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# Beakers and Behavior: The Material Culture of the Science Laboratory

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## Introduction: Rethinking the Laboratory as a Cultural Space

The science classroom is often portrayed as a neutral, utilitarian space: a place where students mix chemicals, conduct experiments, and make observations in pursuit of objective knowledge. Yet when we step into a laboratory, we enter not just a physical environment, but a carefully constructed cultural space shaped by tools, materials, behaviors, and expectations. The laboratory is a place where scientific knowledge is produced, but also a place where scientific identity is performed. In this unit, students will explore how the material environment of the lab shapes what we do, and, in turn, how we understand science itself.

At the center of this exploration is the concept of object agency. The Merriam-Webster Dictionary defines agency as "the capacity, condition, or state of acting or of exerting power; a person or thing through which power is exerted or an end is achieved."[1] By extension, object agency refers to the idea that material things possess a form of power or influence that shapes human behavior, experiences, and social interactions.[2] This concept challenges the common assumption that objects are passive tools controlled entirely by human intention. Instead, it recognizes that objects *act* within human contexts by enabling, constraining, or directing action. Informed by Jane Bennett's theories of thing-power and body materialism, we can understand that materials like glass are not inert but rather vibrant actors with their own vitality, capable of affecting human bodies and behaviors in subtle yet profound ways.[3] For example, the fragile nature of a glass beaker does not simply exist to be handled; its vulnerability demands careful attention, influencing how students move, how they conduct experiments, and even how they think about safety. Similarly, the design of lab goggles shapes the wearer's vision and awareness while navigating experimentation by guiding their posture, attention, and even sense of self as a participant in scientific work. In this way, the lab is not only a place where students learn science, but also a space where the objects themselves participate in shaping scientific identity, influencing how students see, feel, and act within it.

By materializing the laboratory and bringing attention to the physicality and design of lab tools and spaces, this unit invites students to think critically about the environments in which science takes place. The presence of glass, flames, and specialized instruments co-produces both the culture of safety and the culture of scientific seriousness that defines the laboratory setting. What does it mean to wear gloves before handling a substance? How does the temperature resistance of a ceramic triangle allow us to heat substances safely? What behaviors are expected, and why? These are not just questions of safety or function, but of cultural meaning; they reveal how material objects guide, constrain, and enable scientific practice.

In rethinking the laboratory as a cultural space, students will begin to see their classroom as a living environment shaped by history, design, and human interaction. Drawing on scholarship from material culture studies and science and technology studies, this unit approaches lab equipment not just as instruments for learning science, but as agents with the power to influence how students move, act, and think. By attending to the agency of lab objects, students will gain insight into how materials communicate expectations, create boundaries, and embody the values of scientific work. This awareness will help them develop both practical lab skills and a reflective understanding of what it means to think—and act—like a scientist.

**Glass as Material and Metaphor in the Science Lab**

> “With such horrible materials, the chance of scientific breakthroughs was nearly impossible. Without good glass, science was blind.” —Ainissa Ramirez, *American Scientist,* 2022

Glass is one of the most iconic and omnipresent materials in the modern science laboratory. From beakers and graduated cylinders to microscope slides and petri dishes, glassware is often seen as a neutral, utilitarian tool that holds, measures, or displays. But when we attend closely to glass as both a material and a metaphor, it becomes clear that this substance carries a dense constellation of physical properties, behavioral expectations, historical lineages, and symbolic meanings.

Glass has long been associated with transparency and observation, values that are foundational to the scientific method itself. Its inertness, durability, and ability to be precisely molded make it an ideal medium for experimentation. These features have earned it a privileged status in laboratories since antiquity.[4] As a material, glass reflects scientific values of clarity and control, but it also demands care: glass is fragile and often expensive. Its very presence in the lab disciplines behavior, encouraging students to handle materials with caution and respect. The symbolic weight of glass extends beyond the lab bench. Culturally, glass is a signifier of science itself. Films, television, and textbooks often depict laboratories as dense with complex glass apparatus: distillation columns, condensers, flasks bubbling with colored liquids (see Figure 1). These “glass sculptures,” as one historian has described them, serve as visual shorthand to signal that “real science” is happening.[5] Even when these tools are not in use, their presence communicates authority and legitimacy.

**Figure 1: Scientist Working in a Laboratory, circa 1945.**

Captured on a glass negative, this photograph from the History Trust of South Australia shows a female scientist surrounded by glassware engaged in laboratory work. The image highlights the material environment of the lab, the role of women in mid-20th-century science, and the use of glass both as laboratory equipment and as a medium for photography.[6]

Glass is also an artifact of historical and technological development. Glassmaking dates back over 4,000 years, with roots in ancient Syria and Egypt. The invention of glassblowing and the blowpipe transformed what was possible, leading to the first hollow vessels in the 1st millennium BCE.[7] Early alchemists in Hellenistic Egypt and later in medieval Europe prized glass not only for its chemical neutrality but also for its visual permeability. Maria Hebraica, an early Jewish alchemist from the 1st century credited with inventing the tribikos and bain-marie, noted that glass enabled experimenters to “see” processes unfold without disruption.[8] This visual access remains central to experimental chemistry today. Over time, centers of innovation shifted across the globe from Aleppo to Constantinople to Venice and, eventually, to Jena, Germany.

It was in Jena in the late 19th century that Otto Schott, a chemist-turned-glassmaker, revolutionized laboratory science by inventing borosilicate glass.[9] With its exceptional resistance to heat and chemicals, Schott’s glass transformed laboratory instrumentation. Collaborating with physicist Ernst Abbe and instrument-maker Carl Zeiss, Schott created specialized glassware that met the demands of precision optics, measurement, and chemical experimentation. Their work marked the birth of scientific glass as a standardized, high-performance material technology.[10] A study of twenty famous experiments found that fifteen would have been impossible without glass tools, including Humphry Davy’s 1807 discoveries of potassium and sodium and Antoine Lavoisier’s 1777 discoveries of oxygen and conservation of mass.[11] Schott and his collaborators’ innovations in borosilicate glass were thus critical to the rise of modern chemistry and biology.

