Florida Next Generation Sunshine State Standards:

The following Nature of Science Benchmarks are met throughout* Active Physical Science *and in this section:

SC.912.N.1.2 Describe and explain what characterizes science and its methods.

SC.912.N.1.3 Recognize that the strength or usefulness of a scientific claim is evaluated through scientific argumentation, which depends on critical and logical thinking, and the active consideration of alternative scientific explanations to explain the data presented.

SC.912.N.1.4 Identify sources of information and assess their reliability according to the strict standards of scientific investigation.

SC.912.N.1.5 Describe and provide examples of how similar investigations conducted in many parts of the world result in the same outcome.

SC.912.N.1.6 Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

SC.912.N.1.7 Recognize the role of creativity in constructing scientific questions, methods and explanations.

SC.912.N.2.1 Identify what is science, what clearly is not science, and what superficially resembles science (but fails to meet the criteria for science).

SC.912.N.2.2 Identify which questions can be answered through science and which questions are outside the boundaries of scientific investigation, such as questions addressed by other ways of knowing, such as art, philosophy, and religion.

SC.912.N.2.3 Identify examples of pseudoscience (such as astrology, phrenology) in society.

SC.912.N.2.4 Explain that scientific knowledge is both durable and robust and open to change. Scientific knowledge can change because it is often examined and re-examined by new investigations and scientific argumentation. Because of these frequent examinations, scientific knowledge becomes stronger, leading to its durability.

SC.912.N.2.5 Describe instances in which scientists' varied backgrounds, talents, interests, and goals influence the inferences and thus the explanations that they make about observations of natural phenomena and describe that competing interpretations (explanations) of scientists are a strength of science as they are a source of new, testable ideas that have the potential to add new evidence to support one or another of the explanations.

SC.912.N.3.1 Explain that a scientific theory is the culmination of many scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have to offer.

SC.912.N.3.2 Describe the role consensus plays in the historical development of a theory in any one of the disciplines of science.

SC.912.N.3.3 Explain that scientific laws are descriptions of specific relationships under given conditions in nature, but do not offer explanations for those relationships.

SC.912.N.3.4 Recognize that theories do not become laws, nor do laws become theories; theories are well supported explanations and laws are well supported descriptions.

SC.912.N.3.5 Describe the function of models in science, and identify the wide range of models used in science.

SC.912.N.4.1 Explain how scientific knowledge and reasoning provide an empirically based perspective to inform society's decision making.

SC.912.N.4.2 Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.

Nature of Science

As you begin your journey through *Active Physical Science*, take a few minutes to think about what it means to be involved in science. How would you define science? What makes it different from the other subjects that you study in school? The National Academy of Sciences defines science as "the use of evidence to construct testable explanations and predictions of natural phenomena, as well as knowledge generated through this process."

In this brief introduction to the *Nature of Science*, you will look at what this definition means and try to better understand how scientists conduct science. You will read about the role of investigations, evidence, logic, inferences, and creativity in the quest to better understand the natural world. This will require that you be able to tell the difference between science and what some call "pseudoscience," and how scientific interpretations change over time. You also will consider how science is "human." People do science. Society influences what science is done, and science influences what society does.

The goal of *Active Physical Science* is to provide an opportunity for you to learn about and develop a scientific understanding of the world by doing experiments. You will be involved in inquiry investigations. You will use evidence you have generated to support your explanations. Then you will use that chemistry knowledge to solve real-life challenges using an engineering design cycle. You will not be science students; you will be student scientists. As you work through each chapter, think about what you are doing that makes you a scientist.

