade (Part I & II)

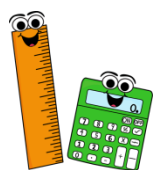
- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS3-4)
- Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation. (MS-LS1-1)
- Small changes in one part of a system might cause large changes in another part. (MS-LS2-4)

\*NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

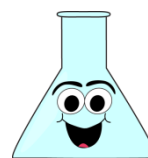


Name \_\_\_\_\_

Grade Level \_\_\_\_\_



# Lets Take a Biochemical Journey Through Osmosis with a Naked Hen Egg Grading Rubric

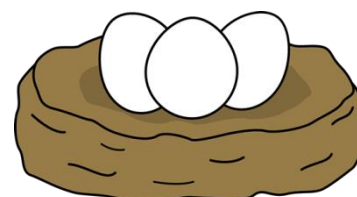


| Criterion                               | Exemplary = 4   | Proficient = 3  | Approaching Proficiency = 2                                | Non-Proficient = 1                                | Score      |
|---|---|---|--|---|------------|
| <b>APPEARENCE</b>                       | Neat and easy to read                                 | Somewhat neat and easy to read                        | Neat and difficult to read                                 | Not neat and very difficult to read               |            |
| <b>HYPOTHESIS</b>                       | Hypothesis stated and explained well                  | Hypothesis stated and vaguely explained               | Hypothesis stated and inadequately explained               | Hypothesis stated but not explained               |            |
| <b>DATA COLLECTION</b>                  | Collected all data correctly                          | Collected most data correctly                         | Collected some data correctly                              | Collected few data correctly                      |            |
| <b>DATA ANALYSIS</b>                    | Calculated all data correctly                         | Calculated most data correctly                        | Calculated some data correctly                             | Calculated few data correctly                     |            |
| <b>GRAPHS</b>                           | Correctly matches all the data analysis tables        | Correctly matches most of the data analysis           | Correctly matches some of the data analysis                | Correctly matches few data correctly              |            |
| <b>USE OF COLOR IN GRAPHS</b>           | Attractive with appropriate use of all color          | Attractive with appropriate use of most of the colors | Attractive with appropriate use of some of the colors      | Attractive with appropriate use of a few colors   |            |
| <b>RESULTS &amp; GRAPH INTEREPATION</b> | Answered all questions correctly                      | Answered most of questions correctly                  | Answered some of questions correctly                       | Answered few questions correctly                  |            |
| <b>DISCUSSION</b>                       | Hypothesis accepted or rejected and clearly explained | Hypothesis accepted or rejected but vaguely explained | Hypothesis accepted or rejected but inadequately explained | Hypothesis accepted or rejected but not explained |            |
| <b>CONCLUSIONS</b>                      | Overall experiment explained                          | Overall experiment mostly explained                   | Overall experiment somewhat explained                      | Overall experiment not explained                  |            |
| <b>Additional Comments:</b>             |   |   |  | <b>TOTAL POINTS</b>                               | <b>/36</b> |

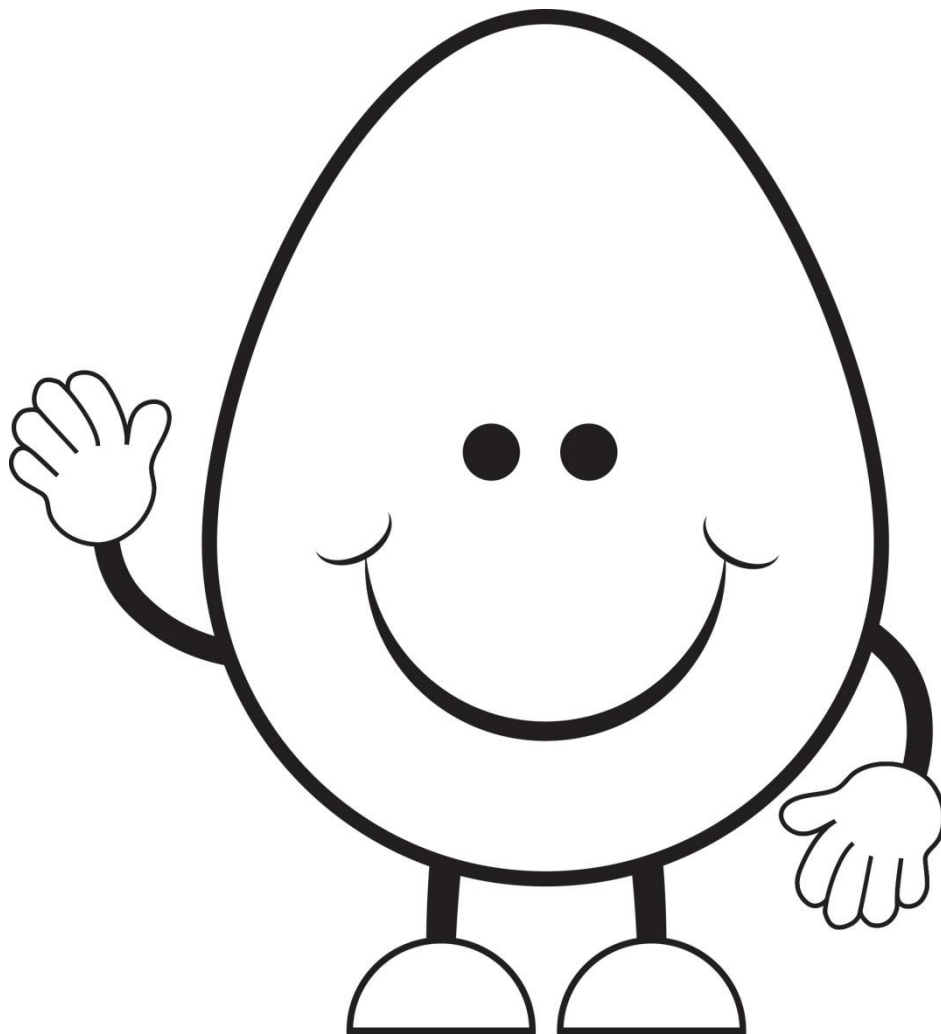
## OVERALL ACTIVITY PERFORMANCE

*Circle the Description that matches each student's score*

| Score      | Descriptive             |
|------------|-------------------------|
| 36-33      | Exemplary               |
| 32-29      | Proficient              |
| 28-26      | Approaching Proficiency |
| 25 or less | Non-Proficient          |



# Lets Take a Biochemical Journey Through Osmosis with a Naked Hen Egg



This Workbook belongs to:

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# Definitions

| Scientific Term       | Definition   |
|-----------------------|--|
| Cells                 | The smallest unit of Life  |
| Eukaryotic Cells      | Cells containing a true nucleus  |
| Nucleus               | Organelle that contains the DNA of eukaryotic cells  |
| Hypotonic             | The amount of water outside the cell is greater than inside cell. The cell swells and increases in size.     |
| Hypertonic            | The amount of water inside the cell is greater than outside the cell. The cell shrinks and decrease in size. |
| Isotonic              | The amount of water inside the cell is equal to amount of water outside the cell                             |
| Diffusion             | Movement of a molecules from a high concentration to a low concentration                                     |
| Osmosis               | A special type of diffusion where water moves across a semi-permeable membrane                               |
| Independent Variable  | The variable hypothesized to affect the dependent variable   |
| Dependent Variable    | The variable that responds to the independent variables  |
| Control Group         | The group of samples that does not receive a treatment and remains unchanged.                                |
| Standardized Variable | Factors that are the same for the control and test group   |
| Test Group            | The group of samples that receives treatment   |



## Background Information

# The Cell and Osmosis

A cell is the basic unit of life. All living organisms are made up of one or more cells. Some cells are simple while other cells contain complex organelles. Never the less, all cells have a **semi-permeable membrane** that regulate the movement of molecules between the cell and its environment.

The chemical composition inside a cell can be identical or different its environment. **Diffusion** occurs when particles move freely from an area with a high concentration to a low concentration until the molecules are evenly dispersed. The movement of water through a semi-permeable membrane is called **osmosis**. When cells are in a **hypotonic** environment, the concentration of molecules are higher inside the cell than its environment and water will move into the cell to establish an equilibrium. If too much water enters the cell, the cell could get very large and eventually burst. Cells located in an **isotonic** environment do not experience water movement across the membrane, because the concentration of molecules inside and outside the cell are equal. **Hypertonic** conditions arise when the concentration of molecules are higher outside the cell than inside the cell, which causes water to move from inside the cell into its environment. If too much water is removed, the cell could shrink and die.

Osmosis is a simple biochemical process that occurs naturally in all living organisms. All life depends on osmosis for survival and to maintain a healthy balance of water. Osmosis allows cells in plant roots to absorb water from the soil and to exchange water between other cells in the roots. When animals consume food and water, their cells absorb and exchange water between cells similar to plant root cells. All cells need salt and sugar to function properly; however too much or too little sugar or salt result in negative cellular responses and poor health. **Table 1** provide information about the molecules that can lead to human diseases. What you eat can impact your health.

**Table 1.** Molecules that can lead to human diseases

| Disease state         | Diagnoses                               | Common name of molecule |
|-----------------------|---|-------------------------|
| Diabetes              | High Blood Glucose                      | Sugar                   |
| Obesity               | Body Mass Index (BMI)                   | Fat                     |
| High – blood Pressure | Blood pressure consistently over 140/90 | Salt (NaCl)             |





# Think about what you eat...

*Below are some foods most people enjoy eating. If you eat these foods often, what type of environment in your body are you creating for your cells. Circle hypotonic, isotonic, and hypertonic, then use your textbook or reliable scientific information to justify your answer.*



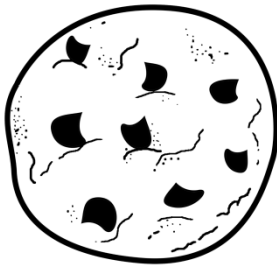
Hypotonic , Isotonic, Hypertonic

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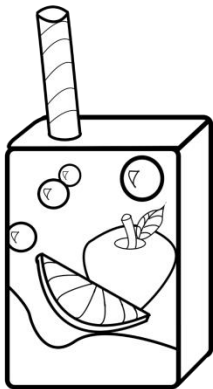
Hypotonic , Isotonic, Hypertonic

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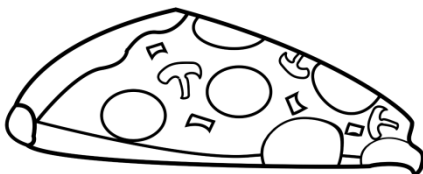
Hypotonic , Isotonic, Hypertonic

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Hypotonic , Isotonic, Hypertonic

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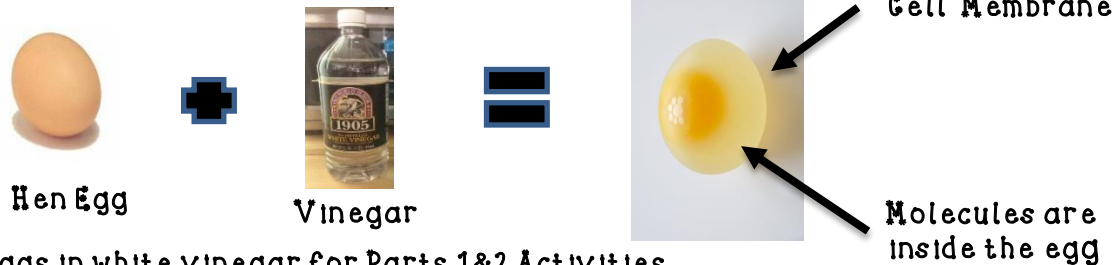




## Procedure

# Osmosis & the Naked Eggs in Various Salt Solutions Activity

A raw egg has a hard protective shell made up mostly of calcium carbonate ( $\text{CaCO}_3$ ) that protects the egg from microbes, prevents dehydration and regulates gas and water exchanges for growing embryos. When the environmental conditions become acidic (pH less than 7) due to pesticide use or atmospheric pollution, the egg shell will dissolve resulting in a shell-less egg called a naked egg. Naked eggs or shell-less eggs prevents birds and chickens from developing into birds or chicks, respectively, thus reducing the number of bird species in the ecosystem. However, for studying about cells and osmosis, naked eggs are valuable specimens. How a naked egg responds in different environments demonstrate how our cells will respond after we eat foods high in salt, sugar, etc. During the Part I activity, students will be able to observe osmosis in an animal cell using various salt concentrations.



### Day 1: Soak Eggs in white vinegar for Parts 1&2 Activities

1. Place 10 eggs in a bowl filled with white vinegar. Cover the bowl with a lid and allow the eggs to remain in the white vinegar for 24 to 48 hours. Prior to beginning the activity, complete the experimental design for "osmosis and naked hen eggs in salt" worksheet.

### Day 2-Day 3: Confirm the removal of egg shell

1. After 24 hours, carefully remove each egg from the solution and run tap water over each egg. If all of the shell comes off each egg while water is running over it, then pour the vinegar out of the bowl and put the egg in water.
2. If all of the shell does **NOT** come off each egg while water is running over it, then place the egg back in the vinegar and let it remain in the vinegar for another 24 hours. Then check if the shell can be removed under running water the egg again out of the bowl and put the egg in water. Place the bowl with the solutions and eggs back on the countertop for another 24 hours at room temperature. Once the eggshells are completely removed, dispose of vinegar solution and cover naked eggs with tap water. Place them in the refrigerator until ready to use. When stored in this manner, naked eggs can last up to 2 weeks.

### Day 4: Naked Egg and Salt

1. Carefully remove the eggs from cold tap water and run tap water over each egg. Use a soft napkin to carefully dry off the egg.
2. Use a balance to measure the mass of the egg then write the mass value for 0% salt in the data table under the 0 minute column. Place the egg in a container with 0% salt. Repeat the same steps for the naked eggs used in the in 3.5% salt and 15% salt solutions.
3. Set the time for three minutes.
4. Every three minutes for a total of 15 minutes, record the mass for each egg.
5. After recording the mass of each egg over a 15 minute period, use the equation below the data table to calculate the percent change. Record the values in the data table.
6. Calculate the relative change for each time period and the average over the 15 minute measurement period for each naked egg
7. Using the values in the data table, create a **line** graph to illustrate the relative change of each naked egg in the different salt solutions over the 15 minute period.
8. Using the average values in the data table, create a **bar** graph to illustrate the average relative change of each naked egg in the different salt solutions.
9. Answer the Part 1 results and conclusion follow up questions.
10. Now it is **YOUR** turn to design and complete **YOUR** own naked egg experiment.



# Osmosis & the Naked Egg in Salt

## Hypothesis

I believe \_\_\_\_\_, because  
\_\_\_\_\_  
\_\_\_\_\_

## Experimental Design

Independent Variable:

Dependent Variable:

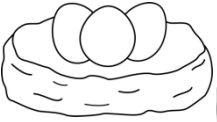
Control Variables:

Standardized Variables:

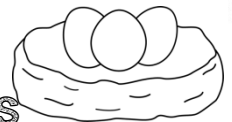
## Data Collection

**Table 1.** Percent change in naked egg weight in different salt solutions over a 15 minute period

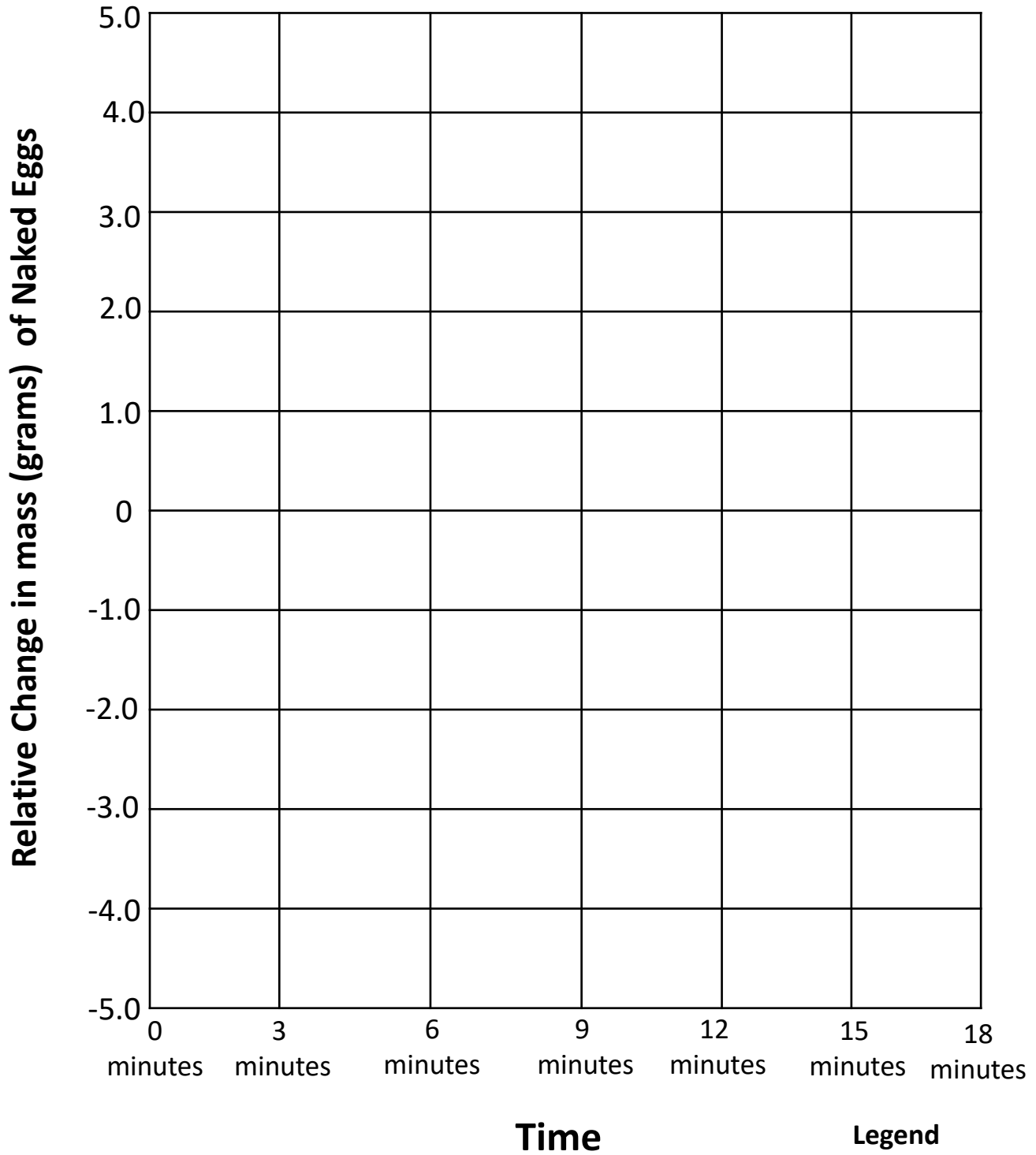
| Egg Sample                            | 0 min | 3 min | 6 min | 9 min | 12 min | 15 min | Average |
|---------------------------------------|-------|-------|-------|-------|--------|--------|---------|
| Water                                 |       |       |       |       |        |        |         |
| Relative Change in Water              |       |       |       |       |        |        |         |
| 3.5% Salt Solution                    |       |       |       |       |        |        |         |
| Relative Change in 3.5% Salt Solution |       |       |       |       |        |        |         |
| 15% Salt Solution                     |       |       |       |       |        |        |         |
| Relative Change in 15% Salt Solution  |       |       |       |       |        |        |         |



