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**Topic:** Scientific Knowledge, Practices, and the Scientific Method  
**Duration:**  
Traditional (50 minute periods): 7 - 10 classes (adjust using professional discretion)  
Block (90 minute periods): 3 - 5 classes (adjust using professional discretion)

**Eligible Content**  
*This is what the State of Pennsylvania wants your students to know and be able to do by the end of the unit.*  
CHEM.A.1.1.2 Classify observations as quantitative and/or qualitative.  
CHEM.A.1.1.3 Utilize significant figures to communicate the uncertainty in a quantitative observation.  
BIO.B.3.3.1 Distinguish among the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.

**Performance Objectives**  
*These are examples, created by SDP teachers, of how you may translate the eligible content into learning goals for your classroom.*

1. **SWBAT** follow a multistep procedure when carrying out experiments IOT apply the scientific method.  
2. **SWBAT** to define scientific law and scientific theory IOT distinguish between them.  
3. **SWBAT** distinguish between accuracy and precision IOT to correctly utilize the SI system of measurements.  
4. **SWBAT** analyze graphs, create graphs, use formulas and convert between units IOT depict quantitative data and explain it.

**Key Terms and Definitions**

1. **Distinguish:** perceive and point out a difference  
2. **Constants:** all of the factors that are the same in both the experimental group and the control group.  
3. **Control:** the factor or subject of an experiment that is not manipulated but can be used to make comparisons between sets of data.  
4. **Dependent Variable:** the factor in an experiment that is changed or determined by manipulation of one or more other factors (independent variables).  
5. **Hypothesis:** a proposed explanation based on limited observation used as the starting point of further investigation.  
6. **Independent Variable:** the factor in an experiment that is deliberately manipulated in an experiment.  
7. **Inference:** a logical interpretation based on prior knowledge or experience. For example: You see a window broken and a baseball on the floor next to the shattered glass. You can infer that a baseball broke your window (Biology Corner, 2016, https://www.biologycorner.com/lesson-plans/scientific-method/scientific-method/)  
8. **Qualitative Observation:** observations that involve the use of one’s senses and are not measurable.  
9. **Quantitative Observation:** observations that involve measurable values  
10. **Scientific Law:** the summary of of many repeated and consistent experimental results and observations, and explanation of observable phenomenon  
11. **Scientific Theory:** an explanation for some phenomenon that is based on observation, experimentation, and reasoning.
12. **Scientific Method**: a series of steps followed to solve problems including collecting data, formulating a hypothesis, testing the hypothesis, and stating conclusions. A method of thinking through a problem to a conclusion that is substantiated.

13. **Scientific Notation**: a method of expressing a quantity as a number multiplied by 10 to the appropriate power. Proper form includes one digit to the left of the decimal times 10 to a specific power (2.0 \( \times 10^3 \))

14. **Significant Figure**: a prescribed decimal place that determines the amount of rounding off to be done based on the precision of the measurement.

15. **SI System of Measurement**: Le Système International d’Unités, the International System of Units or metric system, which is the measurement system that is accepted worldwide.

**Starting Points**

*An overview of how the content and skills of this unit connect to students' prior knowledge.*

**Prerequisite Knowledge:**

Students should already know that scientists follow a generalized set of steps to solve problems called the scientific method. In this unit students will learn that this method is flexible based on the type of problem to be solved or question to be answered, and, they should develop iterative thinking routines as they investigate a problem.

Students should already know that there is a difference between fact and opinion. In this unit the students will learn how scientists use experimentation to establish theories and discover scientific laws.

Students should already know how to obtain quantitative data pertaining to a sample of matter using tools such as a ruler, graduated cylinder, and balance. In this unit, students will learn to distinguish between accuracy and precision as they measure. In addition, they will learn how to convert between units of measurement and become proficient in the use of the metric system.

**Instructional Resources Aligned with Performance Objectives and related Key Terms**

**Learning activities and resources targeted to the eligible content of this unit.**

1. **SWBAT** follow a multistep procedure when carrying out experiments **IOT** apply the scientific method. *(Key terms: Constant, control, dependent variable, independent variable, hypothesis, scientific method)*

   **HOLT Physical Science pages 12 - 15.**


   (notes on the scientific method and all aspects of it)

   b. https://www.youtube.com/watch?v=OMWNFOD3zPs *(Simple demo with bleach and food coloring)*

   - Questions with answers that accompany the video below.
   - Will you be making quantitative of qualitative observations? Qualitative because no numbers are involved ("quant" meaning to have magnitude). You can tell the students "quantity means numbers" (from the Latin quantus meaning how great or how much. In this demo you're not saying the color changes by 10 degrees, etc. It is strictly a qualitative observation (from the Latin qualitas meaning of what kind).
   - What was the dependent variable? Color changing.
   - What are some constants in this demonstration? The size of the bottles, the amount of water, the color of the water.
   - The video mentions a control. Why is the untreated bottle considered a control? Because it allows you to see and compare the treatment effects to a situation with no treatment. See the definition on the previous page "the factor or subject of an experiment that is not manipulated but can be used to make comparisons between sets of data."
Construct your own questions to supplement this as you deem necessary.

c. https://www.youtube.com/watch?v=tk2mBsb3uw (8 minute video on variables) - Questions with answers that accompany this video below. You can cut and paste this into a document as a closed procedure that accompanies the video.