Students perform investigations in an Active Physical Science *classroom.*

Science and Its Methods

Scientists are curious human beings who ask questions about the natural world. To answer these questions, they go through a series of steps that often lead to new questions. Scientists report the results of their work in scientific journals following a strict reporting format. Some people think that the reporting is identical to the methods scientists used to get the results, mistakenly believing there is one "scientific method." They think that there are specific steps that need to be followed in a particular order to lead to scientific discoveries. A deeper look at how scientists work shows that they start their investigations in a variety of ways. The creative discovery process cannot be written out as a simple recipe of steps. However, during their work, scientists are careful to ensure that their work is viewed as good science by following a set of scientific process principles and methods.

First and foremost, scientists know that their scientific claims must make sense and be supported by experimental evidence. All arguments supporting their claims are critically evaluated. Any alternative or contradictory scientific claims and evidence must be considered in the same way. A scientist cannot simply ignore evidence that does not support the claim. Although all evidence must be considered, scientists must critically evaluate the sources of their information and the scientific quality of that information.

Science journals are an important outlet for presenting new research.

Developing evidence requires careful, systematic investigation and experimentation. In preparation for these investigations, scientists search the literature (for example, journals, conference proceedings, books), carefully designing and reporting their studies so that other scientists can replicate the studies. Science requires that anybody performing the same experiment should arrive at similar results.

Science extends across national borders, and scientists are part of an international community. Science is practiced and supported by people all over the world, in all cultures, and by people of all races and ethnicities. In *Active Physical Science*, you will read about scientists from many different places around the world. You also will read about how scientists build on the ideas of other scientists who have come before them or live in different parts of the world.

In *Active Physical Science*, you will be expected to think and act like a scientist. You will be reminded of all of these aspects of science and its methods as you conduct investigations and draw conclusions based on evidence gathered from these investigations. You will be required to consider how your conclusions support or refute theories and organizing principles of science. In every section in *Active Physical Science*, you will answer the question, "How do you know?" At that time, you will provide evidence to support your reasoning. You will be expected to keep a record of all of this in your *Active Physical Science* log. As a scientist, you should also record any new questions you would like to investigate in your log.

Theories and Laws in Science

In science, as in other disciplines, words are precisely defined so that everyone understands their meaning. Sometimes the meaning of a word in science is different from the meaning of the same word in everyday language. For example, in physics, work is defined as a force applied over a certain distance. In everyday language, people use the word "work" to refer to homework, employment, and mental effort. None of these common usages align with the physics meaning of "work" as a force applied over a distance. Similarly, the common usage of the word "theory" includes references to hunches, speculations, or guesses. None of these coincide with the way in which "theory" is defined in science. Similar issues arise with the science usage of the word "law."

In observing the physical world, scientists have noticed patterns and generated scientific laws to describe these patterns. These laws do not explain the patterns but rather provide a way in which to view these patterns.

Robert Boyle

Boyle's law states that for a fixed amount of an ideal gas kept at a fixed temperature, P *[pressure] and* V *[volume] are inversely proportional. Scuba divers rely on Boyle's law to keep track of the oxygen in their air tanks.*

For example, Boyle's law describes the relationship between the pressure and volume of a gas. If you try to squeeze an inflated balloon, you have to apply a small pressure to make a small indentation. You have to apply a much larger pressure to squeeze the inflated balloon into a tiny space. Boyle's law provides a mathematical description that relates the measurement of the pressure to the measurement of the volume. Boyle's law does not explain why the greater pressure is needed.