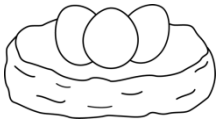
## Percent Change in Mass of Naked Eggs in Different Salt Concentrations



*Create a line graph to illustrate the percent change in mass of naked eggs in the different salt solutions.*



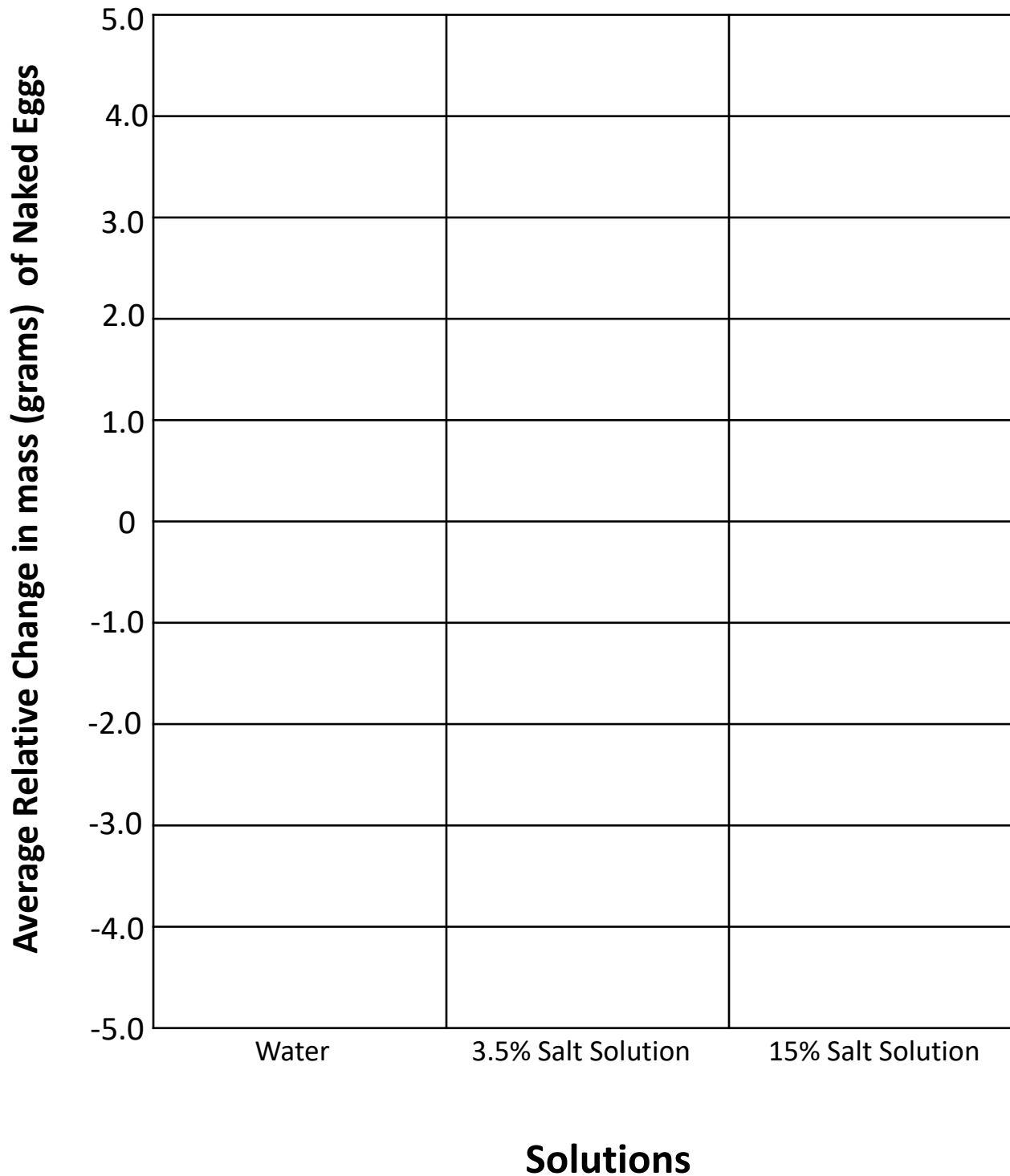
Name \_\_\_\_\_



## Average Relative Change in Mass of Naked Eggs in Different Salt Concentrations



Create a **bar** graph to illustrate the average relative change in mass of naked eggs in the different salt solutions over a 15 minute period.



Name \_\_\_\_\_

## Discussion



*Answer the follow up questions below. Use you your textbook or any other reliable scientific resources to justify your answer.*

Explain if the solutions in this experiment are considered to be *hypotonic*, *isotonic* and *hypertonic* environment? Explain your answer.

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Explain what the line graph is displaying about the weight of naked eggs in the water and salt solutions?

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Explain what the bar graph is displaying about the weight of naked eggs in the water and salt solutions?

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Based on your data, did the egg respond the **same** or **different** in the 3.5% and 15% salt solutions? Explain you answer.

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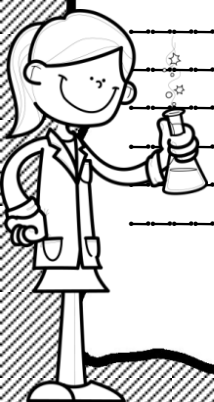
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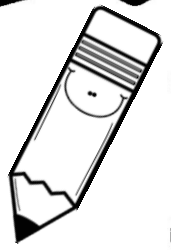
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## Conclusions & What you Learned



*Answer the follow up questions below. Use you your textbook or any other reliable scientific resources to justify your answer.*

Was your hypothesis correct? Circle **Yes** or **No**. Explain your answer.

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Did you experience any limitations while conducting your experiment? Circle **Yes** or **No**. Explain your answer.

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What can you conclude about osmosis from conducting this study?

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What did you learned from participating in the osmosis & naked egg activity?

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## Naked Egg Experiment using a different Solution

*Directions: Use the Part I. procedure to design and carry out your own experiment. After completing the experiment, answer the follow up questions.*

Title: \_\_\_\_\_

### Hypothesis

I believe \_\_\_\_\_, because

\_\_\_\_\_  
\_\_\_\_\_

### Experimental Design

Independent Variable:

Dependent Variable:

Control Variables:

Standardized Variables:

### Data Collection

**Table 1.** Percent change in naked egg weight in different \_\_\_\_\_ solutions over a 15 minute period

| Egg Sample | 0 min | 3 min | 6 min | 9 min | 12 min | 15 min | Average |
|------------|-------|-------|-------|-------|--------|--------|---------|
|            |       |       |       |       |        |        |         |
|            |       |       |       |       |        |        |         |
|            |       |       |       |       |        |        |         |
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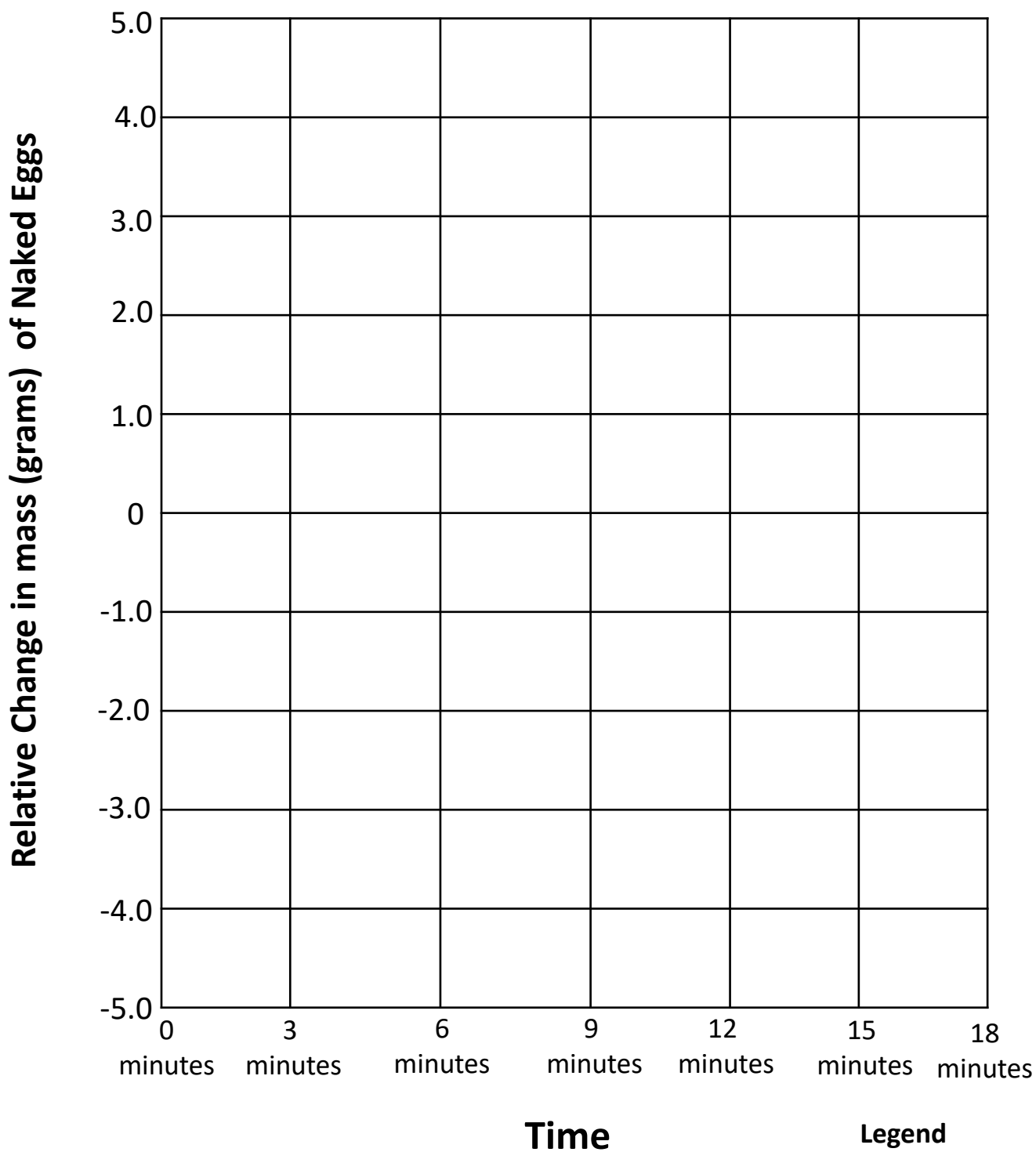
## Part II. Design your own Study



### Average Relative Change in Mass of Naked Eggs in different \_\_\_\_\_ Solutions



Create a *line* graph to illustrate the relative change in mass of naked eggs in the different \_\_\_\_\_ solutions.

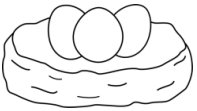


Name \_\_\_\_\_

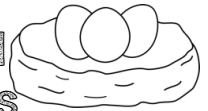
**Legend**

|                          |       |
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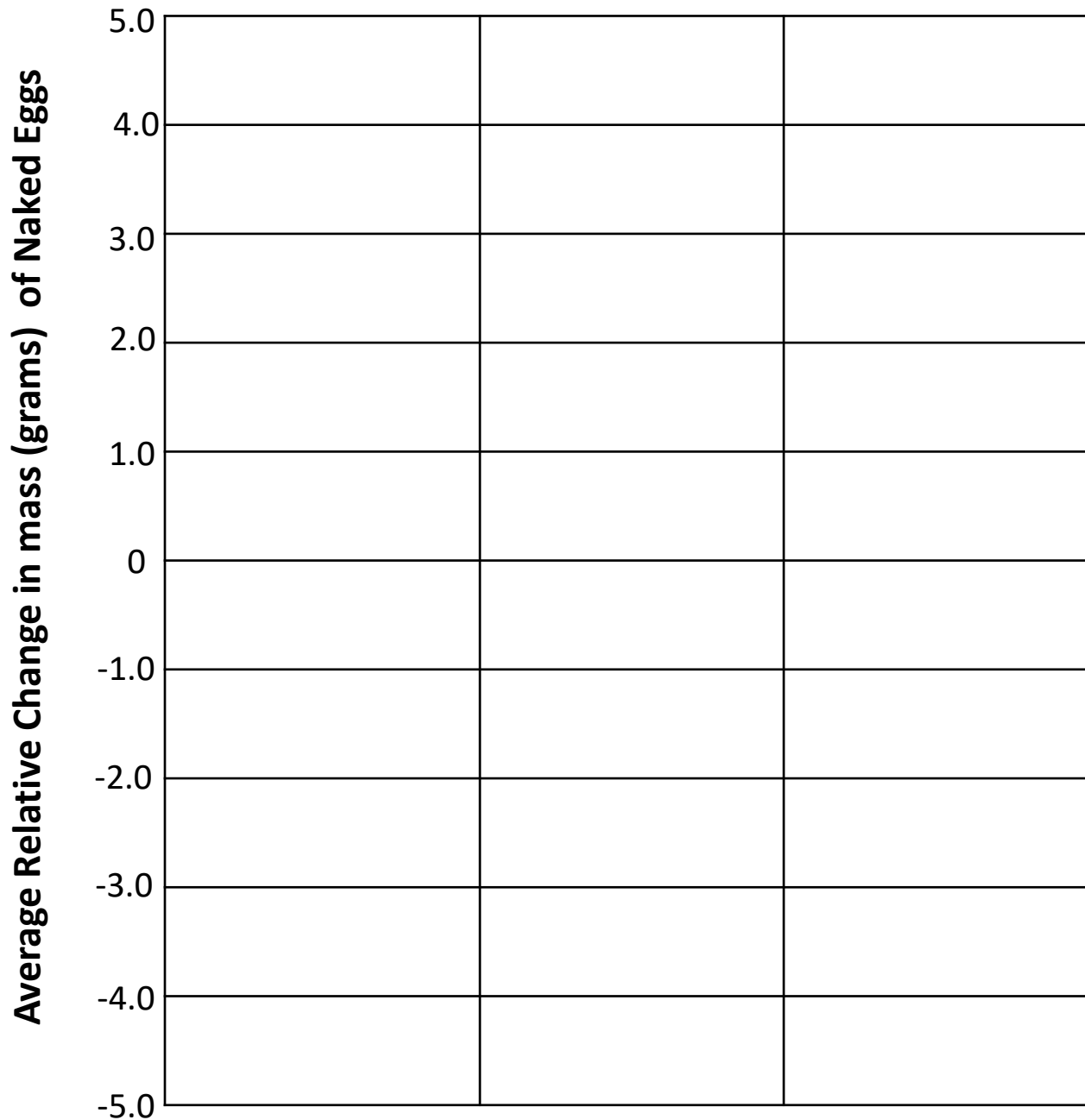
Part II. Design your own Study



**Average Relative Change in Mass of Naked Eggs in different \_\_\_\_\_ Solutions**

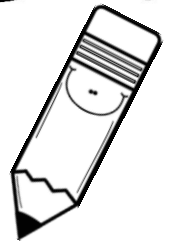


*Create a bar graph to illustrate the average relative change in mass of naked eggs in the different \_\_\_\_\_ solutions.*



Name \_\_\_\_\_

## Discussion



*Answer the follow up questions below. Use you your textbook or any other reliable scientific resources to justify your answer.*

Explain if the solutions in this experiment are considered to be *hypotonic*, *isotonic* and *hypertonic* environment? Explain your answer.

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Explain what the line graph is displaying about the weight of naked eggs in the water \_\_\_\_\_ solutions?

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Explain what the bar graph is displaying about the weight of naked eggs in the water and \_\_\_\_\_ solutions?

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Based on your data, did the egg respond the **same** or **different** in the highest and lowest percentage of \_\_\_\_\_ solutions? Explain you answer.

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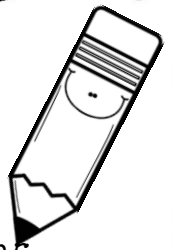
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## Conclusions

*Answer the follow up questions below. Use you your textbook or any other reliable scientific resources to justify your answer.*



Was your hypothesis correct? Circle **Yes** or **No**. Explain your answer.

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Did you experience any limitations while conducting your experiment? Circle **Yes** or **No**. Explain your answer.

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What can you conclude from this study?

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What did you learned while conducting your osmosis & naked egg experiment?