As a metaphor, glass invites students to reflect on visibility and vulnerability. It allows us to see, but also reflects our gaze. It offers access to the inner workings of matter but also breaks if mishandled. In this way, glass becomes more than a vessel; it is a participant in the culture of science. It teaches us that tools are never just tools: they carry histories, meanings, and affordances that shape the very nature of scientific inquiry. Glass does more than contain chemicals; it defines the boundaries between the experimental system and its surroundings. This boundary is not merely physical but conceptual. It demarcates what is being observed, manipulated, or measured from everything else that is not.

In chemistry and physics, systems are often simplified as discrete, closed entities. Reactions take place "in" a beaker, solutions are heated "in" a flask, and measurements are taken "in" a graduated cylinder. But these systems are only bound by the presence of glass. The transparency of glass permits observation without disruption; its chemical inertness ensures it will not interact with the substances inside; and its rigidity maintains a consistent volume and shape.[12] These properties allow scientists to define a domain of inquiry or an "inside" space where known quantities interact under controlled conditions. What lies outside the glass is often treated as noise or contamination, even though it, too, is part of the world being studied.

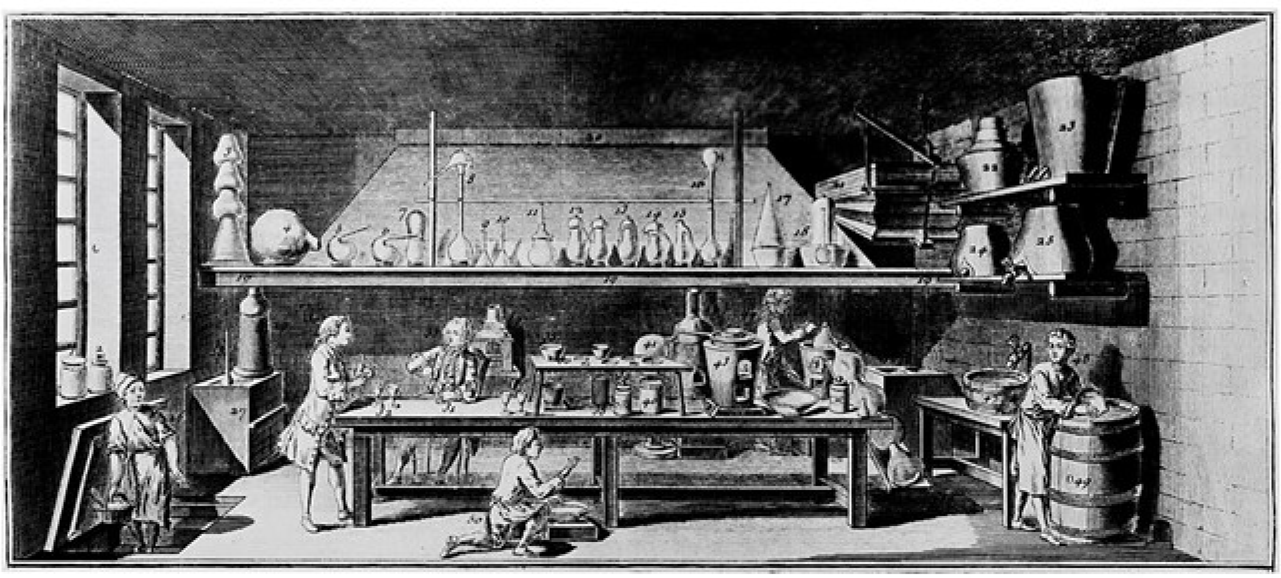

**Figure 2: Chemical Laboratory in Paris, circa 1760s.** This depiction of one of the earliest scientific laboratories highlights a structured workflow with various instruments, furnaces, and glass vessels, reflecting the organized and collaborative nature of early scientific practice.[13]

Glass's evolution from slag byproduct to artisanal craft to industrially engineered precision material parallels the evolution of science itself. Over centuries, the transformation of glass into an essential substrate for observation, measurement, and manipulation underscores how materials do not merely support science; they shape what we know and how we come to know it. But glass also enables something else: collaboration (see Figure 2). Since it standardizes the conditions for observation and measurement, glassware allows scientists across the world and across time to compare results, replicate experiments, and build upon one another's work. A volumetric flask in New Haven functions in the same way as one in Nairobi or Kyoto. In an experiment, groups of students in our chemistry classes measured the density of water and calculated their percent error using identical balances and glass graduated cylinders. When one group achieved a perfect zero percent error, it became clear to the students that the accuracy of the glassware, not just the skill of the scientist, made their findings comparable across space and time. This material consistency makes knowledge portable, verifiable, collectable, and reproducible.

In the classroom, helping students think critically about glassware can deepen their awareness of how scientific knowledge is constructed through shared tools, communal practices, and embedded values. By foregrounding glass as both a substance and a symbol, this unit invites students to encounter the lab not as a static space of facts, but as a dynamic environment of interaction, collaboration, interpretation, and identity formation.[14] Science happens not only in the mind or in the textbook, but in the hands, through materials, and with others.

**Using the Lab to Teach Material Agency, Safety, & Scientific Thinking**

In this unit, the science classroom is reimagined as more than a backdrop for activity; the high school laboratory is a dynamic site of sensemaking, identity development, and cultural practice. Students do not simply follow procedures or verify known results. Drawing from archaeological and material culture studies, students engage with lab equipment as tools, texts, and objects that are “mute” yet encoded with social, historical, and scientific values.[15] Students must figure out how and why lab tools function, how material choices influence safety and design, and what these materials reveal about science as a human endeavor.