- The problem in this video tackles the question: does the c_____ of light affect the r_____ of plant growth. (color, rate)
- The independent variables are the c_____ of the lights. (color)
- The dependent variable is the r_____ of growth. A synonym for rate is sp_____d. (rate, speed)
- The control group is...  (#5)
- The video lists several constants. Why are they important? (Keeping all things constant allows you to isolate the effects of an independent variable. They have to stay the same to 'make it a fair test'.)

Please construct questions or follow up with independent practice where students practice identifying these concepts. It is recommended you bring a plant to class and a flashlight in order to more realistically demonstrate this experiment. Researcher Judith O’loughlin (2010) calls this "realia". Videos and photos are good, but the ability to touch or see realia is more powerful in embedding a learning experience and enhancing recall (O’loughlin, J. Academic Language Accelerator. 2010. Oxford University Press, NY)

d. https://www.youtube.com/watch?v=Bvfl1wat2y8 (5 minute video, no worksheet)

e. http://biologycorner.com/worksheets/scientific_method_experiments.html (Downloadable exercise, no key)

f. https://www.youtube.com/watch?v=Q4EBOE4pJyw (3 minute video that you can do as a demo)

- Run this demo as a prelude to density but use it to focus on the scientific method in terms of tackling a problem. You can use it again when looking at density, but in this instance your lens is on the scientific method. Use a Home Depot bucket instead of an aquarium. It’s easier to fill the Home Depot bucket, it takes less water so it’s substantially lighter than a 10 gallon aquarium, and Home Depot buckets are $2 to $5. Stress making a prediction, forming a hypothesis, and thinking in terms of dependent variable (float or sink) and constants (size of cans, caramel coloring) and independent variables (sugar vs aspartame). Always exercise professional creativity and discretion for demonstrations to broaden their impact. For example, perhaps bring 2 other types of sodas or juices to test them. Perhaps drop a bottle of water in or a bottle of diet soda. Note that the air in the bottles contributes to their tendency to float.


2. SWBAT to define scientific law and scientific theory IOT distinguish between them. 
(Key Terms: Inference, hypothesis, scientific law, scientific theory)

HOLT Physical Science pages 4 - 11, 12 - 15.

a. CK12 - Scientific Induction RST.9-10.4 (Informational text, formative assessment, answer key for quiz only)

b. CK12 - Scientific Law RST.9-10.4, WHST.9-10.9 (Informational text, formative assessment, video, answer key for quiz only)

c. Activity: Identifying opinions, facts, hypotheses, theories and laws. RST.9-10.4 (Informational text, answer key for quiz only)
3. **SWBAT** distinguish between accuracy and precision **IOT** to correctly utilize the SI system of measurements.

*(Key Terms: Qualitative observation, quantitative observation)*

**HOLT Physical Science pages 15 - 19, 22 - 26.**

a. **Printable rulers**  
   https://www.printablerulers.net/

b. **Complete lesson on metric system with answer keys:**  
   http://sciencespot.net/Pages/classmetric.html

c. **CK12 - International System of Units RST.9-10.2 (2 formative assessments, answer key for quiz only)**

4. **SWBAT** analyze graphs, create graphs, use formulas and convert between units **IOT** depict quantitative data and explain it.

*(Key Terms: Independent and dependent variable)*

**HOLT Physical Science pages 20 - 22.**

a. **Scientific notation**  
   1) https://www.youtube.com/watch?v=zwBsL-NgkJE - 2 minute video showing how to convert 642,000 to 6.42 x 10^5; then administer guided practice through the worksheet  
   http://www.mathworksheets4kids.com/scientific-notations/positive-scientific-easy1.pdf - answer key included

   2) https://www.youtube.com/watch?v=gqqO8DXJSTg - 2-½ minute video showing how to convert 0.00512 to 5.12 x 10^-3; then administer guided practice so students can reinforce the skill - answer key included - http://www.mathworksheets4kids.com/scientific-notations/negative-scientific-easy1.pdf


   Mixed practice  
   4) http://www.mathworksheets4kids.com/scientific-notations.php

For more practice

b. **Significant Figures**  
   https://www.youtube.com/watch?v=8Tr2PZG8i5c (3 minute video) -  
   **Independent practice with answer key**  
   https://www.saddleback.edu/faculty/jzoval/worksheet_tutorials/ch1worksheets/worksheet_Sig_Fig_9_11_08.pdf

   **More independent practice with answer keys**  
   https://chemfiesta.org/2015/03/26/sig-figs-graphing-scientific-method/

c. **Scientific Graphing**  
   1) https://www.youtube.com/watch?v=9BkbYeTC6Mo (10 minute video)  
   Questions accompany the video:
   What are the five types of graphs (plots) that scientists utilize to summarize data in their experiments? (Line, scatter, bar, histogram, pie)
   How are bar graphs different from histograms? (The bars don't touch!)
   Line graphs show change over ____ (time)
Scatterplots show a correlation of variables. They are very important in science!! The independent variable goes on the X-axis. The dependent variable goes on the Y-axis. Bozeman wants to see how ice cream sales change - so he wants to see how the dependent variable changes. So that is the Y-axis. The temperature goes on the X-axis because it is the independent variable.