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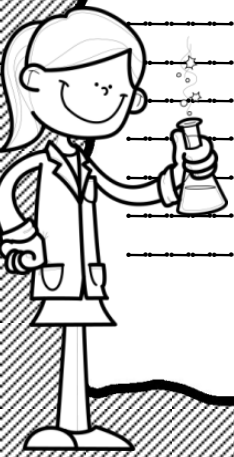
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Answer the follow up questions below. Use you your textbook or any other reliable scientific resources to justify your answer.

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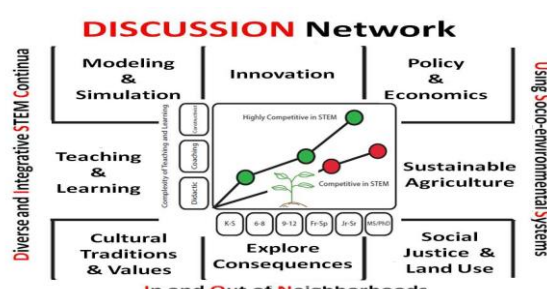
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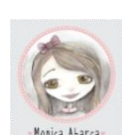
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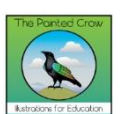
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<https://www.teacherspayteachers.com/Store/The-Enlightened-Elephant>

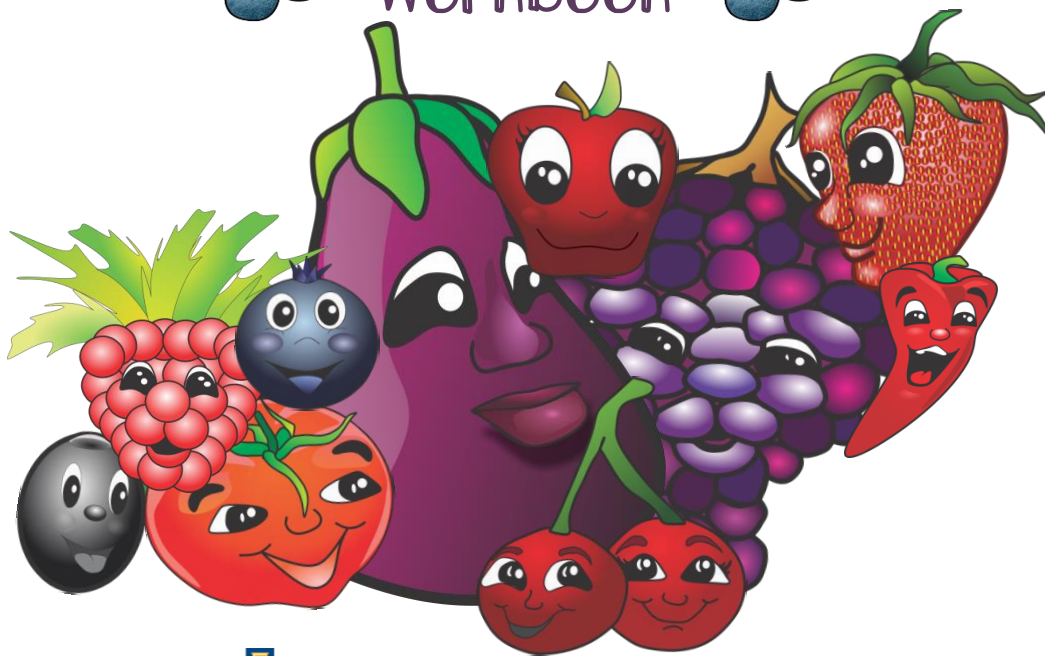


<https://www.teacherspayteachers.com/Store/Studio-Devanna>

Food, Energy, and Water Learning Module (FEWLM)

# The Beneficial Health Impacts of Fruits and Vegetables

## Workbook

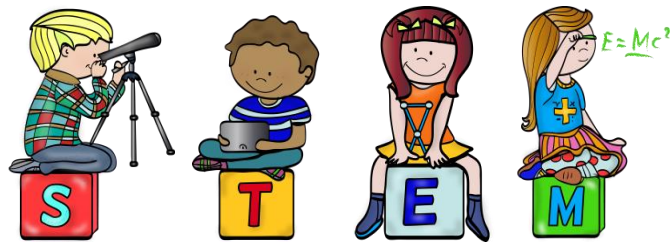


Sponsored by NSF Award Numbers 1649255 and 1649263

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# The Beneficial Health Impacts of Fruits and Vegetables Workbook



## SUMMARY

The “**Beneficial Health Impacts of Fruits and Vegetables**” is an inquiry-based learning activity that introduces elementary and middle school age youth to using fruits and vegetables as pH indicators as well the natural defenses of antioxidants against cellular oxidative stress. Students will learn: (1) about the importance of healthy eating, (2) how red cabbage juice can be used as a pH indicator solution and (3) to measure the strength of antioxidants against free radicals in the presence of hydrogen peroxide. During this activity, students observe the changes in color for solutions for various fruits and vegetable while expanding their knowledge about scientific inquiry by identifying independent, dependent, experimental and standardized variables. They learn the difference between qualitative and quantitative data and when to illustrate their data using a bar graph. Students mimic scientists by recording, graphing, analyzing and interpreting data to test a hypothesis and formulate a conclusion. The “**Beneficial Health Impacts of Fruits and Vegetables**” is designed to be an activity where students work in pairs or no more than 4 students.

## QUICK LOOK

**Grade Level:** 3<sup>rd</sup> – 8<sup>th</sup> grade

**Subjects:** Science, Math, Statistics and Writing

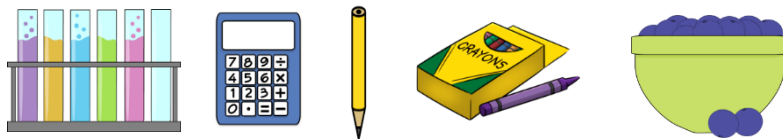
**Preparation:** Instructor will be required to prepare for this experiment at home 24 hours prior to beginning the experiment. Preparation will take about 3 hours.

**Duration:** 2 hours to 24 hours – depending on the instructor

**Group Size:** 4 Students (maximum)

**Initial Estimated Cost:** US \$28.00 7 groups of 4 students

**Year 2 Estimated Cost:** US \$5.00 - \$17.00



**FOCUS QUESTION:** Which fruit or vegetable containing anthocyanins can defend against free-radicals the longest over a 2 hour period?

## LEARNING OBJECTIVES *Based on Next Generation Science Standards\**

### 3<sup>rd</sup>-5<sup>th</sup> grade (Part I)

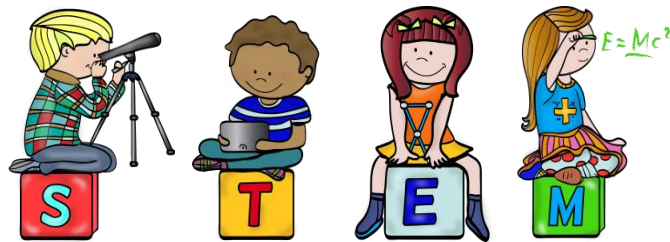
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2), (4-ESS2-1), (4-PS3-2)
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)
- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2), (3-LS4-2)
- Represent data in tables and various graphical displays (bar graphs and pictographs) to reveal patterns that indicate relationships. (3-ESS2-1)
- Most scientists and engineers work in teams. (4-PS3-4)
- Science affects everyday life. (3-ESS3-1), (4-PS3-4)

### 6<sup>rd</sup>-8<sup>th</sup> grade (Part I & II)

- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and control(s), what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS3-4)
- Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation. (MS-LS1-1)
- Small changes in one part of a system might cause large changes in another part. (MS-LS2-4)

\*NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

# The Beneficial Health Impacts of Fruits and Vegetables Workbook



## TEACHER PREPARATION AND INSTRUCTIONS

### *Prior to beginning pH indicator activity:*

1. The cabbage will have to be cut into small pieces prior to boiling it on the stove or in the microwave.
2. Place the frozen fruit in the a separate pot.
3. Boil the cabbage on the stove for at least 20 minutes until the solution is a dark color.
4. Allow each solution to cool until room temperature.
5. Then pour the cabbage juice solution into a storage container, seal it with a lid and store it the refrigerator.
6. **OPTIONAL:** Teachers can prepare the cabbage juice for the pH indicator activity by placing 2 tablespoons in each clear plastic condiment cups and cover with a lid before storing the samples in the refrigerator until the experiment.
7. **Baking Soda Solution:** Prepare a baking soda solution by adding 2 tablespoons of baking power to two cups of water. Stir with a spoon until baking power is completely dissolved.
8. A workbook should be printed and assembled for each student.
9. The teacher should lead a discussion about why red cabbage can be used as a pH Indicator and the importance for measuring pH changes.

### *After completing the activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity.
2. Teachers should lead a class discussion focusing on how red cabbage is used as an indicator for pH and the affects of pH on the survival of organisms.

### *Prior to beginning anthocyanins and free radicals activity:*

1. After purchasing the frozen strawberries, frozen dark cherries, frozen blueberries and fresh red cabbage from Walmart or any local grocery store, use table 1 below to prepare each solution.
2. Place the frozen fruit and chopped up cabbage in the a separate pot.
3. Boil each item separately on the stove for at least 20 minutes until the solution is a dark color.
4. Allow each solution to cool until room temperature.
5. Then pour each solution, through a strainer, into a separate storage container and seal it with a lid. Each solution should be stored in the refrigerator. **Note:** For best results, complete the experiment within 48 hours of preparing the solutions.
6. A workbook should be printed and assembled for each student. Print only the pages appropriate for their grade level.
7. The teacher should lead a discussion about the importance of eating colorful fruits and vegetables and the positive impacts of antioxidants on reducing the risk of chronic diseases.

**TABLE 1. INSTRUCTIONS FOR PREPARING FRUIT AND VEGETABLE JUICES**

| Food Item                   | Amount of Food Item | Amount of Tap Water |
|-----------------------------|---------------------|---------------------|
| Fresh Red Cabbage           | ½ of Red Cabbage    | 4 cups              |
| Frozen Blueberries          | 1 ¼ cup Blueberries | 2 cups              |
| Frozen Strawberries         | 14 Strawberries     | 2 cups              |
| Frozen Pitted Dark Cherries | 21 Cherries         | 2 cups              |

### *After completing the anthocyanins and free radicals activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity.
2. Teachers should lead a class discussion focusing on how we can measure the strength of antioxidants in the presence of hydrogen peroxide (free radicals) using fruits and vegetables containing anthocyanins and their connection to positively impacting human health.



# The Beneficial Health Impacts of Fruits and Vegetables Workbook



## MATERIALS NEEDED FOR ACTIVITY

Below are the materials needed to complete “The Beneficial Health Impacts of Fruits and Vegetables” Workbook . There are two tables listing the items required to carry out the pH indicator and anthocyanins and free radicals activity. Table 2 is the list of supplies the instructor needs to be purchased or ask to be donated by the PTA, parents or the school. To minimize cost, we encourage instructors to reuse items from previous FEWLM activities . Therefore, table 3 provides a list of items that can be reused from the previous FEWLM activities . The price for each item is rounded to the nearest dollar.

**TABLE 2. SUPPLIES NEEDED TO BE PURCHASED** (\*supplies can be used in year 2 or other FEWLM activities)

| Item   | Recommended Vendor | Number of Item | Total Price    |
|--|--------------------|----------------|----------------|
| Fresh Red Cabbage - 2 lb   | Walmart            | 1              | \$3.00         |
| Frozen Blueberries – 1 lb bag  | Walmart            | 1 bag          | \$3.00         |
| Frozen Strawberries – 1 lb bag                                       | Walmart            | 1 bag          | \$2.00         |
| Frozen Pitted Dark Cherries – 1 lb bag                               | Walmart            | 1 bag          | \$4.00         |
| Hydrogen Peroxide*   | Dollar Tree        | 1 bottle       | \$1.00         |
| Clear Plastic Condiment Cups with Lids, 12-ct. Packs                 | Dollar Tree        | 4 packs        | \$4.00         |
| Baking Soda*   | Walmart            | 1 box          | \$1.00         |
| Dawn Liquid Detergent*   | Dollar Tree        | 1 bottle       | \$1.00         |
| Lime Juice*  | Walmart            | 1 bottle       | \$1.00         |
| 9 oz. Clear Solo Cups (50 count)*                                    | Walmart            | 1 bag          | \$4.00         |
| Ginger Ale   | Walmart            | 1 bottle       | \$1.00         |
| Cooking Concepts Mesh Strainers with Handles, 6 in.*                 | Dollar Tree        | 1              | \$1.00         |
| Betty Crocker Square Plastic Storage Containers with Lids, 16.5 oz.* | Dollar Tree        | 2– 5 per pack  | \$2.00         |
| <b>Total</b>   |                    |                | <b>\$28.00</b> |

**TABLE 3. SUPPLIES USED DURING PREVIOUS FEWLM ACTIVITIES**

| Item   | Previous Activity                     |
|--|---------------------------------------|
| White Vinegar                                      | Naked Hen Egg                         |
| Sharpie Fine Point Permanent Marker, Black, 16ct   | Naked Hen Egg                         |
| Cooking Concepts Digital Electronic Kitchen Timers | Naked Hen Egg                         |
| Crayons or Color Pencils                           | m&m’s® or Skittles / Seed Germination |

Name \_\_\_\_\_

Grade Level \_\_\_\_\_



# Beneficial Health Impacts of Fruits and Vegetables

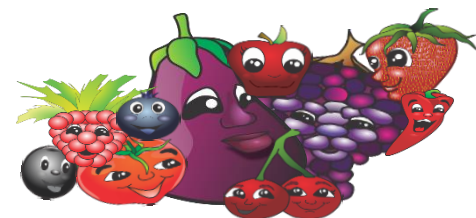


| Criterion                                 | Exemplary = 4   | Proficient = 3  | Approaching Proficiency = 2                                | Non-Proficient = 1                                | Score |
|---|---|---|--|---|-------|
| <b>APPEARANCE</b>                         | Neat and easy to read                                 | Somewhat neat and easy to read                        | Neat and difficult to read                                 | Not neat and very difficult to read               |       |
| <b>HYPOTHESIS</b>                         | Hypothesis stated and explained well                  | Hypothesis stated and vaguely explained               | Hypothesis stated and inadequately explained               | Hypothesis stated but not explained               |       |
| <b>DATA COLLECTION</b>                    | Collected all data correctly                          | Collected most data correctly                         | Collected some data correctly                              | Collected few data correctly                      |       |
| <b>DATA ANALYSIS</b>                      | Calculated all data correctly                         | Calculated most data correctly                        | Calculated some data correctly                             | Calculated few data correctly                     |       |
| <b>GRAPHS</b>                             | Correctly matches all the data analysis tables        | Correctly matches most of the data analysis           | Correctly matches some of the data analysis                | Correctly matches few data correctly              |       |
| <b>USE OF COLOR IN GRAPHS</b>             | Attractive with appropriate use of all color          | Attractive with appropriate use of most of the colors | Attractive with appropriate use of some of the colors      | Attractive with appropriate use of a few colors   |       |
| <b>RESULTS &amp; GRAPH INTERPRETATION</b> | Answered all questions correctly                      | Answered most of questions correctly                  | Answered some of questions correctly                       | Answered few questions correctly                  |       |
| <b>DISCUSSION</b>                         | Hypothesis accepted or rejected and clearly explained | Hypothesis accepted or rejected but vaguely explained | Hypothesis accepted or rejected but inadequately explained | Hypothesis accepted or rejected but not explained |       |
| <b>CONCLUSIONS</b>                        | Overall experiment explained                          | Overall experiment mostly explained                   | Overall experiment somewhat explained                      | Overall experiment not explained                  |       |
| <b>Additional Comments:</b>               |   |   |  | <b>TOTAL POINTS</b><br>/36                        |       |

## OVERALL ACTIVITY PERFORMANCE

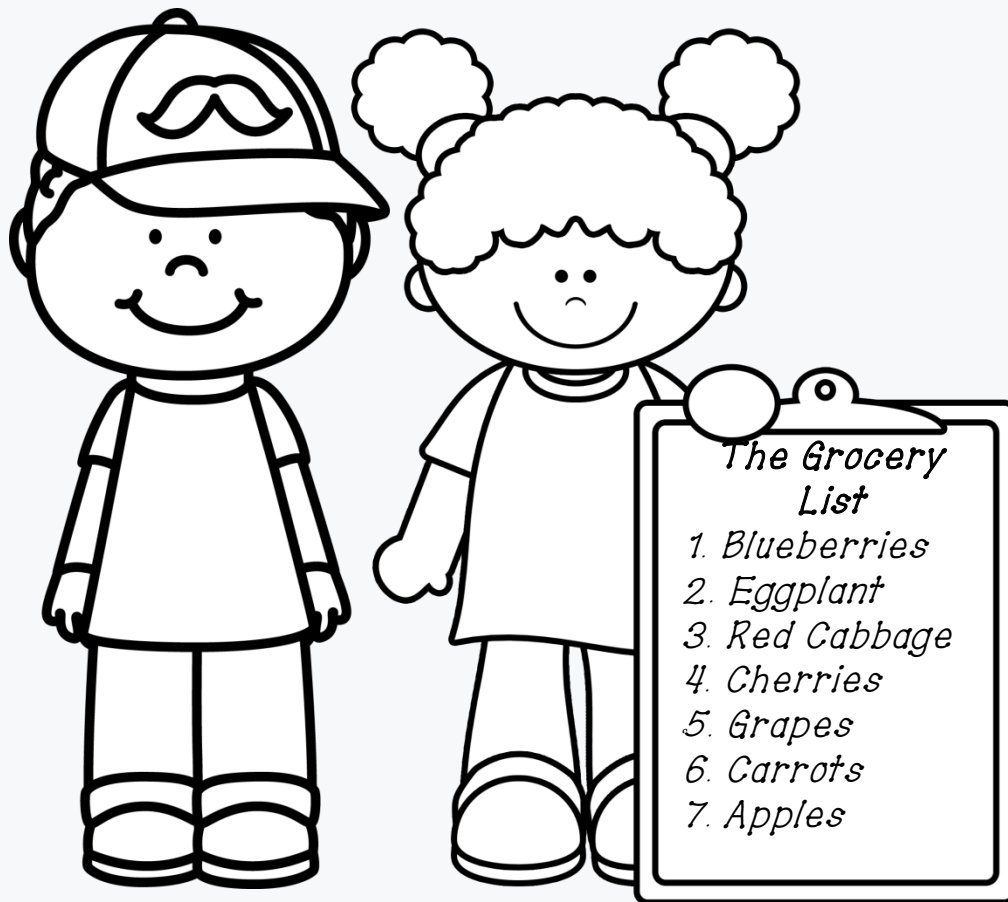
*Circle the Description that matches each student's score*

| Score      | Descriptive             |
|------------|-------------------------|
| 36-33      | Exemplary               |
| 32-29      | Proficient              |
| 28-26      | Approaching Proficiency |
| 25 or less | Non-Proficient          |