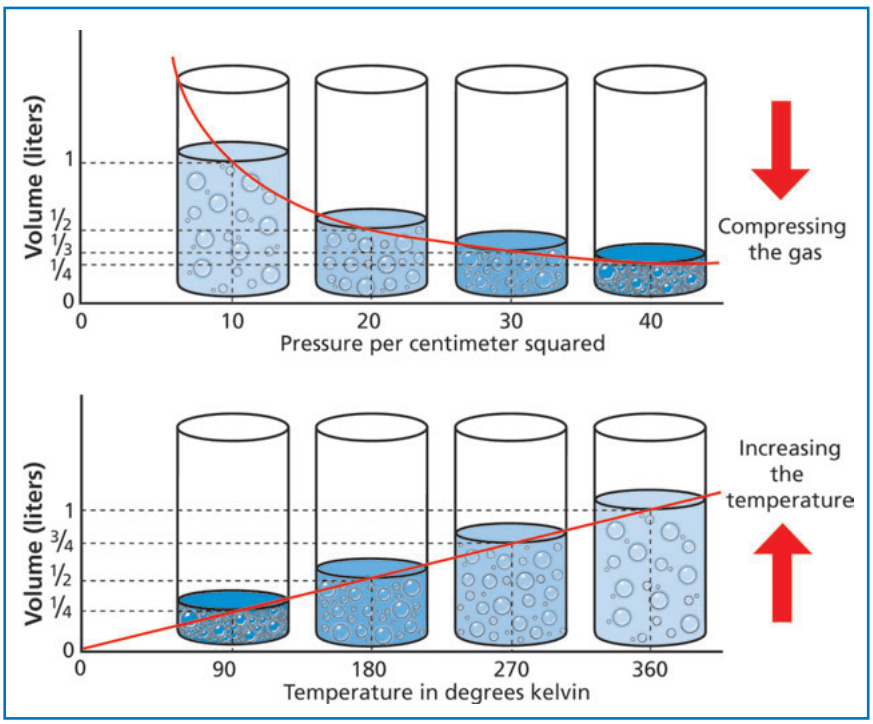
Similarly, Charles's law describes the relationship between the temperature of a gas and its volume. You may have noticed that bread, cake, or pizza crust taken from an oven may have a large bubble of hot gas. As the bread or cake cools, the bubble decreases in size. Charles's law mathematically describes this observation and can predict how much a gas bubble will decrease in size as the temperature of the gas cools. Charles's law does not explain why the volume decreases or how the gas is different at lower temperatures.

A scientific theory brings together many observations and investigations. It provides an explanation for those observations and can be used to predict new phenomena that have not been observed. For example, the kinetic molecular theory of gases describes a gas as being made up of tiny particles (molecules) that are in constant motion (kinetic = motion). The temperature of a gas is a measure of the kinetic energy of these molecules. The pressure of a gas is the result of collisions of these molecules with the wall of the container (for example, a balloon). This theory of gases provides an explanation for Boyle's Law as well as for Charles's Law. It can also help us predict the density of gases and how gases will mix together. This theory of gases is not a hunch or a guess. It is the result of years of experiments, observations, measurements and mathematical applications.

Jacques Charles

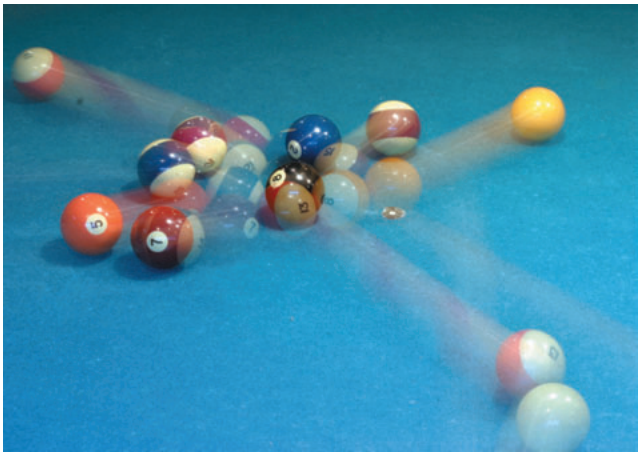
The work of many people over many years culminates in a theory. After that, the work of many people over many years is required for acceptance of that theory in the science community. In common usage, someone may say, "It's *just* a theory." In science, you can say, "It is a *theory*!"

