Unit Title: The Scientific Process
7th grade Science

Unit Summary:

The focus of this unit is the scientific process, first by introducing the steps of the scientific method, then performing an experimental analysis using sunflower seedlings. The first lesson introduces the steps of the scientific process through group discussion and analysis, then allows the students to work through real experimental scenarios to embed the fundamentals of dependent and independent variables, control vs. experimental groups and forming hypotheses, then finally constructing their own experiments. The next lesson focuses on the background research of a large class-wide sunflower growth experiment. The students are tasked with learning about the importance of nutrients for plant growth and the physical effects of nutrient deficiencies. Conducting an organized experiment by testing the effects of various liquids on sunflower seedling growth will allow students to directly experience the scientific process in a simple yet meaningful way. As a wrap-up to the entire experiment, the final lesson involves data analysis by graphing the students' results in Excel and presenting their results and conclusions, including a critical analysis of the experiment, to their peers.

Next Generation Science Standards:

MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

WHST.6-8.7: Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

WHST.6-8.8: Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Learning Objectives:

- List and properly order the steps of the scientific method.
- Describe what a control group is, and how it differs from an experimental group.
- Define and identify independent and dependent variables.
- Determine hypotheses from experimental scenarios.
- Construct conclusions from experimental scenarios.
- Invent an experiment using the steps of the scientific method.
- Present proposed experiment to the class.

- Describe how nitrogen, phosphate, potassium and zinc are important for plant growth and evidence of these nutrient deficiencies in plants.
- Describe how soil and water pH is important and a tolerable range for plants.
- Describe how soil and water salinity is important and a tolerable range for plants.
- Summarize nutrients analyzed and testing methods.
- Compare results of different tests for the same nutrient.
- List difficulties experienced with testing methods.
- Give an example of something to do differently if performing these tests again.
- Rank solutions tested based on nutrient content.
- Support decision of ranked list of solutions.
- Identify the independent and dependent variables of the experiment.
- Determine factors that need to be held constant during the experiment.
- Define the control and experimental groups of the experiment.
- Develop two hypotheses for the experiment.
- Construct the sunflower experiment trials.
- Make and document observations about plant growth.
- Measure and record changes in plant growth over time.
- Summarize results of the sunflower growth experiment.
- Analyze results of the experiment.
- Evaluate whether hypotheses were supported or refuted.
- Support hypotheses using researched information about plant nutrient needs and deficiencies.
- Examine experimental procedures to identify sources of error.
- Evaluate protocol and provide suggestions for improvement to the experiment.
- Present results to an audience.
- Construct a line graph to represent the results of the sunflower experiment.
- Compose a summary of the entire experiment.
- Evaluate methods and judge effectiveness of the experiment.

Keywords

- scientific method
- experimental process
- control
- independent variable
- dependent variable
- constants
- hypothesis
- observation
- inference
- nutrients
- plant growth
- macronutrient
- micronutrient
- pH
- salinity
- water quality
- concentration
- parts per million
- units
- plant growth
- error sources
- line graph

Lesson Title - Brief Description	Learning Objectives	NGSS Addressed	Materials Required
Lesson 1 - Scientific method Overview of the scientific method and related terms	• List and properly order the steps of the scientific method. • Describe what a control group is, and how it differs from an experimental group. • Define and identify independent and dependent variables. • Determine hypotheses from experimental scenarios. • Construct conclusions from experimental scenarios. • Invent an experiment using the steps of the scientific method. • Present proposed experiment to the class.	**MS-ESS3-3** **MS-LS2-4** **WHST.6-8.7**	• Whiteboard - 1/group • Marker - 1/group • **Scientific Method** PowerPoint • **Scientific Method** handout • **Design Your Own Experiment** handout

