Landmark Lesson Plan:

Setting the Standards of Excellence

Grades: 9-12
Subject Areas: Chemistry and History
Based on the National Institute of Standards and Technology National Historic Chemical Landmark
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The following inquiry-based student activities are designed for use in high school chemistry lesson planning, but they apply to all science subjects as well as history. Some middle school teachers may also find the lesson outline helpful. The lesson plan will help students understand the need for standards in all areas of science as well as how standards have evolved during the past two centuries. The last activity in the lesson plan invites students to reflect in writing on how standards relate to their lives.

The lesson plan is designed as a ready-to-go lesson, easily implemented by a teacher or his/her substitute, to supplement a unit of study. The chemistry activities relate to physical and chemical properties of substances. The history activities connect the chronology of standards development with the need for standards. Students also practice critical reading and writing skills in the lesson.

All resources are available online at www.acs.org/LandmarkLessonPlans.

While these activities are all thematically linked to the need for standards development, each is designed to stand alone as an accompaniment for the handout. Teachers may choose activities based on curricular needs and time considerations.

- Take a few minutes to introduce the lesson with a few conversation starters. What things do we measure in chemistry (or another science)? How do we know we have measured correctly? Why do we need standards in measurement? Who defines the standards?
- If you use the Anticipation Guide, do not distribute the handout about standards until students have indicated their initial opinions or, for the optional engagement exercise, come up with their own ideas. Then distribute the handout for students to check their answers and find the passage that supports or refutes their initial thoughts.
- For the remaining activities, distribute the exercise(s) selected for the class along with the handout about standards. Make sure students understand the directions for each activity. While students are reading, they should complete the exercise(s).
- For additional information, refer students to NIST's homepage (https://www.nist.gov/) and NIST's Standards & Measurements page (https://www.nist.gov/services-resources/standards-and-measurements).
- After all students have read the handout and completed the exercise(s), use the Answer Guide to provide student feedback and promote further discussion.

Student Activities with Objectives

Anticipation Guide and Handout on the "National Institute of Standards and Technology"
(5 minute introduction, followed by 15-20 min. of reading)

- Students examine their ideas about the importance and development of standards.

History Exercise: Chronology of Standards Development
(10-15 min.)

- Students chronologically order events in the reading.
- Students relate development of standards to world events.

Graphic Organizer: Chemistry and NIST
(10-15 min.)

- Students describe industries initially served by standards development, and measurement units used for each standard.

Writing Exercise: Standards and You
(20-25 min.)

- Students examine three ways the work of NIST affects their lives, including the chronology and how their lives would be different without this work.

National Institute of Standards and Technology

The year was 1901. The Victorian era had ended and the age of technology had dawned. The U.S. was poised for progress and competition but there were few national standards for measuring, comparing and evaluating its products. A foot in Illinois was longer than a foot in Virginia. Eight different values defined a gallon. Time-keeping was local. Electric power lacked defined units. That March, Congress responded by approving a charter for a new laboratory, the National Bureau of Standards (NBS), which became the National Institute of Standards and Technology (NIST) in 1988.

The initial staff of 12 — whose charge was to establish standards for electricity, length, temperature and time — has since grown to include thousands of scientists, engineers, technicians and support personnel. NIST's programs in materials characterization and standards, measurement, calibration and synthesis have strengthened the U.S. economy and improved the quality of life. They provide a common language to measure and evaluate performance, enable interoperability of components made by different companies, and protect consumers by ensuring safety and durability.

The Earliest Standards

Heat and thermometry were early interests. In 1901, lab personnel acquired special thermometers from Europe and were prepared to perform certification but lacked a unified standard. In 1927, after years of research, labs in the U.S. and abroad adopted an international temperature scale.

In 1905, the railroad industry was trying to prevent derailments caused by fracturing of cast iron wheels. The industry asked NIST's Chemistry Division to provide "standardizing" materials to calibrate measuring systems for quality control during production. The first Standard Samples defined composition of various types of iron.

In 1906, the laboratory began the Standard Reference Materials (SRMs) program. SRMs have well-characterized properties and composition and are used to calibrate instruments, develop new measurement methods and test product quality. Examples include samples of peanut butter (for comparing nutritional content) and steel (to measure hardness).

Around that same time, NIST determined the heating behavior of calcium chloride brines used in refrigeration. Engineers had requested the data so they could make refrigeration more efficient.