The NGSS (Next Generation Science Standards)-aligned concept of sensemaking is central to this approach. According to Illuminate Education, sensemaking is the process in which learners “actively engage with the natural or designed world, wonder about it, and then develop, test, and refine ideas.”[16] Sensemaking ties together science and engineering practices (SEPs) and requires that students not only do science but use science to answer authentic, phenomena-based questions. In this unit, we aim to shift the classroom dialogue from “What are you learning about?” to “What are you trying to figure out?”

The National Science Teaching Association recommends grounding lab-based learning in four key elements of sensemaking.[17] Science as a discipline is deeply material. Science learning happens in relation to things, and those things influence what and how students come to know:

- **Phenomena**: Students begin with authentic objects and materials as the anchor of exploration—graduated cylinders, goggles, lab coats—not just as tools, but as phenomena in their own right.
- **Science and Engineering Practices**: Students engage in constructing explanations, developing and using models, and obtaining, evaluating, and communicating information. These SEPs promote not just skills, but identity and ownership of science.
- **Student Ideas**: Through structured discussion, observation, and reflection, students bring lived experiences and intuitive understandings into dialogue with scientific concepts.
- **Disciplinary Core Ideas**: Students connect their observations of lab objects with core chemistry and physical science ideas, including properties of matter, thermal conductivity, and chemical safety.

This approach aligns with recent shifts in science education away from rote procedure and toward culturally responsive pedagogy. As Millar (2002) argues, hands-on activity in the lab is often assumed to guarantee learning, but it must be paired with minds-on strategies to be truly effective.[18] Practical work should be carefully chosen and designed to build conceptual understanding and procedural fluency.[19] The goal is for students to make meaningful links between their observations and the scientific ideas they represent. This approach to the classroom laboratory honors both the cognitive and cultural complexity of lab work. By leveraging the cultural and symbolic dimensions of lab materials, this unit makes scientific thinking visible and teaches students to see themselves as co-constructors of knowledge.

**Space & Place: Fostering Student STEM Identity in the Lab**

> "The time is surely past when science teachers must plead the case for school laboratories. It is now widely recognized that science is a process and an activity as much as it is an organized body of knowledge, and that, therefore, it cannot be learned in any deep and meaningful way by reading and discussion alone." *—National Science Teachers Association, 1970*

This quote underscores a central premise of this unit: that the laboratory is not simply a room in which science is taught, but a cultural and material space in which science is lived. Drawing on Catherine Bell's framework on ritual and embodiment, we can understand scientific practices as secular embodied rituals that shape not only what we know but who we become.[20] Even the act of walking into a room and putting on a lab coat is an act of ritual performance—a deliberate shift in identity that signals an individual's participation in the scientific community.[21] Geraci argues that laboratory work is not only technical but also a form of human ritual, akin to religious ceremonies in its role of knowledge making.[22] Careful, repeated actions that define experimentation—the wearing of personal protective equipment, the handling of instruments, the observation, the detailed recording—are ritualized practices that shape how scientific knowledge is produced and integrated into our broader understanding of the world. Repeated gestures such as following protocols become embodied ways of knowing and belonging, cultivating an awareness of self as a participant in a shared scientific tradition.

Jan Koster's work further expands this view by emphasizing that ritual's ultimate goal is the formation and reinforcement of community identity, centered on the collective group itself.[23] In the science classroom, this means that the rituals we enact—whether donning safety gear, working in sync during experiments, or adopting shared lab language—help students move beyond individual identity toward a sense of belonging within a collective scientific culture. Just as synchronous movements or common dress unify participants in both religious and secular rituals like sports or political gatherings, the science lab's embodied rituals and material culture function as powerful tools of identity management and community building.[24]

The classroom laboratory is where students learn not only the procedures and content of scientific work but also begin to see themselves as participants in that work. Building on the work of Bourdieu, identity is closely linked to four forms of capital—cultural, social, linguistic, and material—that students bring with them and acquire through their experiences.[25] Within science education, the concept of science identity frames how students come to see themselves, and are seen by others, as "science people."[26] In this sense, the classroom laboratory is an incubator for STEM identity; the lab is a place where behaviors, tools, and norms all shape how students come to understand what science is and who gets to do it. Shared laboratory rituals help students speak, move, and act as one, reinforcing their place in the shared enterprise of science and fostering a collaborative spirit that transcends individual differences.

While lab safety, scientific reasoning, and technical skills are essential foundations of science education, equally important is the cultivation of students' identities as capable and thoughtful participants in scientific inquiry. As Avraamidou notes, science identity is not fixed; students' STEM identities evolve over time through interactions, representations, and opportunities to participate meaningfully in science practices.[27] The classroom laboratory is not a neutral backdrop for scientific work, but an active space that shapes behavior, reinforces norms, and communicates values. In this unit, the physical environment of the lab—the arrangement of space, the design of tools, and the expectations embedded in the materials—becomes a powerful influence on how students see themselves as scientists.[28] By intentionally exploring this environment, students begin to recognize how space and place co-construct their understanding of what science is, how science is performed, who does science, and who science is for.

Just as laboratories have historically shaped scientific practice from 18th-century chemical labs to modern-day research spaces, the classroom lab serves as both a site of experimentation and a space where students negotiate their roles and identities as budding scientists. Through structured observation and object-centered analysis, students reflect on how their interactions with lab equipment influence their sense of belonging and scientific capabilities. Wearing goggles, for example, can feel exciting yet awkward at first, but, with time, this act signals membership in a shared scientific culture. The careful handling of fragile glassware teaches restraint, focus, and intentionality; these behaviors are all associated not just with safety, but with professionalism. Even seating arrangements, storage systems, and access to materials can shape students' agency and confidence as they navigate lab spaces.