Lesson 2 - The importance of nutrients
 	
Water quality analysis lab and related research
	• Describe how nitrogen, phosphate, potassium and zinc are important for plant growth and evidence of these nutrient deficiencies in plants.
	• Describe how soil and water pH is important and a tolerable range for plants.
	• Describe how soil and water salinity is important and a tolerable range for plants.
	• Summarize nutrients analyzed and testing methods.
	• Compare results of different tests for the same nutrient.
		MS-ESS3-3
		
		WHST.6-8.7
		
		WHST.6-8.8
			• Computer/Chromebook (internet access)
			• **pH & ppm Presentation** PowerPoint
			• **Nutrient Information** handout
			• Water quality testing equipment (will vary depending on what tests are performed)
			  ○ HACH DR 900 Multiparameter Handheld Colorimeter
			  ○ Refractometer
			  ○ API freshwater test kit
			• Solutions to test
			  ○ Coffee
			  ○ Fertilizer
			  ○ Saltwater

	• List difficulties experienced with testing methods. • Give an example of something to do differently if performing these tests again. • Rank solutions tested based on nutrient content. • Support decision of ranked list of solutions.		○ Sugar water ○ 10% bleach ○ 10% vinegar • **Water Quality Lab** handout • **Water Quality Lab Results Table** handout • **Water Quality Report** handout
Lesson 3 - Sunflower growth experiment Watering sunflower seedlings with various solutions to test their effect on plant growth	• Identify the independent and dependent variables of the experiment. • Determine factors that need to be held constant during the experiment. • Define the control and experimental groups of the experiment. • Develop two hypotheses for the experiment. • Construct the sunflower experiment trials. • Make and document observations about plant growth. • Measure and record changes in plant growth over time. • Summarize results of the sunflower growth experiment. • Analyze results of the experiment. • Evaluate whether hypotheses were supported or refuted. • Support hypotheses using researched information about plant nutrient needs and	**MS-LS1-5** **MS-LS2-1**	• **Spring Project Presentation** PowerPoint • Whiteboards - 1/group • Markers - 1/group • **Spring Project booklet** - 1/student • Plastic sheeting • 16 oz. clear plastic cups - 3/group • Sunflower seeds - 3/group • Tape • 100 mL graduated cylinders - 1/group • Water • Soil - ~1.5 quart/group • Empty ice cream buckets • Trowels (optional) • Baking trays • Gravel • Rulers

	deficiencies. • Examine experimental procedures to identify sources of error. • Evaluate protocol and provide suggestions for improvement to the experiment. • Present results to an audience.		
Lesson 4 - Data analysis Using data collected from sunflower growth experiment to create line graphs and use them to support experimental conclusions	• Construct a line graph to represent the results of the sunflower experiment. • Compose a summary of the entire experiment. • Evaluate methods and judge effectiveness of the experiment.	**MS-LS1-5** **MS-LS2-1**	• Computer/Chromebook - 1/student • **Graphs Presentation** PowerPoint • **How to make a line graph in Excel** handout • **Spring Project booklet** • Data from sunflower experiment

Safety Considerations:

Chemical hazards associated with chemicals used with water quality testing equipment (see SDS included with kit)

Spilled soil

Spilled water - slipping hazard

Evaluation Plan:

Lesson 1:

Written assignment titled "Design your own experiment" to include all steps of the scientific method with brief descriptions.

To evaluate the student's grasp of the scientific method and the steps involved.

Lesson 2:

Written assignment titled "Water quality report" that summarizes the water quality analyses performed in the lab and includes critical evaluation of the results and tests performed.

To evaluate the student’s understanding of the procedures and results of the water quality tests.

Lesson 3:

Completed "Spring project booklet" incorporating the problem, experimental design, variables, hypotheses, background research, results and conclusions of the sunflower growth experiment.

To evaluate the student's comprehension of the scientific method in a real world scenario.

Lesson 4:

Oral presentation communicating the results of each group's sunflower growth experiment.

To evaluate the students' understanding of experimental results and their significance.