Food, Energy, and Water Learning Module (FEWLM)

# Beneficial Health Impacts of Fruits and Vegetables Workbook



This Workbook belongs to:

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# Definitions

| Scientific Terms  | Definition   |
|-------------------|--|
| Antioxidants      | Molecules that delay or protect the cells in your body from damage caused by free radicals by making them become less reactive.  |
| Chemical Reaction | Interaction between 2 or more substances that results in a different the substance(s).   |
| Disease           | A condition that weakens the structure and/or function of an organism.   |
| DNA               | Deoxyribonucleic Acid (DNA) is double helix genetic material that is passed down from parents to offspring. DNA stores genetic codes (information) and provides the instructions for producing proteins.   |
| Enzymes           | Are molecules that speeds up chemical reaction without begin consumed or changed.  |
| Fruit             | A part of the plant that contains seeds. Fruits protect the seeds and promotes spreading of seeds to different locations with the assistance of animals, wind and water. Many fruits are mistaken as vegetables such as tomatoes, green peppers, pumpkins, green beans, etc. |
| Indicators        | A measure of change in a condition for a given situation.  |
| Metabolism        | A process of chemical reaction(s) that occur in our cells. During metabolism, enzymes are used to create substances or break down existing substances.   |
| Qualitative Data  | Data collected that describes the subject using words instead of numbers. Examples are describing emotions, colors, texture, etc.  |
| Quantitative Data | Data collected using numbers. The quantity of the subject is measured. Examples are the length of a plant, the mass of an egg, the amount of candies in a bag, volume of water in a cup, etc.  |
| Scientific Data   | Qualitative and quantitative data gathered while conducting experiments and making observations.   |
| Vegetables        | A part of the plant that does not contain seeds. Vegetables are the leaves, roots and stems of the plant. Examples are lettuce, collard greens, turnip roots, cabbage, broccoli, cassava (yuca root), etc.   |





# Using the Anthocyanins in Red Cabbage Juice as a pH Indicator Solution

Anthocyanins are antioxidants found in fruits and vegetables with a purple, blue or red color, such as red cabbage, berries, eggplants, cherries, etc. The anthocyanins in red cabbage juice can be used as a technique for indicating changes in pH levels<sup>1</sup>. This technique is useful because all biological organisms are sensitive to changes in pH levels. For example, the red cabbage grows in acidic soils and green to yellowish cabbage grows in alkaline soils<sup>2</sup>. Furthermore, when environmental conditions shift from the ideal pH levels that support the growth, development and survival for living organisms to less than favorable environmental conditions, the organism could eventually die.

pH indicators measures presence or absence of  $H^+$  ions in a solution. The pH scale ranges from 0 to 14; 0 which is the most acidic, a pH of 7 is neutral, and 14 is the most alkaline (basic). The pH scale is logarithmic and as a result, pH 8 is ten times more alkaline (basic) than 7, and pH 9 is hundred times more alkaline. The alkalinity of a solution is the opposite of pH.

The basic colors of blue, purple, red and orange have a direct relation with the number of hydroxyl groups ( $OH^-$ ). More acidic solution creates a pinkish to red color, while a more alkaline solution produces blue through green to yellow color. For example, when the pH value equals 7, the cabbage juice is a royal purple color and the number of  $H^+$  ions are equal to  $OH^-$  ions. As the pH value drops below 7, the color of the cabbage juice changes from a purple to pink and/or red color indicating the amount of  $H^+$  is greater than the  $OH^-$  ions. As pH values increases from a value of 7 to 9, the color of the cabbage juice changes from purple to a bluish-green suggesting the amount of  $OH^-$  is slightly higher than the  $H^+$  ions. As the pH continues to increase beyond a value of 9, the color of the cabbage juice becomes a dark green or greenish-yellow and the amount of  $H^+$  ions is much lower than  $OH^-$  ions.

During this activity, elementary and middle school youth will use cabbage juice as a pH indicator solution to determine the pH value for several different household liquids. Before beginning the experiment, read over the laboratory procedure and ask your instructor any questions. Enjoy and have fun!

## References

1. Science Buddies. 2012. Cabbage Chemistry--Finding Acids and Bases. Scientific American. <https://www.scientificamerican.com/article/bring-science-home-cabbage-chemistry/>
2. Nolte, Kurt. Red Cabbage. College of Agriculture and Life Sciences. Yuma County Cooperative Extension. University of Arizona. Tucson, Arizona. [https://cals.arizona.edu/fps/sites/cals.arizona.edu/files/cotw/Red\\_Cabbage.pdf](https://cals.arizona.edu/fps/sites/cals.arizona.edu/files/cotw/Red_Cabbage.pdf)





# Laboratory Procedure

1. Prior to beginning the experiment, your instructor will prepare the cabbage juice and the baking soda solution.
2. At your table, there should be 1 red cabbage color code, 1 container with soapy water, 1 tablespoon, and 6 clear plastic condiment cups containing 2 tablespoons (30 mL) of cabbage juice.
3. Record the pH of cabbage juice:
  - a. Use the crayons to shade the labeled cup on the data sheet to match the observed color in the clear plastic condiment cup.
  - b. Use the red cabbage color code to determine the numerical pH value and to categorize the solution as acidic, neutral or basic.
  - c. Complete table 1 with evidence collected from part 3b
4. Remove the lids from one clear plastic condiment cup containing cabbage juice.
5. Add 1 tablespoon of white vinegar to the clear plastic condiment cup.
6. Observe the cup to witness if white vinegar changes the color of red cabbage juice.
7. Record the pH of white vinegar on the data sheet:
  - a. Using crayons to shade the labeled cup on the data sheet to match the observed color in the clear plastic condiment cup.
  - b. Using the red cabbage color code to determine the numerical pH value and to categorize the solution as acidic, neutral or basic.
  - c. Complete the table 1 with evidence collected from 7b.
8. Repeat steps 4 to 7 to determine the pH for lime juice, baking soda, dawn detergent, and ginger ale using the cabbage juice indicator solution..
9. After completing the dataset, answer the questions on the "What I Learned From This Activity..." worksheet while reflecting on what you learned during this experiment.
8. Have fun!



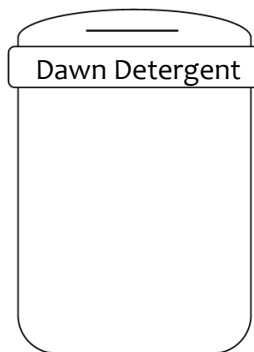
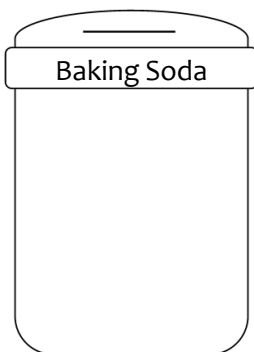
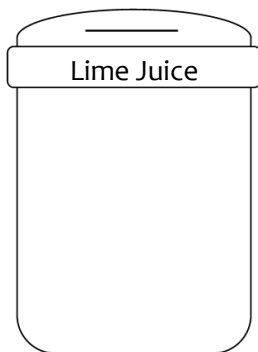
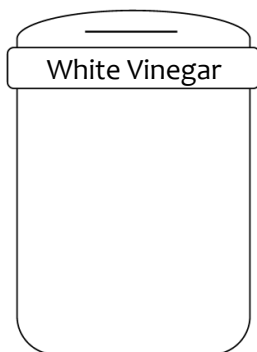
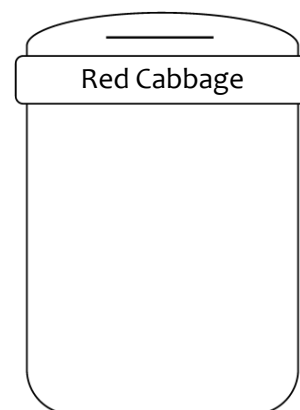
# Red Cabbage Juice as pH indicator Solution

The anthocyanins in red cabbage juice can be used as a natural technique for indicating changes in pH levels. This technique is useful because all biological organisms are sensitive to changes in pH levels. When environmental conditions shift from the optimum pH levels for living organisms to survive, the end result is death. pH indicators, such as red cabbage juice measures presence or absence of  $H^+$  ions in a solution. The pH scale ranges from 0 to 14; 0 which is the most acidic, a pH of 7 is neutral, and 14 is the most alkaline. The pH scale is logarithmic and as a result, pH 8 is ten times more alkaline than 7, and pH 9 is hundred times more alkaline. The alkalinity of a solution is the opposite of pH. More acidic pH solution creates a pinkish to red color, while a more alkaline solution produces blue through green to yellow color.

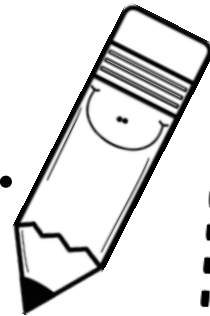
**INSTRUCTIONS:** Using a measuring spoon, add 60 mL (2 tablespoons) of red cabbage juice to each cup. Then add 30 mL (1 tablespoon) to each solution to a different cup. Use crayons or color pencils to color the container labeled for each solution and record the pH value in table 1 below.

Table 1. pH values using Red Cabbage as an Indicator Solution

| Solution                      | pH value<br>Using the Color Code | Acidic, Neutral, or<br>Basic |
|-------------------------------|----------------------------------|------------------------------|
| Red Cabbage                   |                                  |                              |
| White Vinegar                 |                                  |                              |
| Lime Juice                    |                                  |                              |
| Baking Soda<br>Solution       |                                  |                              |
| Dawn Liquid Dish<br>Detergent |                                  |                              |
| Ginger Ale                    |                                  |                              |



## What I Learned From This Activity...



*Answer the follow up questions below. Use you your textbook or any other reliable scientific resources to justify your answer.*

Based on your results, which items were acidic? Explain your answer.

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Based on your results, which items were basic? Explain your answer.

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What can you conclude about using cabbage juice as a pH indicator solution from conducting this experiment?

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What did you learned from participating in the red cabbage juice pH indicator activity?

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# Fruits and Vegetables Containing Antioxidants called Anthocyanins

Antioxidants are produced naturally in your body and have been identified in a variety of fruits, vegetables, nuts, legumes, grains, beverages, chocolate, spices herbs, fish, and meat products<sup>1</sup>. Antioxidants are molecules that fight to protect the cells in your body from damage caused by oxidative stress, by stabilizing free radicals thus making them become less reactive. One approach to hindering oxidative stress is to eat a balanced diet consisting of a variety of colorful fruits and vegetables, because a high plant-based diet potentially reduce oxidative stress<sup>1</sup> and lowers the risks associated with developing several chronic diseases<sup>2</sup>.

Free radicals are unstable, oxygen-containing molecules with an uneven number of electrons. Free radicals can be both beneficial and harmful to the human body. As a normal part of the human body's complex system, free radicals are continuously formed during processes associated with cellular respiration, exercise and inflammation. For example, one of the major sources for creating free radicals in the human body is the process associated with breathing<sup>3</sup>. The free radical produced is hydrogen peroxide ( $H_2O_2$ ), which is generated during mitochondrial respiration. Hydrogen peroxide is a powerful source for oxidative damage and ageing<sup>3</sup>.

In addition, we can also be exposed to free radicals in the environment (i.e. ozone, certain pesticides and cleaners, cigarette smoke, radiation and pollution). When the amount of free radicals is greater than antioxidants, the free radicals can start doing severe damage to fatty tissue, DNA, and proteins in your body. Over time, the damage (oxidation) can lead to several diseases such as diabetes, atherosclerosis, inflammatory conditions, high blood pressure, heart disease, neurodegenerative diseases (e.g. Parkinson's and Alzheimer's), cancer and aging.

There are many different types of antioxidants to defend against oxidative stress. Anthocyanins are a type of antioxidant that is water-soluble pigments responsible for the red, purple, and blue colors of fruits and vegetables. Blueberries, acai berries, blackberries, pomegranates, red grapes, raspberries, cranberries, red cabbage, black currants, purplish blue-colored leafy vegetables, grains, roots, and tubers that are the edible vegetables also contain anthocyanins. The amount of anthocyanins varies among the different fruits and vegetables<sup>2</sup>. Traditionally, anthocyanin pigments have been used as natural food colorants and as medicines to treat diseases<sup>2</sup>. Scientists continue to research the anthocyanins found in these plants and foods to create phytopharmaceutical products. Research suggests eating foods containing anthocyanins are beneficial for reducing the risk for cardiovascular disease, cancer, and diabetes, improving visual health, suppressing weight gain, fighting against microbial activity<sup>2</sup> and improves memory and brain function<sup>4</sup>.

## References

1. Carlsen, M. H., Halvorsen, B. L., Holte, K., Bøhn, S. K., Dragland, S., Sampson, L., Willey, C., Senoo, H., Umezono, Y., Sanada, C., Barikmo, I., Berhe, N., Willett, W. C., Phillips, K. M., Jacobs, D. R., & Blomhoff, R. (2010). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutrition Journal*, 9(1), 3. <https://doi.org/10.1186/1475-2875-9-3>
2. Khoo, H. E., Azlan, A., Tang, S. T., & Lim, S. M. (2017). Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food & nutrition research*, 61(1), 1361779-1361779. doi:10.1080/16546628.2017.1361779
3. Giorgio, Marco, Mirella Trinei, Enrica Migliaccio and Pier Giuseppe Pelicci. 2007. Hydrogen peroxide: a metabolic by-product or a common mediator of ageing signals? *Nature Reviews Molecular Cell Biology* 8:722-728
4. Krikorian, R., Shidler, M. D., Nash, T. A., Kalt, W., Vinqvist-Tymchuk, M. R., Shukitt-Hale, B., & Joseph, J. A. (2010). Blueberry supplementation improves memory in older adults. *Journal of agricultural and food chemistry*, 58(7), 3996-4000. doi:10.1021/jf9029332



# Lab Procedure

1. Prior to beginning the experiment, read the background information sheet about antioxidants and anthocyanins and complete the "Do you like to eat fruits and vegetables?" worksheet.
2. At your table, you will find 4 clear cups, each containing 60 milliliters (mL) or 4 Tablespoons (Tbsp.) of a different juice: red cabbage, blueberry, dark cherry and strawberry. There should be 4 clear cups each containing 60mL (4 tablespoons) of hydrogen peroxide. Another item at your desk will be a timer.
3. Set your timer to zero.
4. Pour, at the same time, one cup of hydrogen peroxide (free radical) into one cup of juice. (**NOTE:** this can be achieved by each student in the group pour the hydrogen peroxide at the same time.).
5. Immediately start the timer.
6. Look at the cups every 5 minutes for an hour.
7. Place an X in the box for each solution in a 5-minute interval until the solution becomes clear. After the solution becomes clear, do not place an X in the box.
8. At the end of the activity, use the data recorded in your workbook to create a bar graph illustrating the amount of time (minutes) needed for the hydrogen peroxide (free-radicals) to remove the purple/red color from the solution.
9. After creating the bar graph, students should answer the questions on the discussion, conclusion and applications of scientific concept worksheets.
10. Have fun!



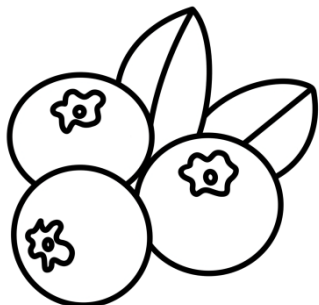


# Do you like to eat fruits and Vegetables?

*Below are some are some foods high in antioxidants. Share if you like or dislike eating the fruits or vegetables below. Explain why these foods are good for your health .*

**Do you like eating blueberries? Circle YES or NO**

Explain why blueberries are healthy to eat.



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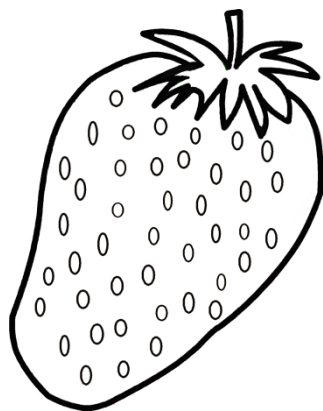
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**Do you like eating strawberries ? Circle YES or NO**

Explain why strawberries are healthy to eat.



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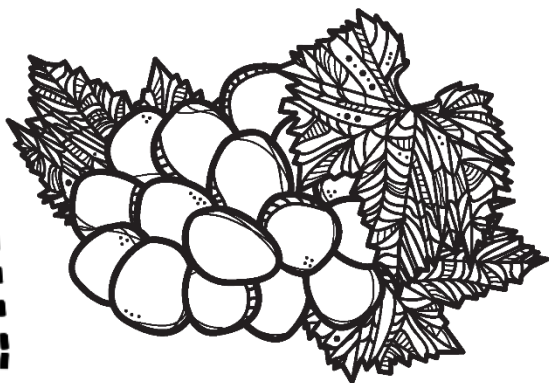
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**Do you like eating grapes? Circle YES or NO**

Explain why grapes are healthy to eat.