Moreover, this unit helps students understand that scientific identity is not just about what you know, but how you move, speak, write, listen, and engage in a space designed for inquiry. By foregrounding material culture and environmental contexts, we encourage students to see themselves not as passive recipients of knowledge, but as active participants whose actions, safety, decisions, and sense of care all contribute meaningfully to the scientific process. This unit takes seriously the call for inclusion, not by simply placing students in the lab, but by helping them interpret, critique, and claim ownership of it.

As a high school science educator at Wilbur Cross High School in New Haven, I work with students who arrive each day with a variety of academic backgrounds, home circumstances, and life experiences. My classroom reflects a mixture of ethnicities, economic backgrounds, and social and emotional strengths and challenges. Because this unit emphasizes material culture, students engage with science both inside the classroom and beyond, including field trips to the Yale University Art Gallery and the Yale Peabody Museum of Natural History. While the curriculum is framed for science classrooms, teachers of history, social studies, art history, and English Language Arts can also adapt activities, emphasizing different aspects to fit their content.

Etienne Wenger reminds us that “learning transforms who we are and what we can do; it is an experience of identity.”[29] That transformation happens in a space where students are not only performing experiments, but interpreting their tools, questioning their environments, and seeing themselves as active contributors to scientific knowledge. By examining the material culture of the lab—glassware, safety goggles, measurements, and lab benches—students begin to see science as something they are not only doing, but shaping.[30] They develop agency, not only through inquiry, but through reflection on how their presence and practices matter in this space. Ultimately, by cultivating awareness of the lab as a space of belonging, this unit supports students in developing not just lab competence, but a reflective, empowered STEM identity grounded in care, curiosity, and community.

## Content Objectives: Matter, Energy, & the Meaning of Materials

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This unit aims to develop students' foundational understanding of key chemistry concepts while simultaneously fostering critical awareness of the cultural and material significance of laboratory tools. These objectives are framed through both a scientific and cultural lens, asking students not only *what* materials are used in science, but *why*, and *what that means* in broader social and historical contexts. Students will explore how laboratory tools are designed with both safety and functionality in mind, and how these objects shape student behavior, scientific norms, and cultural perceptions of science itself. By the end of the unit, students will be able to:

- **Recognize the role of laboratory materials and equipment as active agents that shape scientific practice**, influencing not only experimental outcomes but also student behavior, safety protocols, and the culture of scientific inquiry.
- **Explain how the design and material composition of laboratory tools reflect both scientific function and cultural values**, linking historical developments in lab equipment with evolving scientific understanding and social expectations.
- **Describe and explain the physical and chemical properties of materials commonly used in laboratory settings**, such as glass, metal, plastic, and ceramics, including their roles in conducting or insulating heat, resisting chemical reactions, and maintaining structural integrity.
- **Interpret and use scientific measurement tools and SI units accurately**, including volume, mass, temperature, and time, with proficiency in unit conversions and proper data recording to support precise laboratory work.
- **Understand and apply concepts of energy transfer, especially heat conduction and thermal resistance**, through hands-on investigations and models that reveal how different materials respond under varying experimental conditions.
- **Develop and communicate scientific explanations connecting material properties and energy interactions to observed phenomena**, supported by evidence from experiments and observations.
- **Investigate the intersections of science, culture, and history** by exploring how material choices in laboratory tools and everyday objects reflect cultural identity, technological innovation, and societal needs over time.

## Student-Centered Learning in Hands-On Classroom Laboratories

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In many classrooms, lab safety is taught through rote rules and cautionary tales. While rules are necessary, they often fail to encourage deeper understanding or engagement. This unit takes a different approach: it treats the laboratory not just as a site of experimentation, but as a material and cultural environment that can be studied and learned from through its objects. Through careful observation, structured discussion, and hands-on experience, students learn how the physical properties of lab equipment influence scientific behavior, safety protocols, and even their sense of identity as scientists. Students begin to internalize lab safety not just as a rule set, but as a responsive behavior influenced by the affordances of the materials around them. By explicitly focusing on material agency, this unit uses the laboratory itself as a learning tool for both scientific content and scientific thinking.

At the start of the unit, students are introduced to a Lab Safety Contract that outlines expectations for material handling, behavior, and personal protective equipment. Rather than presenting rules as fixed mandates, students engage in a collaborative review of the contract, using object-centered analysis to explain why each rule exists.

Students will engage in a close reading and collaborative discussion of the Lab Safety Contract. After the in-class review and discussion, students are required to take the contract home for parent/guardian review and signature. Both the student and guardian must sign and return the form before the student may participate in any laboratory activities. A district-mandated quiz that assesses both content knowledge and reflective reasoning around safe lab practices will be given to students. To meet district science policy, students must pass a Lab Safety Quiz with a score of **90% or higher** to be cleared for laboratory work. This practice not only fulfills school policy but reinforces a shared understanding of the seriousness and cultural norms of lab conduct.

This foundational activity sets the tone for the unit by reframing lab safety as an opportunity for students to reflect on how materials shape their actions, decisions, and responsibilities in the lab environment. Rather than memorizing a list of do's and don'ts, students will use object-centered analysis and evidence-based reasoning to interpret the *why* behind each rule. This positions lab safety as a meaningful scientific practice tied to the properties and design of lab tools, reinforcing the idea that materials influence behavior and responsibility.

By the end of this unit, students will not only meet school safety requirements but will also develop a deeper, more reflective understanding of why lab rules exist. They will recognize that lab safety is not arbitrary, but rooted in the scientific and material realities of the tools we use. This lays the groundwork for viewing the lab as a space of intentional practice, where scientific thinking, responsibility, and identity are co-produced by human behavior and material context.