Industry Standards

The laboratory addressed construction industry standards in 1911, testing thousands of samples of cement bought for government projects. By 1912, a single standard for chemical composition governed all federal construction purchases.

During World War I (WWI), NIST performed composition analysis and property determinations for chemicals and steels used in weapon production.

Auto industry standards, pursued in 1922, involved research on engines to increase operating efficiency. Also in the lab's early years, chemists standardized a sugar purity test. This improved the U.S. Customs Service's method for determining tariffs on imported sugar, a major source of government revenue.

In 1940, NIST developed new methods for analyzing impurities in uranium and for purifying it for the Manhattan Project, which developed nuclear weapons for World War II (WWII). That same decade, NIST developed tests to measure freezing points — a way to determine material purity.

NIST

NIST tests such as this one in 1928 led to fire standards for buildings.

Rubber and Polymers

When WWII cut off U.S. imports of natural rubber in 1943, NIST helped determine which types of synthetic replacements to use. NIST's application of viscometry to test the viscosity of rubber became an indispensable tool. During the 1940s and 1950s, the lab's determinations of the heat of combustion and the heat of formation of compounds gave an important boost to the nascent synthetic polymer industry. Today, most manufacturers of polymer resins rely on NIST's SRMs.

The chemist's right hand

In 1952, NIST's 1,200-page circular, *Selected Values of Chemical Thermodynamic Properties*, evaluated and systematized data that appeared in chemistry literature. The book became the bible of thermochemists.

The Electrochemistry Division's testing of a commercial battery additive called AD-X2 led to Congressional hearings in 1953. By helping to expose fraudulent claims, NIST garnered praise for its testing procedures and integrity.

During the 1950s, NIST developed a new method to accurately measure the percentage or "abundance" of isotopes in SRMs used in nuclear chemistry and geochemistry. In the early 1960s, this process helped determine the Faraday constant — a measure of electric charge — and improved the accuracy of weight determination for standardized units of atomic mass. NIST continues to develop SRMs and reference materials for specific needs.

In later work with industry, NIST helped ensure that air pollution reduction goals were met.

From nanotechnology to biotechnology

As an aid to industry, NIST developed high-resolution measurement tools that enable chemical characterization at the millimeter to nanometer scale.

In 1967, a measurement for serum cholesterol became the first of 12 health care markers. The first standard for DNA profiling, released in 1992, paved the way for the acceptance of DNA as evidence in court.

In 1999, the Advanced Chemical Sciences Laboratory began addressing 21st-century needs from pharmaceutical manufacturing to pollution monitoring and nutritional analysis to tissue engineering. A new Advanced Measurement Laboratory opened in 2004 to help chemists and others keep pace with emerging technologies.

Recent advances

NIST continues to refine standards and measurements. In 2018, for instance, the agency developed a prototype design using ultracold trapped atoms to precisely measure pressure under near-vacuum conditions. The technique could be useful to ensure contaminant-free production of semiconductors.

NIST's Contributions to Everyday Life

• Measuring meters *A platinum alloy bar was the measure of the meter in 1901 and scientists attempted for years to provide a redefinition. In 1972, a NIST physicist made a measure of the frequency of laser light, which led to an international redefinition in 1983.*

• Hoses and hydrants *A raging fire in Baltimore in 1904 drew firefighters from as far away as New York, only to stand by helplessly as more than 1,500 buildings burned to the ground. The couplings of their hoses would not fit the hydrants, leading NIST to help develop national standards for hose couplings.*

• Radiation standards *NIST provided physical measurement standards to assure the safety of radium and X-rays, which helped bring about the 1931 X-ray safety code.*

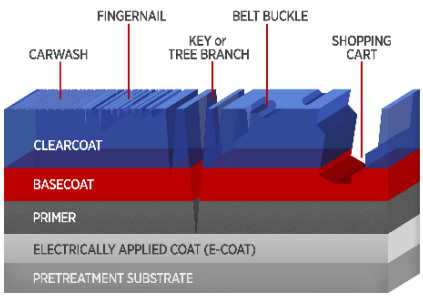
• The nation's clock *NIST has maintained time standards from the pendulum to the first atomic clock, developed in 1949. Atomic clocks improve timekeeping, navigation and measurement of Earth's gravity.*

• The dawn of computers *In 1947, NIST began building the first operational internally programmed digital computer in the U.S.*