Laws do not become theories and theories do not become laws. In *Active Physical Science*, you will learn laws of science as well as its theories. You also will be introduced to the models scientists use to help explain theories. You will learn how newer theories replace older theories in science and the process by which the community of scientists accepts a new theory. After each section, you will be asked to answer a *Why do you believe?* question. The response to this question will require you to see how the new chemistry observations and laws that you learn fit into the larger context of science. You will see how the new knowledge is part of the "big ideas" of science and how the new knowledge meets specific science requirements.



Boyle's Law (top) and Charles's Law (bottom) describe basic phenomena of chemistry, but do not explain them or their relationship to each other. A theory must do that.

Understanding the universe often requires you to develop and adopt models to explain phenomena. When explaining the behavior of gases, you can think of the gas molecules as colliding billiard balls. This billiard-ball model helps you with your understanding. When trying to explain the nature and properties of an electron, scientists sometimes adopt a wave model that can help them describe the behavior of an electron in an atom. At other times, they adopt a particle model for an electron that can help them describe what happens when electrons hit a television screen. The model is not the phenomenon. An electron is neither a wave nor a particle. Any model of the electron will have attributes that help scientists with their understanding.

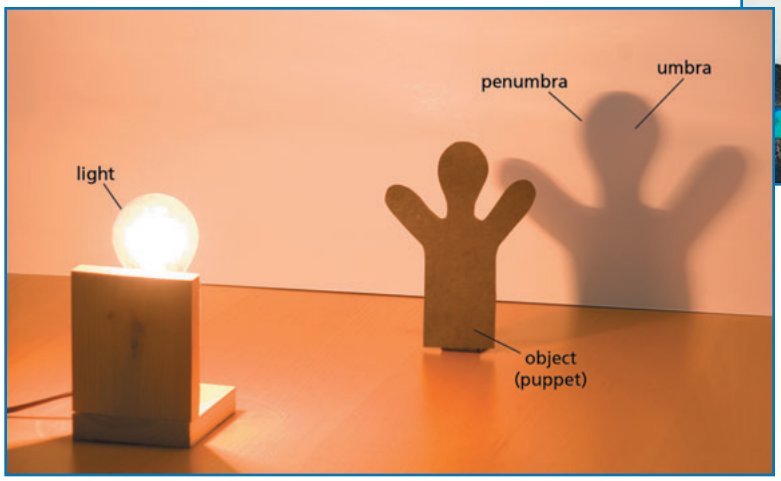


Some people would liken the movement of gas atoms in a balloon to the colliding billiard balls on a pool table.

All models are limited. It is important to adopt models to help you understand phenomena in science. It is also important to recognize the limitations of models. As you encounter models in *Active Physical Science*, you will be reminded of the limitations of each model.

Science versus Pseudoscience

There are many ways in which humans have tried to understand and make sense of the world around them. People have used art, historical analysis, music, religion, and language to explore and interpret their experiences. Art expression cannot replace literature or music. Science cannot replace historical analysis, dance, or religion. Each of these ways of viewing the world provides different insights and tries to answer different questions.



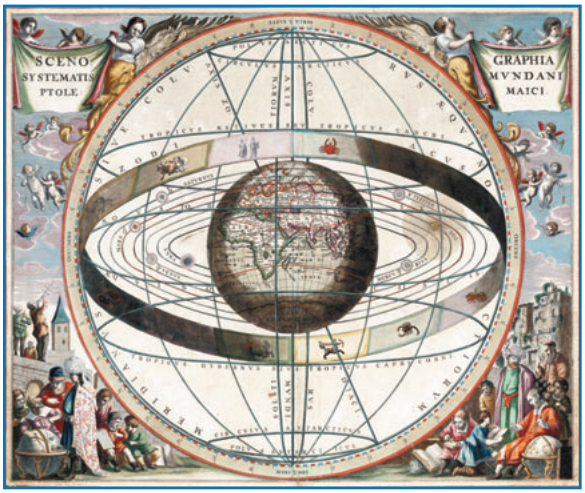
Artists and scientists both try to understand the world. The tools and perspectives of their respective disciplines may differ, but the results can be strikingly similar.