## Teaching Strategies

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Effective teaching strategies help create a classroom environment where students actively engage with ideas, collaborate meaningfully, and connect concepts to their own experiences. Whether reimagining lab tools, analyzing cultural representations, or practicing lab safety, students learn not only through ideas but through the shared actions and collaborative habits that make science a living, communal practice. In this unit, these approaches support students as they explore the cultural, material, and social dimensions of scientific work.

- **Facilitating Peer-to-Peer Engagement:** This strategy encourages students to actively learn from and with each other through structured interaction. In this unit, peer discussions allow students to share diverse perspectives and deepen understanding collaboratively.
- **Think-Pair-Share:** Students first think individually about a question, then discuss their thoughts with a partner before sharing with the larger group. Use this during reflections on scientific identity or lab safety scenarios to promote thoughtful engagement.
- **Turn & Talk:** Students briefly discuss a question with a nearby peer before sharing with the whole class. This quick verbal exchange helps build confidence and prepare students to participate in broader

conversations about scientific practices.

- **1-Minute Paper:** Students quickly write a brief response to a prompt, helping teachers assess comprehension and encourage reflection. As an exit ticket, this can capture students' immediate thoughts on how materials influence scientific work.
- **Step Up, Step Back:** Students are encouraged to contribute ideas ("step up") or listen more attentively ("step back") to balance participation. Use this to manage group discussions so all voices, including those of quieter students, contribute to conversations.
- **Probing:** Teachers ask follow-up questions to deepen student thinking and clarify reasoning. During lab safety discussions or design challenges, probing helps students justify their ideas and explore material properties more critically.
- **Revoicing:** The teacher restates a student's idea to clarify and validate their thinking, inviting further input. This is useful when students share observations about lab objects, reinforcing understanding and encouraging elaboration.
- **Wait Time:** Deliberate pauses after asking a question give students time to think before responding. Implement wait time after complex prompts like "How do lab rituals shape identity?" to encourage deeper, more thoughtful answers.
- **Talk Facilitation Moves:** Techniques like summarizing, inviting others to speak, or redirecting questions help keep discussions focused and inclusive. Use these moves to maintain productive dialogue during group work and whole-class discussions on lab culture and safety.

## Instructional Activities

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**I. Gallery Walk: Rethinking the Draw-A-Scientist Test**

- **Description & Objective:** Students explore common cultural images of scientists by drawing their own mental picture and discussing it with peers. They then create self-portraits as scientists, imagining themselves in STEM roles, followed by a gallery walk to observe diverse identities. Finally, students reflect on how their perceptions of scientists compare to their own scientific identities and what this reveals about inclusion in STEM. The objective of this activity is to challenge stereotypes about what scientists look like and foster students' sense of belonging in STEM by encouraging them to envision themselves as active participants in scientific communities.
- **Opening Discussion:** In small groups, discuss the question: *What do scientists look like?* Consider clothing, tools, workspaces, and demeanor. Draw on images you've seen in media, books, or everyday life.
- **Initial Drawing:** Individually, create a quick drawing of "a scientist" based on your current mental image. This can be realistic or symbolic.
- **Classroom Discussion:** Share and compare your drawings. What patterns do you notice? What kinds of scientists did you draw? Do certain items, clothing styles, or settings appear repeatedly? Why might that be? Did your scientist work alone or with others? Was your scientist indoors, outdoors, or in another type of space? What gender, race, or age did your scientist appear to be? Did you think about this while drawing? Where do you think the images or ideas you drew came from (i.e. TV, books, school, personal

experience)? Do you think your drawing represents most scientists in the real world?
- **Self-Portrait as Scientist:** Now draw yourself as a scientist. Think about what you'd be wearing, what tools you'd use, where you'd be, and what kind of work you'd be doing.
- **Gallery Walk:** Hang the student self-portraits around the classroom. Students walk around to see the variety of roles, settings, and identities represented.
- **Reflection:** Write a short paragraph reflecting on how your self-portrait compares to your original drawing of "a scientist." What changed? What stayed the same? How does imagining yourself as a scientist change the way you think about science or your place in it? How can our classroom environment support everyone feeling like they belong in science?

### II. Role Play: SI Units & the French Revolution

- **Description & Objective:** Students will explore the importance of standardized units of measurement by imagining themselves as servants in Versailles before the French Revolution, when units varied widely between regions and trades. Embodying these roles, students grasp why uniform measurement systems like SI units were essential for science and society. They will discover how inconsistent measurements could lead to mistakes, waste, or conflict, and why the eventual move toward unit standardization was transformative for work, trade, and science. Through roleplay, students will understand the historical origins of the metric system and relate standardized measurement to practical daily tasks through role play.
- **Historical Context:** In 18th-century France, measurement was a chaotic system with an estimated over two hundred fifty thousand different units in use across the country. Different towns and regions measured length, weight, and volume in their own ways; a "pound" in one area might not equal a "pound" in another. On top of this, rulers and local authorities issued decrees that frequently changed or added to the array of measurement standards, deepening the confusion and amplifying inconsistencies. For the servants of Versailles, these inconsistencies could cause real problems in their daily tasks.
- **Roles:**
    - **Servant (General Household Duties):** Performs a variety of tasks such as cleaning, organizing, and assisting other staff, often using measurements for quantities like water or cleaning supplies.
    - **Gardener:** Tends to the gardens by planting, watering, and pruning, measuring soil, water, and plant spacing to maintain the grounds.
    - **Tailor:** Creates and alters clothing and uniforms, using precise measurements of fabric and body dimensions.
    - **Cook:** Prepares meals by following recipes that require careful measurement of ingredients for taste and consistency.
    - **Cobbler:** Repairs and makes shoes, measuring foot sizes and materials to ensure proper fit and durability.
    - **Stable Hand:** Cares for horses, measuring feed and water to maintain their health and performance.
    - **Chambermaid:** Cleans and maintains rooms, measuring linens and cleaning supplies to ensure proper use and presentation.
- **Prompt:** Assume the role of a servant working at the Palace of Versailles and describe how you use measurement units in your job. What tasks do you perform daily? What tools and materials do you use, and how do units of measurement help you carry out your work accurately?