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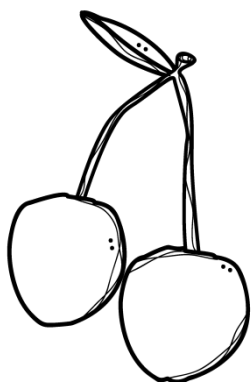
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**Do you like eating dark red cherries? Circle YES or NO**

Explain why dark red cherries are healthy to eat.



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# Experimental Design



In your own words, what are anthocyanins?

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In your own words, what are free radicals?

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In your own words, why are anthocyanins important for human health?

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What is your research question?

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What is your hypothesis ?

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Independent Variable \_\_\_\_\_

Dependent Variable \_\_\_\_\_

Experimental Variables \_\_\_\_\_

Control Variable \_\_\_\_\_

Standardized Variables \_\_\_\_\_

Name \_\_\_\_\_

Date \_\_\_\_\_

# Using Hydrogen Peroxide to Measure Antioxidant Strength in Fruits and Vegetables

## Data Collection Sheet

**INSTRUCTIONS:** Place an X in the box for each solution in a 5-minute interval until the solution becomes clear. After the solution becomes clear, do not place an X in the box.

**Table 1.** The amount of time (minutes) for the solution to become clear after adding hydrogen peroxide (free radicals).

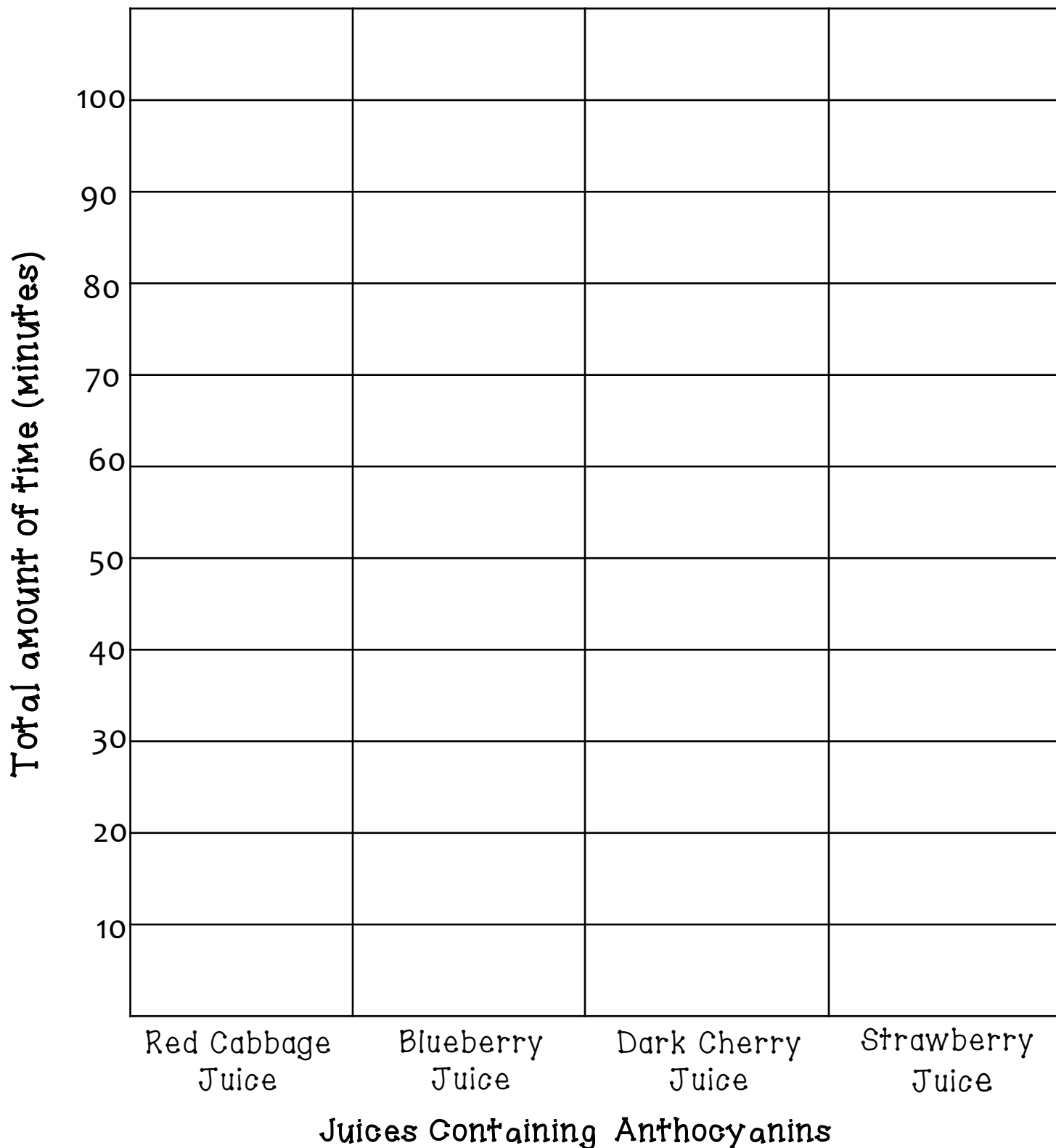
| Solution          | 0 min | 5 min | 10 min | 15 min | 20 min | 25 min | 30 min |
|-------------------|-------|-------|--------|--------|--------|--------|--------|
| Red Cabbage Juice |       |       |        |        |        |        |        |
| Blueberry Juice   |       |       |        |        |        |        |        |
| Dark Cherry Juice |       |       |        |        |        |        |        |
| Strawberry Juice  |       |       |        |        |        |        |        |

**Table 2** The amount of time (minutes) for the solution to become clear after adding hydrogen peroxide (free radicals).

| Solution          | 35 min | 40 min | 45 min | 50 min | 55 min | 60 min | 65 min |
|-------------------|--------|--------|--------|--------|--------|--------|--------|
| Red Cabbage Juice |        |        |        |        |        |        |        |
| Blueberry Juice   |        |        |        |        |        |        |        |
| Dark Cherry Juice |        |        |        |        |        |        |        |
| Strawberry Juice  |        |        |        |        |        |        |        |

# Total Amount of Time for the Fruit and Vegetable Juice to Become Clear Bar Graph

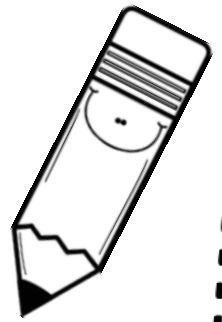
Create a **bar** graph illustrating the amount of time (minutes) needed for the hydrogen peroxide (free-radicals) to remove the purple/red color from the solution.



Name \_\_\_\_\_

Date \_\_\_\_\_

# Discussion



*Answer the follow up questions below. Use your textbook or any other reliable scientific resources to justify your answer.*

Based on your data table, did all of the fruits and vegetable lose their color after interacting with hydrogen peroxide for 60 minutes? Explain you answer.

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Which fruits or vegetable defended the longest against free radicals? Explain your answer.

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Which fruits or vegetables defended the shortest against free radicals? Explain your answer

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Based on your data, which fruits or vegetables included in this experiment have the highest amount of antioxidants? Explain you answer.

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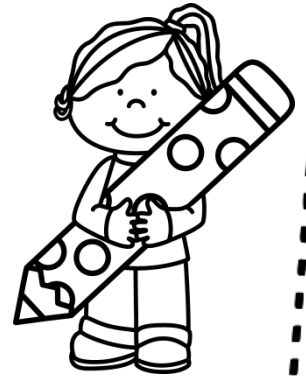
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# Conclusions



*Answer the follow up questions below. Use your textbook or any other reliable scientific resources to justify your answer.*

Was your hypothesis correct? Circle **Yes** or **No**. Explain your answer.

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Did you experience any limitations while conducting your experiment? Circle **Yes** or **No**. Explain your answer.

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What can you conclude from this study?

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What did you learned from participating in this anthocyanins study?

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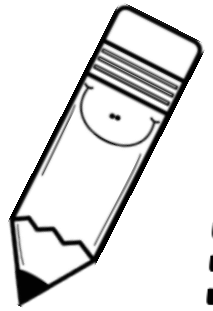
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## Application of Scientific Concepts



*Answer the follow up questions below. Use your textbook or any other reliable scientific resources to justify your answer.*

Based on what you learned about anthocyanins, which fruits or vegetables other than red cabbage, blueberries, strawberries, and dark cherries could you find at a grocery store or farmer's market to include in your diet? Explain your answer.

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What can you do to improve your study? Explain your answer.

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If you could conduct another anthocyanin experiment, list **3** fruits and vegetables you would like to test. Explain your answer.

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Thank you for choosing FEWLM to teach scientific inquiry! 😊

We hope that this workbook provided an enjoyable learning experience for your aspiring scientist. We appreciate teachers, STEM outreach instructors, parents and grandparents for selecting FEWLM to teach scientific inquiry.

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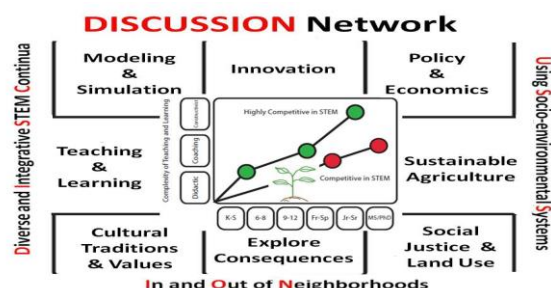
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Food, Energy, and Water Learning Module (FEWLM)

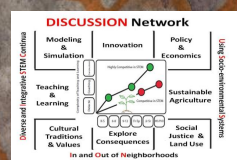
# Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model Workbook



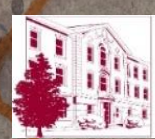
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# Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model



## SUMMARY

The “Exploring the Link between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model” workbook is a hands-on multi-week activity that allows students to continue practicing the scientific process while learning about soil physical and chemical properties, gardening practices, and water quality. This is a fun activity for elementary and middle school youth to learn about applying sustainable practices for growing food and the implications of land management on water quality. During this activity, students will collaborate as a research team to create mini-garden models with the aim of investigating the practice of applying organic materials, such as grass clippings, leaves, or straw on plant growth; nitrate leaching and water movement through a soil profile. Moreover, students will learn how the carbon to nitrogen (C:N) ratios of the organic materials influence the rate of nitrogen availability for plant uptake. The mini-garden models will consist of using a 2L plastic bottle, cheese cloth, rubber bands, plastic cups, radish seeds and various layers of soil textures. This activity is designed for students to collect plant, soil and water quality data on a daily basis for at least one month. At the end of the experiment, students will calculate the mean, create line graphs, and use their results to complete their discussion and conclusion worksheets. Moreover, they will be able to self-reflect on what they learned during this experience.

## Background Information

As the population on the planet continues to grow, the need for sustaining healthy ecosystems while meeting the demand for food and other goods and services becomes a challenge. One approach to tackle this challenge is shifting from industrialized methods of supplying food to environmentally-friendly sustainable practices. Sustainable agriculture provides an holistic approach to growing environmentally-friendly foods by integrating the economy (the amount of money generated from the crops), environment (the affects of growing crops on the quality of air, land and water) and society (the impacts of the food on human health).<sup>1,2</sup> The overall principle of sustainable agriculture is to provide the needs of the present society while preserving the quality of natural resources for future generations.<sup>1</sup> Producing food sustainability reduces the use of nonrenewable resources, synthetic fertilizers, non-biological pesticides and manure with excessive amounts of nitrogen.<sup>2</sup> Furthermore sustainable agriculture emphasizes healthy, fertile soils with a diverse population of microorganisms, sufficient organic matter and suitable pH.<sup>2</sup>

There are many different types of sustainable agriculture such as planting crops that naturally increase the amount of nitrogen in the soil without using fertilizers (nitrogen fixating plants), growing a diversity of crops throughout the year to sustain soil quality, mixing trees, shrubs and crops in the same area, applying sensible water management practices and using of biological organisms for pest management.<sup>3,4</sup> For example, growing corn, beans and squash around trees provides green manure, increases crop yield, improves soil structure and the accumulation of organic matter, enhance biological activity, and reduces soil erosion.<sup>1, 4</sup> Learning about and supporting agroecology research is important to help farmers adopt sustainable practices<sup>4</sup>, because the discovery of new scientific evidence could offer a different viewpoint of how society defines sustainable agriculture.<sup>1</sup>

## References

1. Brodt, S., Six, J., Feenstra, G., Ingels, C. & Campbell, D. (2011) Sustainable Agriculture. Nature Education knowledge 3(10): 1
2. Weil, Ray R. (1990) Defining and Using the concept of Sustainable Agriculture. Journal of Agronomy Education. 19(2): 126-130
3. Cunningham, William P. and Mary Ann Cunningham. (2018) Environmental Science – A Global Concern. 14<sup>th</sup> ed. McGraw Hill Education. New York.
4. Union of Concerned Scientists. (2019) Solutions: Advance Sustainable Agriculture - Using Science-based Practices, We Can Produce Abundant Food While Preserving Our Soil, Air and Water.  
<https://www.ucsusa.org/our-work/food-agriculture/solutions/advance-sustainable-agriculture>

## QUICK LOOK

**Grade Level:** 3<sup>rd</sup> – 8<sup>th</sup> graders

**Subjects:** Science, Math, Writing and Statistics

**Preparation:** 24 hours or less

**Duration:** This activity is designed for 19 days

**Group Size :** 4 groups of 8 students per Mini-Garden Model

**Estimated Cost:** \$100.00



**FOCUS QUESTION:** What is the impact of environmentally-friendly gardening practices on radish growth, soil quality and water movement through a soil soil profile?



# Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model



## MATERIALS NEEDED FOR ACTIVITY

Below are the materials needed to complete the mini-garden model. There are two tables provided below that contain the items required to construct the mini-garden model and carryout the experiment. Table 1 is the list of supplies the instructor needs to be purchased or ask to be donated by the PTA, parents or the school. To minimize cost, we encourage instructor s to reuse items from previous FEWLM activities. Therefore we provided a list of items that can be reused from the previous FEWLM activities (Table 2). The price for each item is rounded to the nearest dollar.

**TABLE 1. SUPPLIES NEEDED TO BE PURCHASED** (\*supplies can be used in year 2 or other FEWLM activities)

| Item   | Recommended Vendor  | Number of Item | Total Price |
|--|---------------------|----------------|-------------|
| Radish Seeds   | Home Depot          | 1 pack         | \$2.00      |
| Mosser Lee 5 lbs. Desert Sand Soil Cover                       | Home Depot          | 1 bag          | \$4.00      |
| 32-Quart Harvest Organic Natural and Organic Potting Soil Mix* | Lowes               | 1 bag          | \$9.00      |
| <b>OPTIONAL:</b> Red Clay - Backyard                           | ---                 | ---            | ---         |
| 9-oz. Clear Plastic Tumblers, 10-ct. Packs                     | Dollar Tree         | 1 bag          | \$1.00      |
| Hold All Soil Test Kit   | Lowes               | 3 packs        | \$36.00     |
| Tetra 5 in 1 Easy Strips Accurate Aquarium Test Kit            | Walmart             | 1 pack         | \$12.00     |
| Hydro Crunch Soil Moisture and Light Meter                     | Lowes               | 2 meters       | \$22.00     |
| Cheesecloth  | Walmart             | 1 pack         | \$3.00      |
| Measuring cups   | Dollar Tree         | 6 packs        | \$6.00      |
| <b>DONATED:</b> Empty 2 liter soda bottle                      | Donated by Families | 6 bottles      | \$0.00      |
| Jot Pointed Tip Easy Grip Kids Scissors, 2ct pack              | Dollar Tree         | 6 pair         | \$3.00      |
| <b>Yard Litter</b> – Leaves, Straw , Turfgrass Clippings       | ---                 | ---            | ----        |
| Deionized Water  | Local Grocery Store | 2 gallons      | \$2.00      |
| <b>TOTAL</b>   |                     |                | \$100.00    |

**TABLE 2. SUPPLIES USED DURING PREVIOUS FEWLM ACTIVITIES**

| Item  | Previous Activity  |
|---|--------------------|
| Jot 12 inch Translucent Plastic Rulers 3-ct pack*               | Seed Germination   |
| Teaching Tree Plastic Test Tubes with Holders Set 2 count pack* | Seed Germination   |
| Sharpie Fine Point Permanent Marker, Black                      | Naked Hen Egg      |
| Cooking Concepts Digital Electronic Kitchen Timers              | Naked Hen Egg      |
| Crayons or Color Pencils  | m&m's® or Skittles |



# Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model



## TEACHER PREPARATION AND INSTRUCTIONS

*Prior to beginning this activity:*

1. A workbook should be printed and assembled for each student. Print only the pages appropriate for their grade level.
2. The teacher should lead a discussion about the physical and chemical properties of soils, importance of on healthy soils for crop production and the impacts of agriculture on water quality.
3. This activity can encourage students to aspire to construct a garden in their community.

*After completing the activity:*

1. Teachers should encourage students to reflect on what they learned while completing this activity.
2. Teachers should lead a class discussion focusing the on variability of germination rates for each type of seed, the need for planting several seeds to ensure plant growth, the importance for biodiversity as it relates to food options and how science is applied to our everyday decisions.

