Hitting the Bullseye: Measuring Volume with Precision and Accuracy

Overview

This lesson serves as an introduction to precision and accuracy, the metric system and why the scientific community uses it universally, and pieces of lab equipment relating to volume. Students are not expected to have much background knowledge and would benefit the most from this activity by completing it towards the beginning of the year. An emphasis is placed on techniques and strategies promoted by the American Modeling Teachers Association such as whiteboarding and collaboration, as ways to help create a positive learning environment that is supportive of students' social-emotional development.

Key Search Words

High school/secondary, chemistry, physical science, NGSS, American Modeling Teachers Association, argumentative-driven inquiry, volumetric flask, pipette, graduated cylinder, beaker, Erlenmeyer flask, burette, metric system, imperial system, graduations (separating lines on volume equipment)

Learning Objectives

- SWBAT recognize, name, and choose a suitable volume device when conducting laboratory explorations.
- SWBAT define precision and accuracy.
- SWBAT verbally express the limitations in a measuring device.

Curriculum Alignment

- NGSS:
  - HSN-Q.A.3: Choose a level of accuracy appropriate to limitations on measurements when reporting quantities
  - MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that optimal design can be achieved.
- While the science standards for middle and high school students in North Carolina do not include precision and accuracy, the metric system, and lab equipment, the following statement is included under the North Carolina Essential Standards for chemistry under 'Science as Inquiry" which showcases it is an expectation that students will be familiar with laboratory equipment in order to engage with the other standards:

> "Traditional laboratory experiences provide opportunities to demonstrate how science is constant, historic, probabilistic, and replicable. Although there are no fixed steps that all scientists follow, scientific investigations usually involve collections of relevant evidence, the use of logical reasoning, the application of imagination to devise hypotheses, and explanations to make sense of collected evidence. **Student engagement in scientific investigation provides background for understanding the nature of scientific inquiry. In addition, the science process skills necessary for inquiry are acquired through active experience.** The process skills support development of reasoning and problem-solving ability and are the core of scientific methodologies."

Classroom time required

30-45 minutes

Materials & Technology

- Whiteboards (can be substituted for scratch paper) and Expo markers
- Food coloring (optional)(can be used to make the color easier to see when measuring in the challenge component)
- Volume lab equipment: whatever is available including, but not limited to…
  - Volumetric flask
  - Pipette
  - Graduated cylinder
  - Beaker
  - Erlenmeyer flask
  - Burette
- Household volume equipment: whatever is available including but not limited to…

- Measuring cups/spoons
- Water bottles (with some sort of graduation)
- Jars (with some sort of graduation)

- If the volume is not included on the household item, use a piece of tape and mark it. Use the Imperial System as well as the metric system on different items. Graduations can be included, but are not required. Students can use Google to do conversions as needed.
- Funnel (optional) for pouring water from the student volume device to the standard.

Safety

- Food dye can stain clothing; students should be alerted the day before this lesson; if lab aprons are available, students can wear these to protect their clothing.
- Bookbags and other personal items should be stored under lab benches/desks as students will be moving around the classroom.

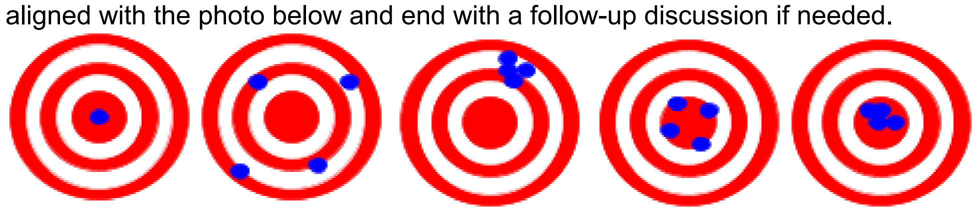
Teacher Preparation for Activity

Gather materials and set aside volume lab equipment for the showcase/presentation.

Student Preparation for Activity

Before completing the challenge (the culminating activity of the lesson), students should be familiar with the metric system and the names of the different pieces of lab equipment that can be used to measure volume.

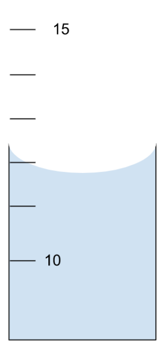
Procedure

<table>
<tr><th><u>Activity and Description</u></th><th><u>Time (minutes)</u></th></tr>
<tr><td><u>Introduction to Precision and Accuracy</u>
1. Whiteboarding 1:
a. Students will be prompted to define precision and accuracy on their whiteboards. “Write accuracy and precision on your whiteboard. What’s the difference?”
b. The teacher will then lead a quick discussion. Key points for discussion:
i. Precision and accuracy are NOT the same thing
ii. Precision: getting similar values repeatedly
iii. Accuracy: getting close to the desired value; hitting the target
2. Video: Students will watch from 0:00-1:18 of the Robin Reaction “Accuracy vs Precision” video (link and information provided under “Required Resources”) or another general introduction to the concept.
a. Accuracy: “how close a measured value is to an actual value” (Robin Reaction, 2018)
b. Precision: “how close the measured values are to each other” (Robin Reaction, 2018)
3. Whiteboarding 2:
a. After watching the video, the PowerPoint will prompt students to draw representations of low accuracy and low precision, low accuracy and high precision, high accuracy and low precision, and high accuracy and high precision.
b. The teacher will circulate the room to check that student representations are aligned with the photo below and end with a follow-up discussion if needed.