**III. Lab Equipment Scavenger Hunt**

- **Description & Objective:** Students will explore and familiarize themselves with common laboratory equipment by locating, visually identifying, and inferring function based on appearance. This activity encourages observation skills, critical thinking, and vocabulary building. This activity builds foundational vocabulary and helps students connect tools to their scientific purposes.
- **Prompt:** Walk around the classroom and find each piece of lab equipment labeled with a letter on the lab benches. Write the letter next to the name of each object on your worksheet. Then below, write the correct name of the laboratory equipment pictured. On the back side of the worksheet, you will match each piece of equipment with its likely use by connecting the letters to a list of possible functions. Since many of you haven't used this equipment before, it's okay to make thoughtful guesses based on what the tools look like. As you work, I'll be walking around to help you think about the shapes and features of the equipment and how those might relate to their uses.

**IV. [Re]Designing a Laboratory Object**

- **Description & Objective:** Students examine standard lab equipment used in a given experiment and identify potential limitations or challenges in its current design. Working individually or in small groups, they brainstorm and sketch modifications that could improve precision, efficiency, accessibility, or safety. By linking their scientific knowledge with engineering and problem-solving skills, students explore how design choices shape laboratory practice and influence experimental outcomes.
- **Sample Redesign Prompts & Ideas:** Given a common experiment, propose a redesign of a lab object to improve accuracy, safety, or usability.
    - Design a pipette that can be easily used by visually impaired students by considering tactile or auditory feedback.
    - Create a new version of tongs that improves grip and prevents burns when handling hot objects near open flames.
    - Modify a beaker to reduce the risk of spills and improve handling for students with limited hand strength.
    - Redesign a graduated cylinder to make reading measurements easier and more precise, perhaps with color-coded markings or a magnifying feature.
    - Develop an improved lab coat with built-in features to enhance safety and comfort during experiments.
    - Redesign goggles to include prescription lenses or magnifying features for students who wear glasses.
    - Design lab goggles that fog less during experiments to improve visibility and fit different face shapes and sizes, ensuring a secure seal for all students.

**V. CER Assessment (Claim-Evidence-Reasoning)**

- **Objective & Description:** Students will carefully study a lab safety incident or image depicting unsafe conduct. They will identify the unsafe action and articulate their claim about the risk it poses. Using their knowledge of material properties (like fragility, flammability, or chemical reactivity) and classroom norms, students provide concrete evidence. Finally, they explain their reasoning, linking how the observed unsafe behavior could cause accidents or harm, thus demonstrating the importance of safety practices grounded in material understanding. Students will strengthen scientific communication by analyzing unsafe lab behaviors through the CER framework.
- **Prompt:** Examine the provided lab safety scenario and write a clear CER paragraph. Make a claim

about what behavior is unsafe, support it with evidence from your understanding of lab materials and classroom safety rules, and explain why this behavior endangers students, demonstrating how their understanding of materials directly informs lab safety and conduct.

## VI. Object Study Session: An Approach to Studying Tools and Technology

- **Objective & Description:** Central to this unit's teaching strategies is the use of an object-centered analysis, which invites students to study lab tools and materials not simply as inert instruments, but as active participants in scientific practice. To guide this exploration, students employ art historian Jules Prown's three-step framework: Description, Deduction, and Speculation.[31] This method, originally developed in material culture studies, supports close observation and critical thinking about objects. As Prown explains, "We have been taught to retrieve information in abstract form, words and numbers, but most of us are functionally illiterate when it comes to interpreting information encoded in objects."[32] By following these stages in order, Prown's framework guides learners from objective observation to critical reflection, enabling a richer understanding of material culture that bridges science, history, and culture.
    - **Description:** *Look closely and describe only what you see.*Focus on color, texture, shape, materials, and condition. Students consider questions like: What materials seem to be used in this object? What colors, textures, or shapes stand out? Does anything look worn, cracked, faded, preserved, or aged? Don't guess or assume; just observe.
    - **Deduction:** *Use your observations and science knowledge to figure out how the object was made or used.*Students consider questions like: What processes might have been involved in making this object? How do you think the object has changed over time, chemically or physically? Based on the shape and form of the object, what could its function be?
    - **Speculation:** *Ask deeper questions and make connections.*Students consider questions like: How does this tool reflect technological advancements or safety priorities? What does its design say about the values or knowledge of the scientific community that uses it? Why were these materials used? What can this object tell us about the people who made it?

### Object Study Session Case: Graduated Cylinders and the Prown Method


**Figure 3: Graduated Cylinders.** Four glass graduated cylinders of various sizes that measure from left to right 10, 25, 50 and 100 milliliters (mL). [33]

To help students internalize the steps of Prown's object-centered analysis, this unit includes a focused case study comparing two laboratory staples: glass and plastic graduated cylinders of different sizes (see Figure 3). These tools are deceptively simple, yet they embody layers of scientific, historical, and cultural meaning. By applying Prown's Method to these objects, students move beyond seeing lab equipment as neutral or utilitarian, instead recognizing how design, material, and context shape practice and behavior.[34] This case study models the kind of deep observational and critical thinking this unit cultivates, bridging scientific content with material literacy.