## LEARNING OBJECTIVES *Based on Next Generation Science Standards\**

### **3<sup>rd</sup>-5<sup>th</sup> grade**

- A system can be described in terms of its components and their interactions. (3-LS4-4)
- Plants acquire their material for growth chiefly from air and water. (5-LS1-1)
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. (3-PS2-2), (4-ESS2-1), (4-PS3-2)
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)
- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2), (3-LS4-2)
- Represent data in tables and various graphical displays to reveal patterns that indicate relationships. (3-ESS2-1)
- Most scientists and engineers work in teams. (4-PS3-4)
- Observable phenomena exist from very short to very long time periods. (3-LS4-1)
- Science affects everyday life. (3-ESS3-1), (4-PS3-4)
- Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-4)
- Science findings are limited to questions that can be answered with empirical evidence. (5-ESS3-1)

### **6<sup>rd</sup>-8<sup>th</sup> grade**

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (MS-LS2-1)
- Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (MS-LS2-5)
- Develop a model to describe phenomena. (MS-LS2-3)
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)
- Analyze and interpret data to provide evidence for phenomena. (MS-LS2-1)
- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena. (MS-LS2-2)
- Science disciplines share common rules of obtaining and evaluating empirical evidence. (MS-LS2-4)
- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS2-5)

\*NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Name \_\_\_\_\_

Grade Level \_\_\_\_\_

# Exploring the Link Between Terrestrial Ecosystems and Water Quality Using a Mini-Garden Model

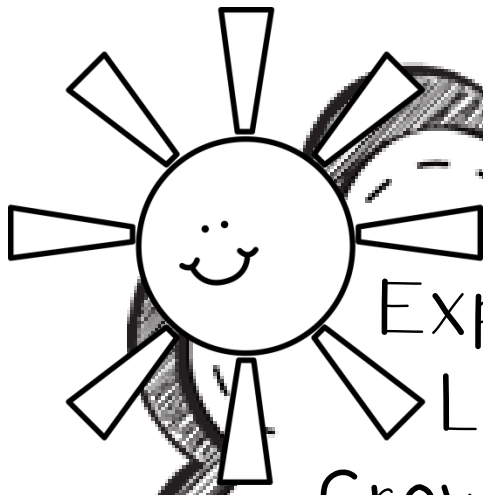
| Criterion                                 | Exemplary = 4   | Proficient = 3  | Approaching Proficiency = 2                                | Non-Proficient = 1                                | Score      |
|---|---|---|--|---|------------|
| <b>APPEARANCE</b>                         | Neat and easy to read                                 | Somewhat neat and easy to read                        | Neat and difficult to read                                 | Not neat and very difficult to read               |            |
| <b>HYPOTHESIS</b>                         | Hypothesis stated and explained well                  | Hypothesis stated and vaguely explained               | Hypothesis stated and inadequately explained               | Hypothesis stated but not explained               |            |
| <b>DATA COLLECTION</b>                    | Collected all data correctly                          | Collected most data correctly                         | Collected some data correctly                              | Collected few data correctly                      |            |
| <b>DATA ANALYSIS</b>                      | Calculated all data correctly                         | Calculated most data correctly                        | Calculated some data correctly                             | Calculated few data correctly                     |            |
| <b>GRAPHS</b>                             | Correctly matches all the data analysis tables        | Correctly matches most of the data analysis           | Correctly matches some of the data analysis                | Correctly matches few data correctly              |            |
| <b>USE OF COLOR IN GRAPHS</b>             | Attractive with appropriate use of all color          | Attractive with appropriate use of most of the colors | Attractive with appropriate use of some of the colors      | Attractive with appropriate use of a few colors   |            |
| <b>RESULTS &amp; GRAPH INTERPRETATION</b> | Answered all questions correctly                      | Answered most of questions correctly                  | Answered some of questions correctly                       | Answered few questions correctly                  |            |
| <b>DISCUSSION</b>                         | Hypothesis accepted or rejected and clearly explained | Hypothesis accepted or rejected but vaguely explained | Hypothesis accepted or rejected but inadequately explained | Hypothesis accepted or rejected but not explained |            |
| <b>CONCLUSIONS</b>                        | Overall experiment explained                          | Overall experiment mostly explained                   | Overall experiment somewhat explained                      | Overall experiment not explained                  |            |
| <b>Additional Comments:</b>               |   |   |  | <b>TOTAL POINTS</b>                               | <b>/36</b> |

## OVERALL ACTIVITY PERFORMANCE

*Circle the Description that matches each student's score*

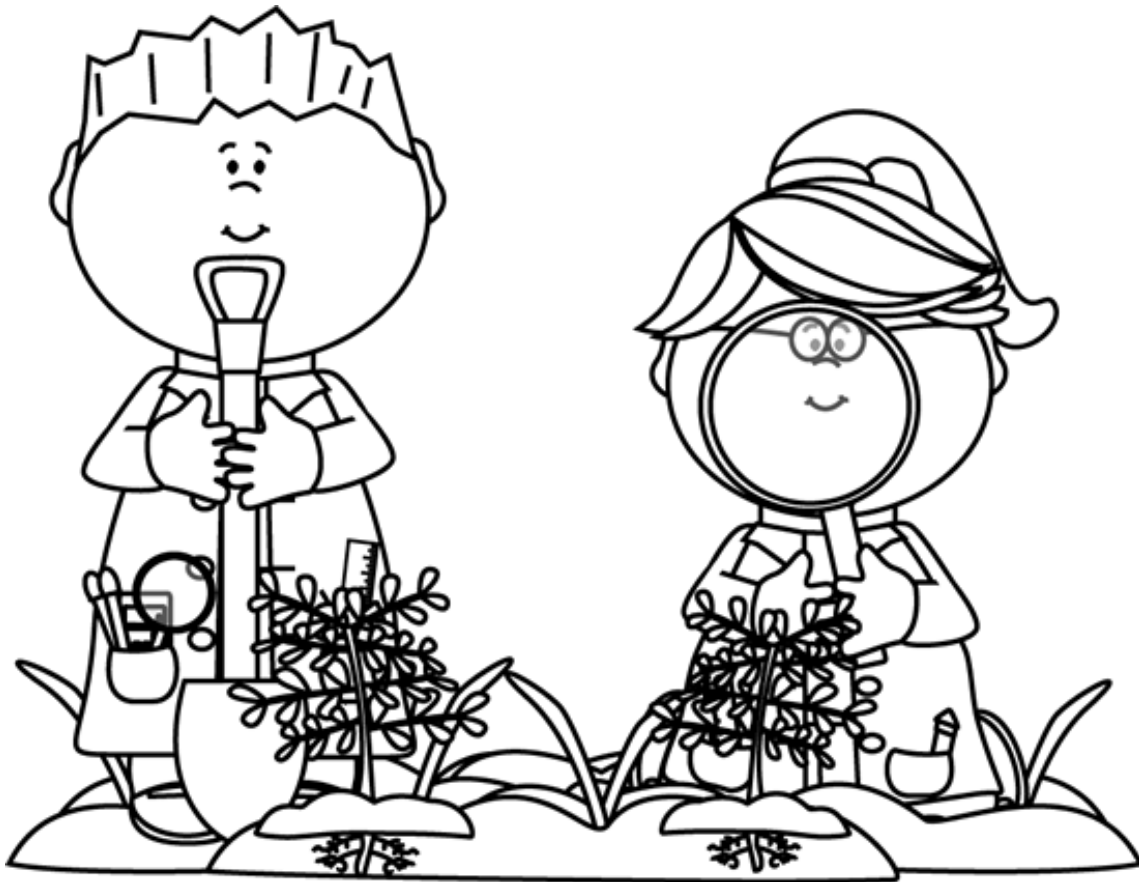
| Score             | Descriptive             |
|-------------------|-------------------------|
| <b>36-33</b>      | Exemplary               |
| <b>32-29</b>      | Proficient              |
| <b>28-26</b>      | Approaching Proficiency |
| <b>25 or less</b> | Non-Proficient          |





Food, Energy, and Water Learning Module (FEWLM)

# Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model



This Workbook Belongs to: \_\_\_\_\_

# Scientific Vocabulary and Definitions

**Abiotic Factors:** non-living (Physical and chemical) components of an ecosystem, such as light, temperature, nutrient availability, oxygen availability, salinity & fire

**Available water:** The amount of water available for plant uptake.

**Biology:** the study of life or living organisms

**Biodiversity:** the variation of species living in the distinct ecosystems within the biosphere on Earth.

**Biomolecules:** are substance provided by living organisms. Biomolecules consist of carbohydrates (sugars), amino acids (proteins), lipids (fats) or nucleic acids (DNA and RNA).

**Biotic Factors:** living or once living components of an ecosystem, such as plants, animals, bacteria, archaea, fungi, & protists.

**Decomposers:** organisms, such as bacteria, fungi, worms, some insects, that breaks down organic molecules in waste and dead plants and animals into simple organic molecules, which are returned to the ecosystems as inorganic nutrients

**Ecology:** The study of the interactions between species and their environment.

**Economy:** Making and selling of products

**Ecosystems:** biotic and abiotic factors interacting within the same area

**Ecosystem Services:** good and services provided by nature that are free and vital for human survival.

**Food security:** the availability of food for people to eat on a daily basis.

**Garden:** a small area of land designated for growing vegetables, fruits, herbs or flowers

**Groundwater:** freshwater that is held deep underground within the lower layers of a soil profile or between permeable or cracked rock layers. The groundwater table begins at the top of the zone of saturation.

**Harvest:** the removal of fully grown plants or crops.

**Limiting factors:** Any biotic or abiotic factor that limits growth and survival of a population of species within an ecosystem.

## Sources

- Hoefnagels, Marielle (2012) Biology: Concepts and Investigation. 2<sup>nd</sup> ed. McGraw Hill Education. New York, NY.
- Brady, Nyle C. and Ray R. Weil. (2004) Elements of the Nature and Properties of Soils. 2nd ed. Pearson Prentice Hall. Upper Saddle River, New Jersey.
- Buol, S.W., R.J. Southard, R.C. Graham, and P.A. MCDaniel (1997) Soil Genesis and Classification. 5<sup>th</sup> ed. Blackwell Publishing Company
- Cunningham, William P. and Mary Ann Cunningham (2018). Environmental Science: A Global Concern. 14<sup>th</sup> ed. McGraw Hill Education. New York, NY.





# Scientific Vocabulary and Definitions

**Non-renewable Resources:** Resources, such as fossil fuels, with a limited or fixed amount available for consumption or use.

**Organic molecules:** biomolecules that contain the carbon atom.

**Organic fertilizers:** materials made by living organisms, such as plants and animals

**Producers:** organisms, such as plants living on land and in the water, that produce oxygen and food for consumers, such as animals, to eat. These species are at the bottom of the food chain and obtain energy and nutrients from non-living sources, such as photosynthesis.

**Soil:** is a natural medium consisting of a mixture of loosely arranged solid particles (minerals and organic matter), water, and air capable of supporting plant growth on land.

**Soil Horizon :** Layer of soil with a color, texture, structure, chemical factors and biological organisms that differ from the layer above and below within a profile. The major soil layers are categorized as one of the following horizons: O (organic matter), A (Topsoil), B (subsoil) C (Parent material) and R (bedrock). (See the next page for the description of each soil layer)

**Soil Infiltration:** Amount of water that enters a soil profile during a given time period

**Soil Permeability:** Amount of water that moves through a soil profile during a given time period

**Soil Porosity:** Amount of space between soil particles. Earth worms and plant roots increase the space between soil particles, which increase the amount of air and water moving in and out of the soil profile.

**Soil Profile:** A vertical section of soil that consists of an series of horizons extending from the soil surface to the bedrock.

**Soil Texture:** The percentage of sand, silt and clay particles. Soil texture is classified based on 12 different types of soils.

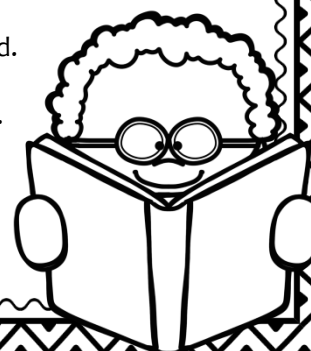
**Synthetic fertilizers:** man-made chemicals used to provide nutrients for plant growth

**Zone of aeration:** area within the soil profile where the soil pores are filled with both air and water

**Zone of saturation:** the area within the soil profile where the soil pores are filled only with water.

## Sources

- Hoefnagels, Marielle (2012) Biology: Concepts and Investigation. 2<sup>nd</sup> ed. McGraw Hill Education. New York, NY.
- Brady, Nyle C. and Ray R. Weil. (2004) Elements of the Nature and Properties of Soils. 2<sup>nd</sup> ed. Pearson Prentice Hall. Upper Saddle River, New Jersey.
- Buol, S.W., R.J. Southard, R.C. Graham, and P.A. McDaniels (1997) Soil Genesis and Classification. 5<sup>th</sup> ed. Blackwell Publishing Company
- Cunningham, William P. and Mary Ann Cunningham (2018). Environmental Science: A Global Concern. 14<sup>th</sup> ed. McGraw Hill Education. New York, NY.





# Major Horizons or Layers of a Soil Profile

The soil profile below highlights the major horizons. Older soil profiles are well developed and contains several distinct soil horizons; however younger soil profiles consist very limited development. Soil profile development will vary based on the parent material, temperature, amount of rainfall, presence of biological organisms, time and location along the landscape.



**O Horizon (Organic Layer):** Layer of decomposing organic materials from plants and animals.

**A Horizon (Top Soil Layer):** contains a mixture of organic material and mineral soils. This layer contains biological organisms such as plant roots, animals and microbiological organisms.

**B Horizon (Subsoil Layer):** buildup of clay and other minerals that moved down (leached) from the A horizon as water move down (percolate) through the soil profile.

**C Horizon (Parent Material Layer):** Breakdown (weathering) of the parent material or bedrock.

**R Horizon (Bedrock):** Layer of solid rock

# Background Information

The sun provides constant energy that is cycled through organisms, atmosphere, water and soil. All organisms require energy to live, grow, reproduce and survive. As the energy flows through ecosystems, producers transfer energy to consumers and decomposers through food chains and food webs. However, a large percentage of the energy in each food source is lost as heat at each trophic level.

Photosynthesizing organisms (i.e. Plants, algae, phytoplankton, etc.) are the basis of food webs. These autotrophic organisms use inorganic chemicals to produce sugars and organic compounds. Primary consumers (i.e. rabbits, caterpillars, deer, zooplankton, etc.)<sup>2</sup> obtain energy from eating only producers. Secondary consumers are heterotrophic organisms that eat producers, primary consumers and some decomposers<sup>2</sup>. Many secondary consumers are carnivores (i.e. lizards, some birds, spiders, etc.)<sup>3</sup>, but can be omnivores (i.e. coyotes, humans, bears, red fox, raccoons)<sup>3</sup>. Tertiary consumers (i.e., bald eagles, bobcats, snakes, hawks, alligators, etc.)<sup>2</sup> are the carnivores that eat primary consumers (herbivores) and secondary consumers (omnivores). Decomposers (bacteria, fungi, worms, some insects) are heterotrophs that breakdown dead tissue and organic waste from all the trophic levels and recycle the inorganic nutrients back into the environment to be used by plants and other organisms. Individual organisms can be involved in multiple food chains. For example, earthworms can be primary consumers and decomposers, because they eat plants and dead organisms.

Abiotic factors, such as sunlight, moisture, temperature, nutrient availability, oxygen availability, salinity, etc. influence the diversity of species within ecosystems. Scarcity of water, nutrient and food availability, climate, competition within and amongst species, predation, disease, etc. are limiting factors that restrict the success of species developing, reproducing and surviving within an ecosystem. Each species has a range in which they can tolerate environmental changes. Species sensitive to environmental changes are often used as indicator species to examine the health of ecosystems.<sup>1</sup>

Water connects terrestrial (land) and aquatic (water) ecosystems. Freshwater systems such as lakes, ponds, streams and rivers are naturally low in nutrients. Plants such as forest and grasses uptake nutrients and keep topsoil in place. Soils are complex ecosystems. The interaction between plants and soils slows down the movement of water through landscapes and soil profiles, by intercepting the rainfall and reducing the frequency and volume of overland flow. Furthermore, the soil texture within each horizon influences the movement of air, water and nutrients needed for plant growth. Plant roots and organisms, such as earthworms, increase the amount of large soil pores (macropores), which influences the rate of soil infiltration and permeability. Organisms, such as bacteria, archaea, fungi, protozoa, nematodes etc., residing in the topsoil (A horizon) filter out, recycle and remove nutrients from the soil solution prior to reaching the nearest water system.

## References:

1. Hoefnagels, Marielle (2019) *Biology: The Essentials*. McGraw Hill.
2. Simon, Eric J. (2015) *Biology: The Core*, Pearson
3. NC Wildlife Commission. North Carolina Species. 2018. <http://ncwildlife.org/Learning/Species>





# Background Information

As the population on the Planet continues to grow, the need for sustaining healthy ecosystems while meeting the demand for food and other goods and services becomes a challenge. One approach to tackle this challenge is shift from industrialized methods of supplying food to environmentally-friendly practices. Sustainable agriculture provides an holistic approach to growing environmentally-friendly foods by integrating the economy (the amount of money generated from the crops), environment (the affects of growing crops on the quality of air, land and water) and society (the impacts of the food on human health)<sup>1,2</sup>. The overall principle of sustainable agriculture is to provide the needs of the present society while preserving the quality of natural resources for future generations<sup>1</sup>. Producing food sustainability reduces the use of nonrenewable resources, synthetic fertilizers, non-biological pesticides and manure with excessive amounts of nitrogen<sup>2</sup>. Furthermore sustainable agriculture emphasizes healthy, fertile soils with a diverse population of microorganisms, sufficient organic matter and suitable pH<sup>2</sup>.