• Outer space *The space program required new measurements on plasmas and on fuel combustion and rocket thrust. By 1964, NIST was routinely measuring plasma temperatures in the 20,000° C range as well as calibrating devices to measure the forces in large rockets.*

• Smoke detectors *In 1974, NIST helped develop the first standards for smoke detectors. Extensive work in fire research also includes standards on children's sleep wear and mattresses. In 1997, NIST produced the only validated method for quantifying lethality of smoke, now routinely used in fire hazard analysis.*

• Auto coatings *NIST and industry partners developed a laboratory method in 2018 for simulating scratch processes on the clear surface layer of automobile paint. The test could help manufacturers understand the mechanisms behind those processes so future coatings will be more scratch resistant.*



To improve scratch resistance, NIST is studying damage to automotive coatings.

Eastman Chemical Co./ K. Irvine, NIST

Student Name:_____ Date:_____ Period: _____

Anticipation Guide
Setting the Standards of Excellence

Directions: ***Before reading*** the handout, in the first column, write "A" or "D" to indicate your agreement or disagreement with each statement. ***While you read***, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. By the mid-1800s, the United States had national standards for measuring products.
		2. The mission of the National Institute of Standards and Technology (NIST) is to develop measurements and standards that strengthen the U.S. economy and improve our quality of life.
		3. Today, the U.S. has 12 people who work to maintain national measurement standards.
		4. In the early 1900s there was no unified standard for thermometers.
		5. NIST performed an important role in weapon production during World War I.
		6. Today, NIST develops tools to make measurements at the nanometer scale.
		7. NIST time standards have included the pendulum.
		8. DNA profiling techniques were standardized before NIST was established.
		9. NIST cannot measure temperatures above about 5000° C.
		10. NIST developed the standards for smoke detectors.

Student Name:_____ Date:_____ Period: _____

Optional Engagement Idea

Instead of using the Anticipation Guide, your teacher might ask you to do this:

1. Before reading the handout and NIST website, record how standards are important in your everyday life.
2. How, when and why do you think standards developed?
3. Using the handout and NIST website (https://www.nist.gov), record at least three of your ideas that were confirmed by the reading, and at least three pieces of information that surprised you and why.

Student Name:_____ Date:_____ Period: _____

History Exercise: Chronology of Standards Development

Preparation: Your teacher will print several copies of the events below and then cut the events apart and place them in an envelope for each student or student group.

Challenge: Put the following events in chronological order prior to reading.

Then, while you read, re-order the events correctly.

After reading, write a paragraph describing how world events influenced development of standards.

A. The meter was redefined based on a frequency of laser light.

B. An international scale for thermometers was developed.

C. The first standard for DNA profiling was released.

D. A single standard for all federal construction purchases was adopted.

E. Tests to measure freezing point to establish material purity were developed.

F. The first atomic clock was developed.

G. The X-ray safety code was established.

H. Standard Reference Materials® (SRMs) certified as possessing specific properties and composition were initiated to calibrate instruments and test product quality.

I. Measurement of serum cholesterol, the first of 12 healthcare markers, was developed.

Student Name:_____ Date:_____ Period: _____

Chemistry and NIST

Directions: For each standard, describe the industry or industries that initially needed the standard, why the standard is needed, and how it is measured. If appropriate, include both U.S. customary units as well as SI units. You can refer to the reading, your science textbooks and the NIST website about scientific units.

Standard	Industry(ies) served initially	Reason standard is needed	Measurement units
Thermometry and temperature			
Pressure			
Viscometry			
Isotopic abundance			

Write a one-sentence summary (20 words maximum) of the importance of NIST to chemists.

Student Name:_____ Date:_____ Period: _____

NIST and You

Choose three ways the work of NIST affects your life. For each, write a paragraph describing when the service or standard was developed and how it makes a difference to you. Refer to the reading and the NIST website for details.

Optional Engagement Idea

Instead of writing paragraphs, your teacher might ask you to prepare a poster about a selected service or standard and how it relates to your life.

NIST Answer Guide: Anticipation Guide

Anticipation Guide
Setting the Standards of Excellence

Anticipation guides engage students by activating prior knowledge and stimulating student interest before they read the handout. If class time permits, discuss students' responses to each statement ***before*** they read the article. Then, while they read the handout, students should look for evidence supporting or refuting their initial responses.