Long ago, most scientists believed in astrology. Astrology is the idea that the position of the planets at the time of your birth could determine your personality, strengths, weaknesses, and your destiny. Today, some people still believe that astrology provides insights, while others read their horoscopes as a form of entertainment. Nobody in the scientific world thinks that there is scientific basis for astrology. Astrology does not meet the criteria of a science.

Astrology is one belief that people used to think had scientific meaning.

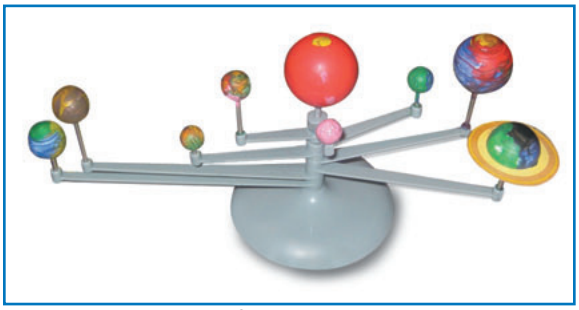
All scientific theories must be falsifiable. This means that there must be a way in which new evidence can show that a theory is false. For example, assume that a scientific theory predicts that one event is always followed by a second event. If someone is able to find an instance where that event is not followed by the predicted event, then the theory has been shown to be false and must be changed or rejected.

There are many examples in the history of science in which theories that were widely accepted had to be rejected. This occurred because new evidence was discovered through scientific investigations that proved that the theory was not always true. A new theory was then created that could account for all the observations of the old theory as well as the new observations. The cycle then continued. Every theory must have the possibility of being proven false for it to be considered a scientific theory.



A Ptolemaic model of the solar system.

Occasionally, people try to strengthen their way of making sense of the world by saying that their theories are identical to scientific theories. A way in which to check their assertions is to ask them to describe evidence that could be found that would falsify their theory. If there is no way to do this, then their theory is not a scientific theory.



A modern-day model of the solar system.

As student scientists in *Active Physical Science*, you will learn how to conduct scientific investigations and to consider how the results of those investigations fit in with the models and theories of science. In every section, you will answer the question, "Why do you believe?" To answer this question, you will need to identify how the new science content connects with other science content. You will learn how theories have evolved over time. You will read about instances when an accepted theory was tossed aside and a new theory became the accepted one because only the new theory was consistent with the evidence.

Science and Society

Science is one of society's greatest achievements. Society influences what science is studied and science influences the lives of everyone in society. When communities attempt to confront problems, they turn to science to help identify the causes of the problem and to help identify and weigh specific solutions to the problems. Science can inform people about what is possible, what is risky, and how to weigh the costs and benefits associated with other solutions to a problem.

Technology is the application of scientific principles to improve lives. Since people have different values, they will also have different views on a specific technology. Dynamite can be used to build roads and to destroy buildings. Building a road has positive consequences (ease of movement) and negative consequences (dislocating people who live by the new construction). Destroying buildings can be an act of war or part of a redevelopment project to replace poorly constructed housing with safer, newer housing. There is no simple answer to the question, "Is dynamite good or bad?" Scientists must work with engineers as well as economists, politicians, sociologists, lawyers, and community representatives when dealing with complex problems.

Dynamite can be used for things that benefit society as well as things that are destructive. When a construction company and demolition experts implode a building, it could be seen as a positive event or a negative event.

In *Active Physical Science*, you will apply science principles to solve different challenges. You will design a game for students to use to learn about the periodic table and a toy that uses the gas laws for its operation. You will design an improved safety device for a car, build a museum display, and create a light and sound show to entertain your friends. You will also consider the cost of electricity and which uses are "green." At the end of each section in *Active Physical Science*, you will also be asked to answer the question, "Why should you care?" This will be your opportunity to relate the science you learned to your *Chapter Challenge* and to see how science and society influence each other.