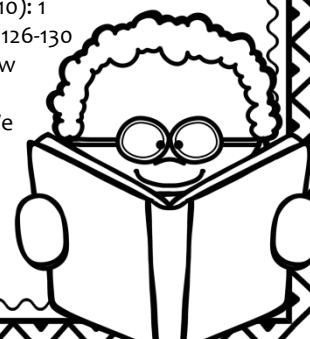
There are many different types of sustainable agriculture such as planting crops that naturally increase the amount of nitrogen in the soil without using fertilizers (nitrogen fixating plants), growing a diversity of crops throughout the year to sustain soil quality, mixing trees, shrubs and crops in the same area, applying sensible water management practices and using of biological organisms for pest management<sup>3,4</sup>. For example, growing corn, beans and squash around trees provides green manure, fruit or firewood, increases crop yield, improves soil structure and the accumulation of organic matter, enhance biological activity, and reduces soil erosion<sup>1,4</sup>. Learning about and supporting agroecology research is important to help farmers adopt sustainable practices<sup>4</sup>, because the discovery of new scientific evidence could offer a different viewpoint of how society defines sustainable agriculture<sup>1</sup>.

The “Exploring the Link Between Land Management, Plant Growth and Water Quality Using a Mini-Garden Model” is a fun activity for elementary and middle youth to continue applying the scientific process while learning about applying agricultural practices to a garden and the implications of land management on water quality. During this activity, students will collaborate as a research team to create mini-garden models with the aim of investigating the practice of applying organic materials, such as turf grass clippings, leaves, other natural materials on plant growth as well as nitrogen leaching and water movement through a soil profile. Moreover, students will learn how the carbon to nitrogen (C:N) ratios of the organic materials influence the rate of nitrogen availability for plant uptake.

The mini-garden models will consist of using a 2L plastic bottle, cheese cloth, rubber bands, plastic cups, bean seeds or other seeds and various layers of soil textures. This activity is designed for students to collect plant, soil and water quality data on a weekly basis for up to 19 days. At the end of the experiment, students will calculate the mean, create line graphs, and use their results to complete their discussion and conclusion worksheets. Moreover, they will be able to self-reflect on what they learned during this experience. So let's begin to construct your Mini-Garden Model, observe the interactions between the abiotic and biotic factors influencing plant growth and water quality by collecting data to test your hypothesis.

## References:

1. Brodt, S., Six, J., Feenstra, G., Ingels, C. & Campbell, D. (2011) Sustainable Agriculture. *Nature Education knowledge* 3(10): 1
2. Weil, Ray R. (1990) Defining and Using the concept of Sustainable Agriculture. *Journal of Agronomy Education*. 19(2): 126-130
3. Cunningham, William P. and Mary Ann Cunningham. (2018) *Environmental Science – A Global Concern*. 14<sup>th</sup> ed. McGraw Hill Education. New York.
4. Union of Concerned Scientists. (2019) *Solutions: Advance Sustainable Agriculture - Using Science-based Practices, We Can Produce Abundant Food While Preserving Our Soil, Air and Water*.  
<https://www.ucsusa.org/our-work/food-agriculture/solutions/advance-sustainable-agriculture>



# Environmental Quality Parameters

**Carbon to Nitrogen Ratios (C:N):** Soil microorganisms, like other living organisms, require nutrients, such as carbon and nitrogen to survive. Carbon is needed to build biomolecules and obtain energy to do work. Nitrogen is needed to produce enzymes, amino acid, DNA.<sup>1</sup> The amount of time it takes microorganisms to “eat” or breakdown organic material depends on the ratio of carbon and nitrogen. The C:N ratio is the amount of organic carbon to the amount of all the nitrogen in a organic material.<sup>1,2</sup> For example, on average, microorganisms have a C:N of 8:1, which means for every 8 grams of carbon, 1 gram of nitrogen is needed for their survival. Microorganisms prefer their food options (crop residues and organic materials) have a C:N ratio of 24:1. When the C:N ratio of crop residues and organic materials exceeds 30:1, the amount of time they need to eat increases and the most of the nitrogen is incorporated into them. On the other hand, when the C:N ratio is less than 30:1, microorganisms “eat” faster and more nitrogen is released in the environment for plants to uptake. The C:N ratio is important for the recycling and availability of nitrogen in soils for plant uptake.<sup>1,2</sup> Carbon to Nitrogen ratios for organic materials are provided in Table 1.

**Nitrogen:** Nitrogen is essential for all living organisms. Naturally, nitrogen concentrations are very low in freshwater systems.

**Nitrate:** Nitrate is a limiting nutrient for land and aquatic plants. High nitrate concentrations combined with high phosphate levels can result in excessive algae growth; a decline in dissolved oxygen; increase in biological oxygen demand and reduction in aquatic species (fish kills). The surface and groundwater standard for nitrate-nitrogen is 10 mg/L.<sup>2,3</sup>

**pH:** measure the acidity of a substance (concentration of H<sup>+</sup> ions) and an important limiting factor for organisms.<sup>1</sup> Environmental shifts from the ideal pH level disrupts biochemical reactions within organisms and potentially resulting in death. The ideal pH range for healthy freshwater systems to support a diversity of aquatic life and secondary recreational activities is 6 to 9.<sup>2</sup> The groundwater standard for pH ranges between 6.5 and 8.5.<sup>3</sup>

**Soil Moisture Content:** generally is the amount of water in the soil.

**Temperature:** is considered a limiting factor for living organisms, because it influences the rate of biochemical process occurring in organisms, dissolved oxygen concentration, the ability of water to carry an electrical current, and the flow of water. The temperature can vary depending on the ecosystem, time of day, and season.<sup>1</sup> Elevated temperatures increases the rate of decomposition or the break down of organic materials.

**Table 1. Carbon to Nitrogen Ratios for Organic Material Used in Gardens<sup>5</sup>**

| Organic Materials <sup>5</sup> | C:N       |
|--------------------------------|-----------|
| Vegetable Waste                | 12-20:1   |
| Grass Clippings                | 12-25:1   |
| Coffee Grounds                 | 20:1      |
| Fruit Waste                    | 35:1      |
| Leaves                         | 40-80:1   |
| Corn Cobs                      | 50-120:1  |
| Pine Needles                   | 80:1      |
| Paper                          | 150-200:1 |
| Shredded Newspaper             | 400-800:1 |

## Sources:

1. Brady, Nyle C. and Ray R. Weil. (2004) Elements of the Nature and Properties of Soils. 2<sup>nd</sup> ed. Pearson Prentice Hall. Upper Saddle River, New Jersey.
2. USDA-NRCS. (2011) Carbon to Nitrogen Ratios in Cropping Systems. US Department of Agriculture. Greensboro, NC. [soils.usda.gov/sqi](https://soils.usda.gov/sqi)
3. Missouri Department of Natural Resources. (2018). Environmental Services Program. Jefferson City, MO <https://dnr.mo.gov/env/esp/waterquality-parameters.htm>
4. NCDEQ – Water Resources Division. (2013) Groundwater Standards. NC Department of Environmental Quality. Raleigh, NC <https://deq.nc.gov/about/divisions/water-resources/planning/classification-standards/groundwater-standards>
5. Browning, Sarah. (2013) Garden Compost. NebGuide G2222. Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln. <http://extensionpublications.unl.edu/assets/html/g2222/build/g2222.htm>





# Soil Horizons Development

Use crayons or color pencils to draw the horizons for the soil profile below. Then write a description for each horizon.



**O**

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# Mini-GARDEN Module Set Up Instructions

## Lab Procedure & Instructions

1. Read the background information sheets and complete the soil horizon worksheet.
2. Design your experiment by completing the worksheets on pages 126-128.
3. After designing your experiment, construct your mini-garden model.
4. **Constructing the Plant Growing Containers**
  - A. Remove the bottle cap and invert a 2L plastic bottle.
  - B. Use a ruler to measure 15 cm from the bottle opening and mark the location with a permanent black marker.
  - C. Use a pair of scissors to remove the top portion of the bottle and to remove any ragged edges. Therefore the rim of the bottle should be smooth.
  - D. Wrap the 2 pieces of cheesecloth around the bottle opening and place a rubber band around the cheesecloth to hold it in place. Then place the plastic bottle inside the clear 9oz solo cup.
5. **Initial Soil Nutrient Measurements.** Use the *Hold All Soil test kits* to measure the soil nitrate, potassium and phosphate concentrations in the soil. Below are a few steps to consider while conducting your soil nutrient measurements:
  - A. **Preparation Day 0:** These steps will be carried out by the *instructor*.
    1. The soil should be dried prior to conducting the soil nutrient measurements.
    2. Place 1 cup of "A horizon" soil in a paper bag.
    3. The top of the paper bag should be slightly folded to prevent spillage, while allowing the soil to air-dry overnight.
  - B. **Preparation Day I:** These steps will be performed by the *youth*.
    1. Add 5 grams of air-dried "A horizon" soil to a 50 mL plastic tube.
    2. After adding the air-dried soil, add 25 mL of deionized water.
    3. Place the cap on the tube. Make sure it securely tightened.
    4. Set the timer for two minutes and shake the tube containing the soil solution.
    5. Set your timer for 30 minutes, then allow the soil solution to sit undisturbed for 30 minutes.
    6. Use the instructions provided with *Hold All Soil test Kit* to determine the amount nutrients in the soil.<sup>1</sup>
    7. Record the soil nitrogen, soil phosphorus and soil potassium data on the DAY I worksheet.
    8. Repeat these measurements on DAY I9 and record the data on the DAY I9 worksheet.

~ Additional Steps are provided on page 15 ~

### Sources

1. Hold All Decorative Plant Accessories. Soil Test Kit Operating Guide.  
[https://pdf.lowes.com/operatingguides/093432601839\\_oper.pdf](https://pdf.lowes.com/operatingguides/093432601839_oper.pdf)



Name \_\_\_\_\_

Date \_\_\_\_\_

## Mini-GARDEN Module Set Up Instructions

# Lab Procedure & Instructions

6. **Soil profile Development.** Begin creating your soil profile by pouring  $\frac{1}{2}$  cup (120mL) of sand in the bottle, followed by  $\frac{1}{4}$  (60mL) of clay (*optional layer*) and  $1\frac{1}{2}$  (~350 mL) of potted soil. Each layer of soils should be dry.
7. **Radish Seeds.** Place 5 radish seeds on top of the potted soil layer.
8. Spread 2 tablespoons (30mL) of dry potted soil to cover the radish seeds. Make sure to spread the soil evenly over the seeds.
9. Place a very small amount of an organic material (i.e. 3 to 5 small pieces of grass clippings) on top of your A horizon.
10. Add  $\frac{1}{2}$  cup of deionized water to the mini-garden model.
11. **OPTIONAL:** If any water move through the soil profile and collects in the 9 oz. clear Solo Cup at the bottom of the mini-garden module, use a nitrate test strip to measure the nitrate concentration in the water. Add the data to your data sheet and nitrate bar graph. This measurement will provide evidence of nitrate leaching through the profile into the “groundwater.” This measurement can occur after periods of watering the radish plants.
12. Now begin taking measurements and record the values on the data collection sheet.
  - A. **Soil pH Measurement:** Use a soil Hydro Crunch Soil Moisture and Light Meter to measure the soil pH. Follow the instructions accompanied with the meter to measure the soil pH. (**NOTE:** Repeat this measurement daily.)
  - B. **Soil Moisture Measurement:** Use a soil Hydro Crunch Soil Moisture and Light Meter to measure the soil moisture. Follow the instructions accompanied with the meter to measure the soil moisture. Repeat this measurement daily. (**NOTE:** Repeat this measurement daily.)
  - C. **Shoot growth:** After the shoot appears beyond the soil surface, use a ruler to measure the height (cm) of each shoot and record the height (cm) on your data sheet. (**NOTE:** Repeat this measurement daily.)
10. Record your measurements and observations on the “**Data Collection Sheet**” as suggested above.
11. HAVE FUN!



Name \_\_\_\_\_

Date \_\_\_\_\_

## A black and white line drawing of a young girl with pigtails, smiling and holding a large pencil that is decorated with polka dots. The pencil is held diagonally across her body.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

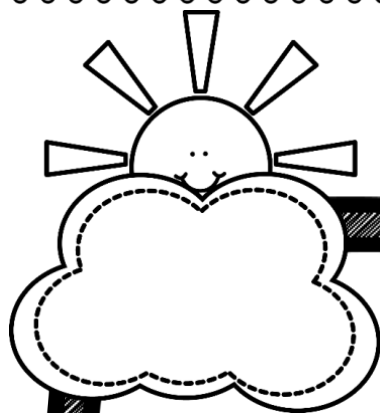
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[illegible]

Date \_\_\_\_\_



Experimental Design

## Design of your Mini-Garden Model

In the space below, draw your mini-ecosystem &  
label each component.

Name \_\_\_\_\_

Date \_\_\_\_\_

# Experimental Design



Describe the organic material your research team plan to use as additional nutrients.

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What is the Carbon to Nitrogen Ratio (C:N) for the selected organic material? \_\_\_\_\_

Why did your research team decide to use \_\_\_\_\_ as the organic material?

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Why are you growing radishes in your mini-garden model?

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What is the preferred soil pH for radishes? \_\_\_\_\_

Describe the horizons for the soil profile in your Mini-Garden Model.

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Name \_\_\_\_\_

Date \_\_\_\_\_



Day 1 Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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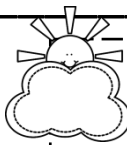
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*Draw your observations in the space below.*

## Measurements

Number of Seeds Germinated \_\_\_\_\_

Radish Seed 1 Shoot Height (cm) \_\_\_\_\_

Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Soil Nitrate (mg/L) \_\_\_\_\_

Soil Phosphate (mg/L) \_\_\_\_\_

Soil Potassium (mg/L) \_\_\_\_\_

Nitrate (mg/L) in "Groundwater" \_\_\_\_\_

If yes, what is the total amount of water added  
to your mini-garden model? \_\_\_\_\_ mL

Name \_\_\_\_\_

Date \_\_\_\_\_

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Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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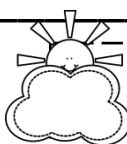
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Number of Seeds Germinated \_\_\_\_\_

Radish Seed 1 Shoot Height (cm) \_\_\_\_\_

Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_

This image shows a full page of blank, lined paper. It features approximately 28 horizontal black lines spaced evenly across the page, typical of notebook paper. The lines are thin and extend from the left edge to the right edge. There are no margins, text, or other markings on the page.

Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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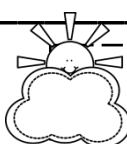
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## Measurements

Number of Seeds Germinated \_\_\_\_\_

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Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_



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Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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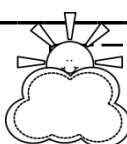
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Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_

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Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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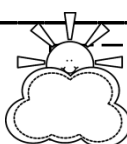
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*Draw your observations in the space below.*

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Date \_\_\_\_\_

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Date \_\_\_\_\_



Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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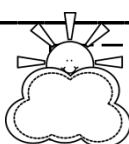
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*Draw your observations in the space below.*

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Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_

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Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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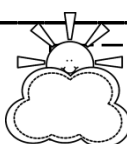
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Name \_\_\_\_\_

Date \_\_\_\_\_

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Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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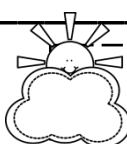
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*Draw your observations in the space below.*

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## Measurements

Number of Seeds Germinated \_\_\_\_\_

Radish Seed 1 Shoot Height (cm) \_\_\_\_\_

Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_



This image shows a full page of blank, lined paper. It features approximately 28 horizontal black lines spaced evenly across the page, typical of notebook paper. The lines are thin and extend from the left edge to the right edge. There are no margins, text, or other markings on the page.

Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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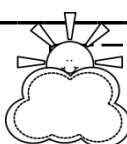
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*Draw your observations in the space below.*

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## Measurements

Number of Seeds Germinated \_\_\_\_\_

Radish Seed 1 Shoot Height (cm) \_\_\_\_\_

Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Date \_\_\_\_\_

Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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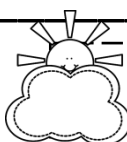
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*Draw your observations in the space below.*

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## Measurements

Number of Seeds Germinated \_\_\_\_\_

Radish Seed 1 Shoot Height (cm) \_\_\_\_\_

Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Does your soil need more water? YES or NO

If yes, how much water did you add you your soil? \_\_\_\_\_mL

Name \_\_\_\_\_

Date \_\_\_\_\_

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Date \_\_\_\_\_

Day 19 Date: \_\_\_\_\_

# Data Collection Sheet

*What do I see today... & What is different...*

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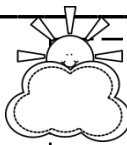
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*Draw your observations in the space below.*

## Measurements

Number of Seeds Germinated \_\_\_\_\_

Radish Seed 1 Shoot Height (cm) \_\_\_\_\_

Radish Seed 2 Shoot Height (cm) \_\_\_\_\_

Radish Seed 3 Shoot Height (cm) \_\_\_\_\_

Radish Seed 4 Shoot Height (cm) \_\_\_\_\_

Radish Seed 5 Shoot Height (cm) \_\_\_\_\_

Average Shoot Height (cm) \_\_\_\_\_

Soil pH \_\_\_\_\_

Soil Moisture \_\_\_\_\_

Soil Nitrate (mg/L) \_\_\_\_\_

Soil Phosphate (mg/L) \_\_\_\_\_

Soil Potassium (mg/L) \_\_\_\_\_

Nitrate (mg/L) in "Groundwater" \_\_\_\_\_

If yes, what is the total amount of water added  
to your mini-garden model? \_\_\_\_\_ mL