Resources (websites):

- YouTube for the "Test Your Awareness" video (used in Lesson 1): https://www.youtube.com/watch?v=Ahg6qcgoay4#t=16 or visit youtube.com and search "Test Your Awareness: Do The Test"
- YouTube for tutorials on how to use the API Freshwater Test Kit (used in Lesson 2): https://www.youtube.com/watch?v=fmcTBzaFW60 https://www.youtube.com/watch?v=SFRlC8q_AOw
- Nutrients for Life game (used in Lesson 2): https://www.nutrientsforlife.org/games/humanity/ or Google "Nutrients for life game" and click on the first link, titled "TFI - Nutrients for Life Foundation".
- Plant Nutrients link for school children (used in Lesson 2): http://www.ncagr.gov/cyber/kidswrld/plant/nutrient.htm
- Excel support (used in Lesson 4): https://support.microsoft.com/en-us/product/office/excel

Brief description of how this unit relates to your graduate research:

For my research, I am studying the issues related to a groundwater contaminant called tetrachloroethene (PCE), its transport and fate in groundwater, and the physiological requirements of certain bacteria found in aquifers that have the ability to detoxify PCE. PCE is a chemical solvent used in dry cleaning and metal degreasing processes. Due to improper storage and disposal, it has become one of the most common groundwater contaminants in the United States. The presence of PCE in groundwater poses a significant human health risk because it causes liver damage and is a suspected carcinogen. One aspect of PCE that makes it especially difficult to remove from groundwater is that it forms a separate phase from water - in the same way that oil separates from vinegar. As a result, PCE accumulates in separate-phase "pools" that contaminate groundwater for decades to centuries, thus creating a long-lasting and harmful environmental legacy.

One of the most useful "tools" that environmental engineers can use to clean up underground contaminant pools are bacteria that detoxify PCE. There is also promising evidence that these bacteria can accelerate the removal of PCE pools and thus greatly reduce the longevity of these contaminant sources. However, key information needed to implement this bioremediation approach in practice is lacking. For example, we do not fully understand how neighboring bacterial species compete for resources in the subsurface, which will affect their growth rates and proximity to PCE pools. Understanding how microbial competition and other factors influence the extent to which bacteria can enhance and accelerate the removal of PCE pools is the main focus of my Ph.D. research. Microfluidic groundwater models have been developed for use in the lab that provide a means to examine the complicated groundwater processes at the pore scale. A two-dimensional pore network is etched onto a silicon wafer to create a microfluidic model of a groundwater aquifer and PCE pool. This “lab-on-a-chip” reduces the resources utilized in the lab and provides a microscopic window into an aquifer.

In order to conduct my research, I perform the scientific process on a regular basis. One variable I study are the types of anaerobic reductively dechlorinating bacteria used to degrade the PCE. *Desulfuromonas michiganensis* was discovered in a contaminated aquifer in northern Lower Michigan; while and *Dehalococcoides mccartyi* was found in a wastewater treatment facility in upstate New York. The cleanup of PCE is influenced by which species of bacteria is present, and at what concentration. The expected cleanup rate and end products when just *D. michiganensis* is present will be different than if just *D. mccartyi* is present, or if they are both present, growing in competition for the PCE. Another variable that will greatly influence the cleanup rate and end products is the flow rate of the water through the groundwater aquifer. Preliminary studies suggest that at low flow rates, the bacteria are allowed to use up as much PCE and other required nutrients as they can, allowing for a more complete cleanup of the PCE pool. However, at high water flow rates, the constituents in the water are flushed past the bacteria too quickly and incomplete removal and detoxification of PCE pools occurs. We are interested in complete removal of PCE pools, and so knowing those threshold flow rate values are imperative to our work.

This unit covers the subject of the scientific process in depth, and these skills are imperative for future scientists to learn early. Giving the students an opportunity to perform the tasks that scientists carry out daily will help educate them in critical environmental issues and hopefully cultivate budding environmental stewards in the process.