**Description** invites students to carefully observe the graduated cylinder. They examine the tall, narrow, cylindrical shape typical of graduated cylinders, noting the smooth, transparent surfaces. There is a small pouring lip at the top and a foot at the bottom. By considering size and the precise measurement markings etched along the side, students think about volume capacity.

Moving to **Deduction**, students infer how the aforementioned physical properties affect the cylinder's function and the behaviors they encourage in the laboratory. For example, the glass cylinder's transparency allows for clear, accurate reading of liquid levels, while its fragile nature demands careful handling to avoid breakage or injury. In contrast, the plastic cylinder, often more durable and lightweight, may be favored for certain tasks where safety and ease of use are prioritized. The narrow shape of both cylinders promotes precise measurement but also requires scientists to pour liquids cautiously, reducing the risk of spills especially when handling hazardous chemicals. The foot or base of each graduated cylinder provides stability and helps prevent tipping. On the glass cylinder, this foot may be fused as a single piece, often heavier to anchor the tall, narrow vessel. By comparing the bases, students begin to understand how even subtle design features, such as the width, weight, and texture of the foot, contribute to the object's functionality. These observations, though seemingly mundane, lay the groundwork for deeper inferences about safety, balance, and laboratory use.

In the **Speculation** phase, students reflect on the broader cultural and historical significance of these graduated cylinders. Speculation on the transition from glass to plastic materials reflects not only evolving safety concerns and technological progress within laboratory environments, but also economic considerations. While glass has long been valued for its clarity, heat resistance, and chemical inertness, it is expensive to produce and easily breakable. The adoption of durable plastic polymers represents a shift toward affordability, disposability, and risk reduction, particularly in educational or high-throughput lab settings. This variation embodies changing priorities, balancing accuracy and sustainability with durability and risk management. The graduated cylinder becomes a lens through which students explore not only laboratory design but the shifting material realities of science itself.

Moreover, students can also **speculate** about how the graduated cylinder's standardized markings along its side embody the scientific values of precision and reproducibility. These uniform measurement increments are not arbitrary; they reflect a long history of efforts to create consistent and reliable standards in science. Students can connect this to the development of the International System of Units (SI), which emerged after the French Revolution as a response to the need for universal, standardized measurements that could be used across countries and disciplines.[35] This standardization revolutionized scientific practice by enabling scientists worldwide to replicate experiments and share data with confidence.

The graduated cylinder, therefore, is more than a measuring tool; all laboratory equipment are symbols of the broader cultural and political movements that shaped modern science's commitment to accuracy, collaboration, and trustworthiness. All laboratory equipment and protocols are living records of the ongoing negotiations between scientific needs, safety considerations, and technological possibilities. Thus, this object study session with the Prown Method helps students appreciate how scientific instruments carry with them histories of human cooperation and the pursuit of shared knowledge.

## Materials & Classroom Resources

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**Classroom Resources**

- **PhET Interactive Simulations** – A free online platform offering interactive science and math simulations across many topics, including chemistry, physics, and earth science. Simulations provide hands-on virtual labs and experiments that complement physical lab activities and reinforce core concepts in an accessible way.[36]
- **CK-12 Simulations** – An extensive library of free, interactive science simulations covering physics,

chemistry, biology, and earth science topics. These browser-based tools allow students to manipulate variables, observe outcomes, and test hypotheses in a safe, virtual environment, making them ideal for pre-lab preparation, concept reinforcement, or remote learning.[37]

- **Science Lab Safety Video Library** – Various sources on YouTube and educational websites provide curated videos illustrating proper lab safety practices, protocols, and common hazards. Visual media supports students' understanding of safety beyond written rules by modeling behaviors and consequences in real lab settings.
- **Google Arts & Culture: Palace of Versailles –** This rich resource offers students access to artworks, virtual tours, and 3D models of the Palace of Versailles, including highlights like the Water Pathway, Gardens, Colonnade Grove, and Hall of Mirrors.[38] It provides immersive experiences through VR and interactive features that help students visualize the historical setting of 18th-century France.[39] Perfect for the *Role Play: SI Units & the French Revolution* instructional activity, these tools enable students to better understand the environment and cultural context of the roles they inhabit.

**Materials**

- **Basic High School Chemistry Lab Equipment:** beakers, Erlenmeyer flasks, graduated cylinders, volumetric flasks, pipettes, test tubes, tongs, lab goggles, hot plates, balances (electronic & triple beam), pipettes, tongs, funnels, watch glasses, thermometer, crucible
- **Safety Gear & PPE:** lab coats, safety goggles, heat-resistant gloves
- **Labeling Supplies:** permanent markers & labels for scavenger hunt
- **Worksheets and Printables:** role play character sheets, scavenger hunt worksheets, CER prompts, gallery walk reflection sheets, lab redesign templates, lab safety contract
- **Writing & Drawing Supplies:** pencils, colored pencils, crayons, markers, sketch paper
- **Technology Resources:** computer/tablet with internet access
- **Visual aids/posters** of lab safety rules and standard units

## Student Reading List

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The readings in this unit are selected to help students explore the laboratory not just as a place for experiments, but as a space full of stories, materials, and practices that shape how science is done and who does it. From understanding the tools they will use, to learning about the history of measurement, to thinking about how science shapes identity, these texts will guide students in seeing science as a living, collaborative process.

Britannica, "Measurement: International System of Units." https://www.britannica.com/science/measurement-system/The-English-and-United-States-Customary-systems-of-weights-and-measures.

Carolina Knowledge Center, "Lab Safety Dos and Don'ts for Students."

https://knowledge.carolina.com/professional-growth/safety/lab-safety-dos-and-donts-for-students/.

Flinn Scientific, “Student Safety Contract.” https://www.flinnsci.com/api/library/Download/80efae9513b548d6999c31d38ac36abe.