Name \_\_\_\_\_

Date \_\_\_\_\_



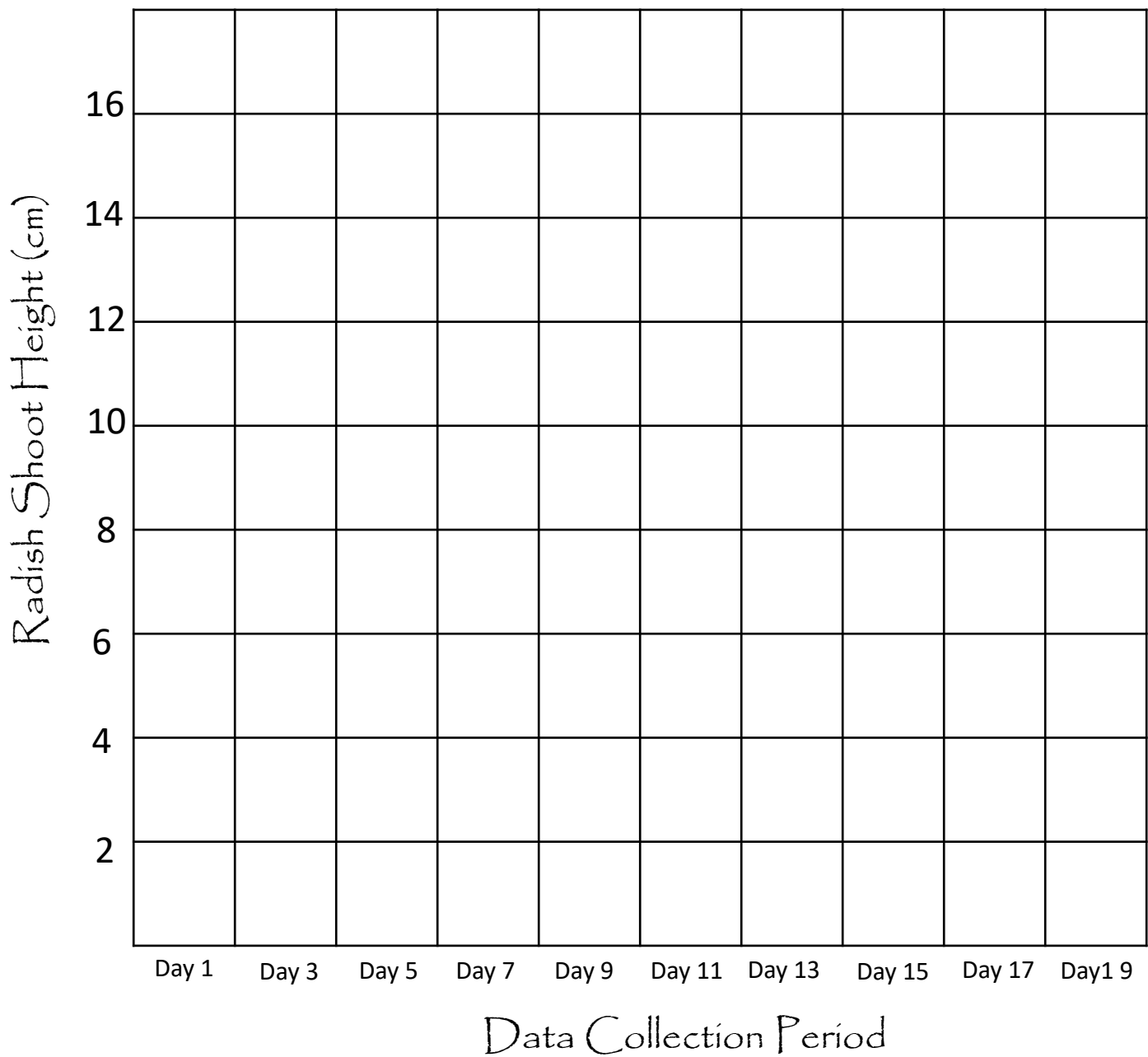
[illegible]

Date \_\_\_\_\_

## Data Collection

# Radish Shoot Height in Mini-Garden Model

Create a line graph showing the radish shoot height in centimeters over a 19 day data collection period.



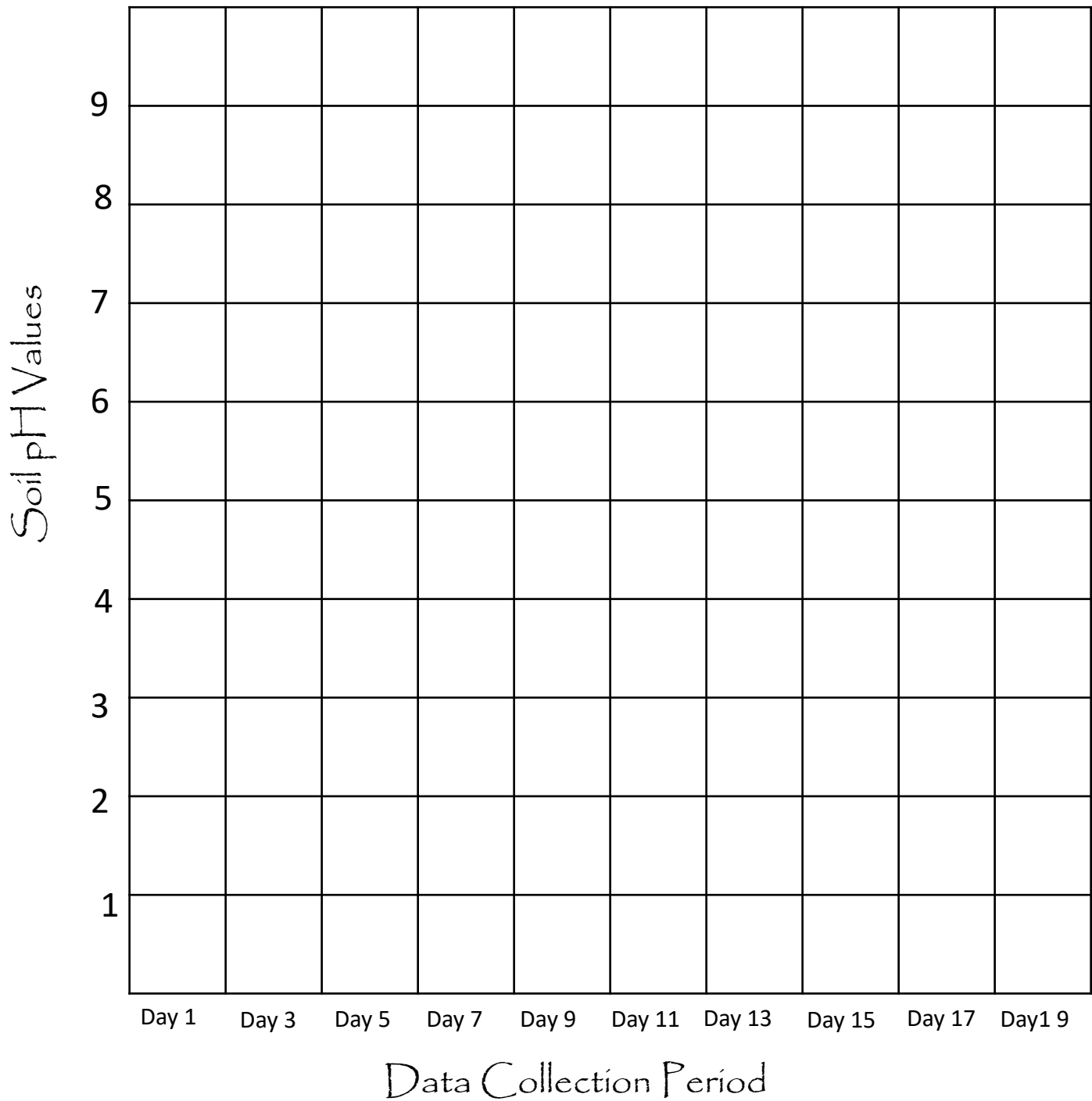
Name \_\_\_\_\_

Date \_\_\_\_\_

Data Collection

## Soil pH in Mini-Garden Model

Create a line graph showing the soil pH over a 19 day data collection period.



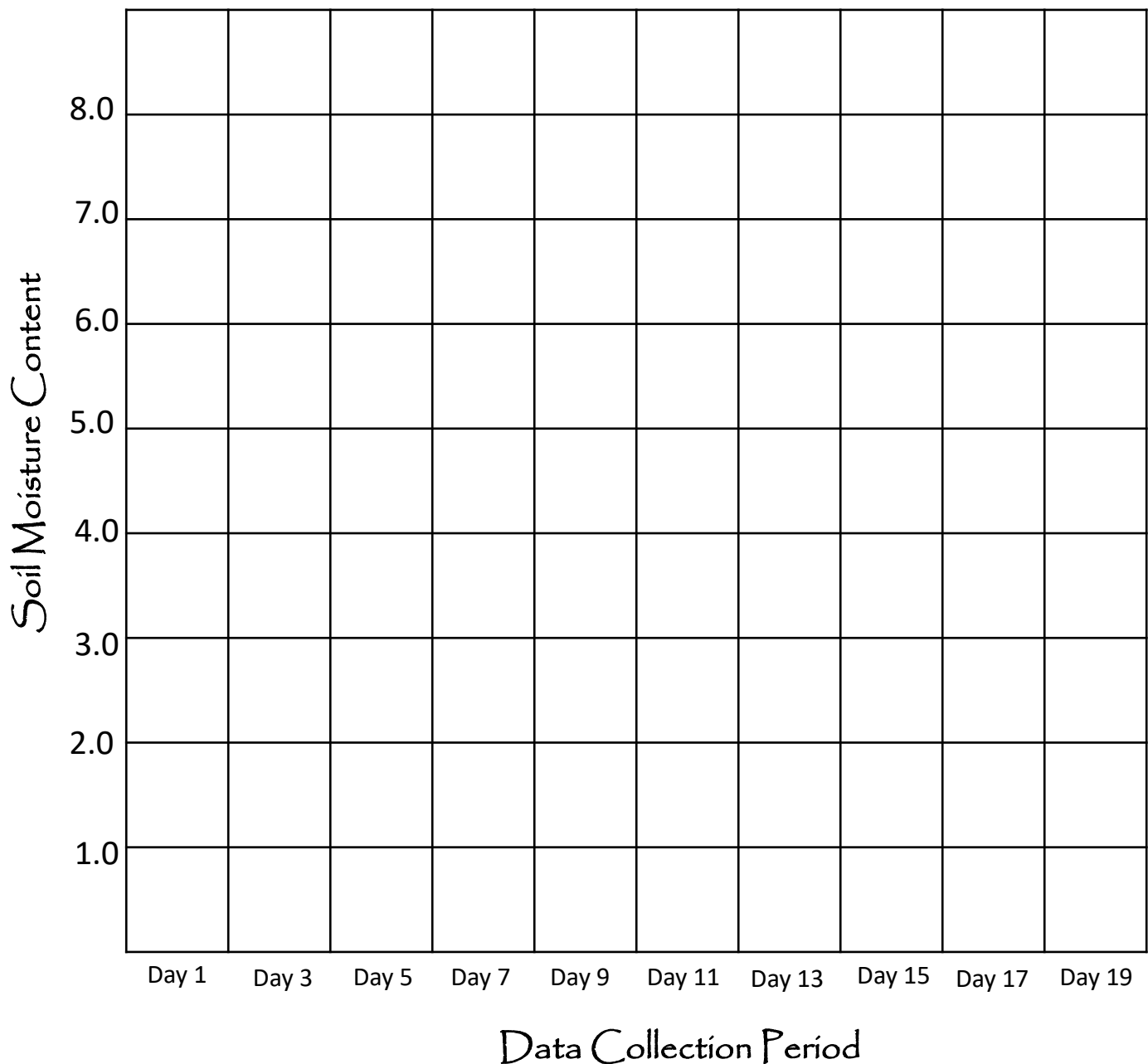
Name \_\_\_\_\_

Date \_\_\_\_\_

Data Collection

# Soil Moisture Content in Mini-Garden Model

Create a line graph showing the soil moisture content over a 19 day data collection period.



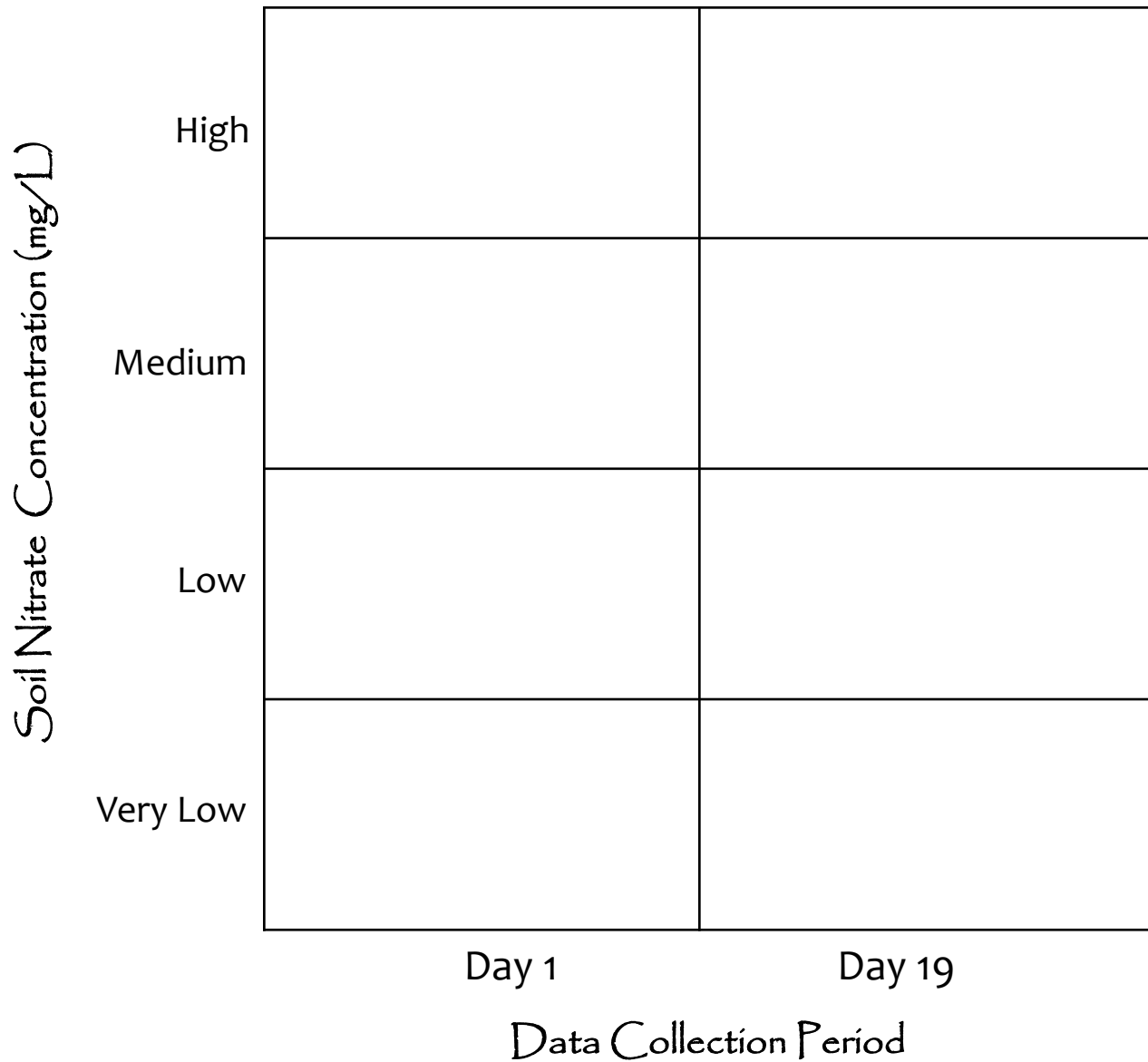
Name \_\_\_\_\_

Date \_\_\_\_\_

## Data Collection

# Soil Nitrate Concentrations in Mini-Garden Model

Create a **bar** graph showing the soil nitrate concentrations at the beginning and end of the 19 day data collection period.



Name \_\_\_\_\_

Date \_\_\_\_\_

# Results



1. How long did you carry out your experiment? \_\_\_\_\_ days.
2. What is the total amount of soil added to your mini-garden model? \_\_\_\_\_ cups
3. How many seeds did you plant in your Mini-Garden Model? \_\_\_\_\_
4. How many seeds germinated? \_\_\_\_\_
5. What fraction of seeds germination? \_\_\_\_\_
6. What percentage of seeds germinated? \_\_\_\_\_
7. What percentage of the radish plants were harvested? \_\_\_\_\_
8. If each radish plant is worth \$2 each, What is the maximum amount of money you could make? \_\_\_\_\_
9. How much money did you make from your harvest? \_\_\_\_\_
10. Did you make money or lose money? Explain your answer.

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11. Using the line graph, on what day was the radish shoot height the highest? \_\_\_\_\_
12. Did the amount of soil nitrate change between the beginning and end of the data collection period? Circle YES or NO.
13. Did the nitrate concentrations measured in the percolated water exceed the water quality standard? Circle YES or NO.
14. Based on the pH data collected, is the soil in your mini-garden model acidic, neutral or basic? Explain your answer.

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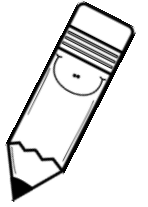
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Name \_\_\_\_\_

Date \_\_\_\_\_



## Discussion & Conclusion



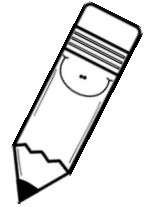
This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[illegible]

Date \_\_\_\_\_

Write it Out

# Self-Reflection



Did you experience any challenges while constructing your Mini-Garden Model? If so explain.

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If you constructed another Mini-Garden Model, discuss the modifications or improvements.

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What did you learn while participating in the Mini-Garden Model activity?

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Name \_\_\_\_\_

Date \_\_\_\_\_

Thank you for choosing FEWLM to teach scientific inquiry! 😊

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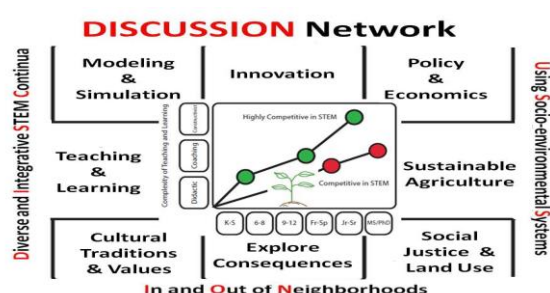
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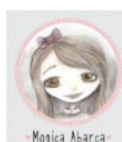
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