Directions: ***Before reading*** the handout, in the first column, write "A" or "D" to indicate your agreement or disagreement with each statement. ***While you read***, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
	D	1. By the mid-1800s, the United States had national standards for measuring products.
	A	2. The mission of the National Institute of Standards and Technology (NIST) is to develop measurements and standards that strengthen the U.S. economy and improve our quality of life.
	D	3. Today, the U.S. has 12 people who work to maintain national measurement standards.
	A	4. In the early 1900s there was no unified standard for thermometers.
	A	5. NIST performed an important role in weapon production during World War I.
	A	6. Today, NIST develops tools to make measurements at the nanometer scale.
	A	7. NIST time standards have included the pendulum.
	D	8. DNA profiling techniques were standardized before NIST was established.

	D	9. NIST cannot measure temperatures above about 5000° C.
	A	10. NIST developed the standards for smoke detectors.

Optional Engagement Idea

Instead of using the Anticipation Guide, consider this idea to engage your students in reading:

1. Before they read the handout and NIST website, ask students to record how standards are important in their everyday lives. If they don't know where to begin, ask, "What measurements did you make this morning? How did you know when to get up? How did you get to school?"

2. After all students have an opportunity to think about the importance of standards, ask them how, when and why they think standards developed. Student answers will vary, but probably most have not thought about the importance of standards.

3. After this discussion, invite students to read the handout and NIST website (https://www.nist.gov) and record at least three of their ideas that were confirmed by the reading, and at least three pieces of information that surprised them and why.

NIST Answer Guide: History Exercise

History Exercise: Chronology of Standards Development

Preparation: Print enough copies of the events below for each student or student group. Cut the events apart and place them in an envelope for each student or student group.

Challenge students to put the following events in chronological order prior to reading.

While they read, students should re-order the events correctly.

After reading, ask students to write a paragraph describing how world events influenced development of standards.

A. The meter was redefined based on a frequency of laser light. (1983)

B. An international scale for thermometers was developed. (1927)

C. The first standard for DNA profiling was released. (1992)

D. A single standard for all federal construction purchases was adopted. (1912)

E. Tests to measure freezing point to establish material purity were developed. (1940s)

F. The first atomic clock was developed. (1949)

G. The X-ray safety code was established. (1931)

H. Standard Reference Materials® (SRMs) certified as possessing specific properties and composition were initiated to calibrate instruments and test product quality. (1906)

I. Measurement of serum cholesterol, the first of 12 healthcare markers, was developed. (1967)

The correct order is: H, D, B, G, E, F, I, A, C.

Most of the events listed above support national (D) and international commerce (E), including the need for efficient refrigeration (B, H). Some came about because of advanced technology (A, F), the need for safety (G), improvements in health care (I), or the need for more accurate court evidence (C).

NIST Answer Guide: Chemistry and NIST

Chemistry and NIST

Directions: For each standard, ask students to describe the industry or industries that initially needed the standard, why the standard is needed, and how it is measured. If appropriate, they can include both U.S. customary units as well as SI units. They can refer to the reading, their science textbooks and the NIST website about scientific units.

Standard	Industry(ies) served initially	Reason standard is needed	Measurement units*
Thermometry and temperature	Refrigeration and space	Determine temperature of plasmas and burning fuel	Degrees Celsius (°C) or Fahrenheit (°F), or Kelvins (K)
Pressure	Semiconductor fabrication	Ensure lack of contaminants	Pascals, atmospheres, torr
Viscometry	Synthetic rubber	Characterize synthetic rubber viscosity	Pascal second, other units are also used
Isotopic abundance	Nuclear chemistry and geochemistry	Improve accuracy of weight determination	Percent

Write a one-sentence summary (20 words maximum) of the importance of NIST to chemists.

NIST Answer Guide: Chemistry and NIST

NIST and You

Ask students to choose three ways the work of NIST affects their lives. For each, they should write a paragraph describing when the service or standard was developed and how it makes a difference to them. Refer to the reading and the NIST website for details.

Optional Engagement Idea

Instead of asking students to write paragraphs, consider having them prepare a poster about a selected service or standard and how it relates to their lives.

Student choices should be based on information in the reading and on the website.

Suggested rubric:

Score	Description	Evidence
3	Very good	Complete; details provided; three different NIST topics selected.
2	Fair	Complete; some details provided; NIST topics overlap
1	Poor	Incomplete; few details provided; all information based on similar NIST topics
0	Not acceptable	So incomplete that no judgment can be made about student understanding