2) CK12 - Scientific Graphing RST.9-10.7 (Instructional reading, formative assessment, key for quiz only)

d. Converting using the Factor/Label method
1) https://www.youtube.com/watch?v=UBzVf8XeMYA (10 minute video) For more help see Unit 1 HOLT Resources Math Skills folder worksheet titled “Conversions” 18 problems with answers.

Textbook References
You must be logged into Schoolnet in order to access the online teacher text.
1. Chapter 1, p. 1 - 35
2. Lab skills & How to Write a Lab Report, p.839 - 841
3. Safety in the Laboratory, p. xx - xxiii

Quizlet is a FREE online flashcard app that can be used on cell phones! Students can download the Quizlet app on their phone and practice their vocabulary. The app is also free and easily usable on Chromebooks, laptops, etc.

Philadelphia Core Curriculum References (Green Spiral Bound Book)
1. Lab Safety and Identifying Lab Apparatus, p. 32-33

Science documentary and movie database: http://moviesheets.com/

************************************************************************************
Enrichment
Enroll your students into a Philadelphia tradition - Carver Science Fair www.carversciencefair.org ! 
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Sample questions from PDESAS Assessment Creator that align with this unit, Diagnostic Section: Biology
Additional formative and summative assessment items available in the shared Google Doc Test Bank that aligns with this unit.

1. What is the volume of the liquid in the graduated cylinder shown below?

![Graduated Cylinder Image]

(1) 23 mL  
(2) 26 mL  
(3) 27 mL  
(4) 28 mL

Answer: (2)

2. A mineral supplement designed to prevent the flu was given to two groups of people during a scientific study. Dosages of the supplement were measured in milligrams per day, as shown in the table below.

<table>
<thead>
<tr>
<th>Group</th>
<th>Dosage (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>200</td>
</tr>
</tbody>
</table>

After 10 weeks, neither group reported a case of the flu. Which procedure would have made the outcome of this study more valid?
(1) test only one group with 200 mg of the supplement  
(2) test the supplement on both groups for 5 weeks instead of 10 weeks  
(3) test a third group that receives 150 mg of the supplement  
(4) test a third group that does not receive the supplement.

3. A student conducted an experiment to determine if listening to different types of music would affect pulse rate. She thought that pulse rate would change with different types of music. Each person participating in her experiment listened to seven different selections of music for 30 seconds each. The
pulse rates were taken after each 30-second interval of music. Based on her experiment, the student concluded that a person's pulse rate changed when listening to different types of music.

The component missing from this experiment is a
(1) prediction
(2) hypothesis
(3) control group
(4) research plan

Essential Question
1. How are both quantitative and qualitative observations critical to scientific problem solving? (Qualitative observations provide us the beginning of inquiry. Your perception is your instant reality. Hot, cold, increase, decrease - these are all qualitative perceptions. Quantitative observations give a standard to track changes in your perceptions. Everyone can refer to a degree Celsius or a minute and describe a change in phenomenon more exactly with a unit of measure. Science, which is simply reasoning applied to facts, needs these 2 critical parts - your personal experience and a way to measure and record it with precision.)
2. Why are controls and constants arguably the most important parts of the scientific method? (They allow you to see the effects of your tests.)

PA Standards
These are the PA Standards that underlie the Eligible Content in this unit.
3.2.10.A6: Science as Inquiry
1. Compare and contrast scientific theories.
2. Know that both direct and indirect observations are used by scientists to study the natural world and universe.
3. Identify questions and concepts that guide scientific investigations.
4. Formulate and revise explanations and models using logic and evidence.
5. Recognize and analyze alternative explanations and models.
6. Explain the importance of accuracy and precision in making valid measurements.

3.1.B.C3 - Constancy and Change
1. Compare and contrast various theories of evolution. PATTERNS Discuss the implications of a universal genetic code for evolution.

Note: (This is clearly a biology standard; however, the eligible content correlated with this standard is salient so it is listed. It is "BIO.B.3.3.1 Distinguish among the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation". This underscores the importance that physical science can play in preparing students for the Biology Keystone Exam. The theory of evolution is not addressed herein per se, but it can be used as an example of a scientific theory versus law. The standard is included as its eligible content explicitly makes use of terms that define the scientific method.)

Common Core Standards Connections in ELA/Literacy and Mathematics
These are Common Core Standards that are related to the Eligible Content in this unit.
RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
RST.9-10.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9 - 10 texts and topics.
RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
WHST.9-10.1 Write arguments focused on discipline specific content.
**WHST.9-10.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

**WHST.9-10.9** Draw evidence from informational texts to support analysis, reflection, and research.

**Next Generation Science Standards**

*These are Next Generation Science Standards that are related to the Eligible Content in this unit.*

**Science and Engineering Practices in the NGSS, Appendix F:**

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information