Indeed Editorial Team, “What is a Scientist? Definitions and Types.” https://www.indeed.com/career-advice/career-development/what-is-a-scientist.

Mark Miodownik, “Stuff Matters: Exploring the Marvelous Materials That Shape Our Man-Made World.”

Mark Miodownik, “Liquid Rules: The Delightful and Dangerous Substances That Flow Through Our Lives.”

Mark Miodownik, “It's A Gas : The Sublime And Elusive Elements That Expand Our World”

Quora, “Why Diversity In Science Is So Important.” https://www.forbes.com/sites/quora/2022/05/28/why-diversity-in-science-is-so-important/.

National Research Council (US) Committee on Prudent Practices in the Laboratory, “Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards: Updated Version.” https://www.ncbi.nlm.nih.gov/books/NBK55882/.

Nature Editorials, “Science Benefits from Diversity.” https://www.nature.com/articles/d41586-018-05326-3.

Understanding Science 101, “The Scientific Community: Diversity Makes the Difference.” https://undsci.berkeley.edu/understanding-science-101/the-social-side-of-science-a-human-and-community-endeavor/the-scientific-community-diversity-makes-the-difference/.

## Annotated Bibliography & Resources for Teachers

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Avraamidou, Lucy. “Science Identity as a Landscape of Becoming: Rethinking Recognition and Emotions through an Intersectionality Lens.” *Cultural Studies of Science Education* 15, no. 2 (2020): 323–45. This article frames science identity as dynamic and socially situated, informing this unit’s approach to fostering inclusive and participatory science identities in the classroom.

Banchi, Heather and Randy Bell, “The Many Levels of Inquiry,” *Science and Children* 46, no. 2 (2008): 26–29, http://www.jstor.org/stable/43174976. This article presents the Levels of Inquiry Continuum and provides guidance on scaffolding inquiry-based learning in the classroom.

Bell, Catherine. *Ritual Theory, Ritual Practice.* New York: Oxford University Press, 1992. This book frames rituals as embodied performances that structure experience and social roles.

Bennett, Jane. “The Force of Things: Steps toward an Ecology of Matter.” *Political Theory* 32, no. 3 (2004): 347–72. http://www.jstor.org/stable/4148158. This article develops the concept of “vibrant matter,” emphasizing the active role of nonhuman things as agents that shape events.

Geraci, Robert. “Laboratory Ritual: Experimentation and the Advancement of Science.” *Zygon: Journal of*

*Religion and Science* 37, no. 4 (2002): 891–908. https://doi.org/10.1111/1467-9744.00463. This article examines the performative and ritualistic aspects of laboratory work, exploring how experimental procedures shape knowledge production and scientists' identity.

Hoskins, Janet. "Agency, Biography and Objects." In *Handbook of Material Culture*, edited by Chris Tilley et al. London: Sage Publications, 2006. This chapter provides a foundational framework for understanding how objects possess "biographies" and "agency," offering tools for analyzing laboratory equipment as both cultural and scientific artifacts.

Jenkins, Edgar. 2007. "What Is the School Science Laboratory For?" *Journal of Curriculum Studies* 39 (6): 723–36. https://doi.org/10.1080/00220270601134425. This article explores the evolving purposes of the school science lab and its role in supporting scientific understanding.

Millar, Robin, Fred Lubben, Richard Got, and Sandra Duggan. "Investigating in the School Science Laboratory: Conceptual and Procedural Knowledge and Their Influence on Performance." *Research Papers in Education* 9, no. 2 (1994): 207–48. https://doi.org/10.1080/0267152940090205. Explores how students' conceptual understanding and procedural skills interact to influence their success in school laboratory investigations.

National Research Council. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press, 2012. This framework underpins the Next Generation Science Standards.

Prown, Jules David. "Mind in Matter: An Introduction to Material Culture Theory and Method." Winterthur Portfolio 17, no. 1 (1982): 1–19. http://www.jstor.org/stable/1180761. This article introduces the Prown Method, which is used in this unit for structured object study and analysis.

## Appendix on Implementing District Standards

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"From Beakers to Behavior: The Material Culture of the Science Laboratory" supports New Haven Public Schools' vision for rigorous, inquiry-based science instruction and fully aligns with the Next Generation Science Standards.[40] This unit centers on three key Science and Engineering Practices.[41] These practices are embedded throughout the unit to help students build both content mastery and scientific identity rooted in thoughtful lab behavior.

Students engage deeply in Constructing Explanations (SEP 6) as they investigate the physical and chemical properties of everyday lab materials and explain why certain tools are made from specific substances. Rather than memorizing safety rules, students are encouraged to explain the rationale behind them, fostering deeper conceptual understanding and personal responsibility.

Throughout the unit, students also Obtain, Evaluate, and Communicate Information (SEP 8) from a variety of sources, including visual art, historical texts, contemporary lab manuals, and classroom experiments. They critically analyze how scientists and labs are represented in media, comparing those depictions with the realities of their own classroom lab environment. Communication in this unit is not limited to written reports; it includes visual analysis, discussion protocols, and reflective writing that reinforces safety, identity, and respect for scientific spaces. This emphasis on sensemaking and communication supports the development of both science literacy and lab citizenship.

Additionally, students Develop and Use Models (SEP 2) to visualize the structure, function, and behavior of lab tools and scientific concepts. They draw and label diagrams of equipment, model how heat moves through different materials, and represent molecular structures of matter. These models help students connect abstract scientific ideas to the real, tangible tools they use, bridging chemistry content with cultural understanding of how science is practiced in context.

By grounding SEPs in the material realities of the lab, this unit supports district goals for building critical thinking, disciplinary literacy, and responsible scientific engagement. By the end of this unit, students will not only know how to "think like scientists," but also act like them with care, clarity, and curiosity.

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