Actual value | Low accuracy and precision | Low accuracy and high precision | High accuracy and low precision | High accuracy and precision
4. Additional resource for students who need review: Students can watch a Professor Dave video entitled “Accuracy and Precision for Data Collection” (link and information provided under “Required Resources”) where the material is presented in a slightly different way.</td><td>10</td></tr>
<tr><td><u>Introduction to the Metric System</u> (can be omitted if this has already been covered)</td><td>4 (optional)</td></tr>
</table>

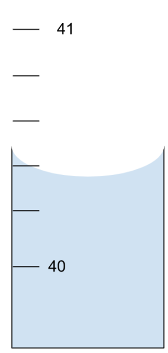
1. **World Map:** Students will be asked which 3 countries still use the Imperial System. “Which 3 countries use the Imperial system (cups, ounces, pounds, miles, etc.) to measure instead of the metric system (meters, liters, grams etc.)?” Answer:
    a. United States
    b. Myanmar
    c. Liberia
    d. United Kingdom* (uses metric system for most things, but Imperial System for some such as miles, pints, and gallons)
2. **Discussion:** Students will briefly discuss the following two questions at their lab benches and then with the class:
    a. “Why do we use the metric system (meters, liters, grams etc.) in science instead of the imperial system (cups, ounces, pounds, miles, etc)?” Key points:
        i. Easier to convert within this system (base of 10)
        ii. Scientists decided to use the metric system for constants/equations → everything is built off of this
    b. “Which piece of equipment from around the room would give the lowest margin of error (most accurate AND precise) to measure volume?” Key points:
        i. There is not a 100% correct answer, but ideally a volumetric flask/burette would be available
        ii. Something where the liquid would have a lower surface area/room for error

Introduction to Volume — 8

1. **Lab Equipment Showcase:** Different pieces of lab equipment used to measure volume will be presented to the class. During the presentation, students will make a chart in their lab notebooks that includes the lab equipment name and a drawing of the piece of equipment. To save time, “Appendix A” is a printout that can be given to students that only requires them to draw the piece of lab equipment.
2. **Reading the meniscus:** Students will learn how to read the volume of a graduated cylinder. The steps are as follows:
    a. The graduated cylinder should be on a flat surface.
    b. To read the volume, you must be on the same level as the top of the liquid.
    c. You always read from the bottom of the visible circle.
    d. You can add one estimated digit (NO MORE THAN ONE)



1.



2.

1. ~11.9 mL 2. ~40.35 mL

Activity — 12-25

1. **Challenge:** Get as close to X mL (according to a chosen DEVICE; whatever volume/device that is selected by the teacher) as possible using a piece of equipment from the front. The teacher-selected volume device will be referred to as the standard.
    a. Discussion points to raise when introducing the standard:
        i. Who decides/determines what 1 mL is? Who decides what any measurement is?
        ii. Have you ever had/seen an item for the store that has a mistake? (i.e. misprint, incorrect number of items than what was advertised, etc.)
        iii. It is possible for lab equipment to be misaligned, but the class is choosing to trust the lab equipment is correct in scale
    b. Each piece of equipment can only be used by one group.
    c. Volume devices can include lab equipment and common household items listed

under materials. i. If the volume is not included on the household item, use a piece of tape and mark it. ii. Use the Imperial System as well as the metric system. Students can use Google to do conversions. iii. Graduations can be included, but are not required in order to increase the difficulty in obtaining accuracy. iv. In order to stress the ease of use of the metric system and equipment with smaller graduations when accuracy is needed, it is recommended that graduations are few and large. d. Group size depends on the number of volume devices available. e. Order of device selection is by lottery. f. Once students are finished, they will bring their labeled volume device to the front. g. Students should have as much time (5 minutes or less is suggested) as the teacher deems necessary to get as close to the standard. h. Recommended way to determine the winner: i. Students will vote for who they believe are the top contenders after completing a quick gallery walk. ii. These groups will then designate one person to pour their volume of water into the standard. iii. Food dye could be placed in the solution so it is easier to visualize within the standard. iv. A ruler with small graduations (if using a volumetric flask) or the difference in volume from the standard (if using a burette) will be used to calculate the difference. v. If time allows, also demonstrate how groups that had large graduations and household items compare to the standard. 2. **Post-challenge reflection questions:** a. Options for delivery: i. Discussion ii. Exit ticket iii. Write-up b. Which volume device was the easiest to get to X mL? Which was the hardest? Why? Key points: i. Smaller graduations leads to higher precision and accuracy ii. Large graduations leads to lower precision and accuracy c. What piece of lab equipment is most appropriate for each scenario? i. Scenarios = making Kool-aid, mixing a salt solution, ii. What level of precision is needed? iii. Is high precision and accuracy needed all the time? d. What degree of precision would you want for the following scenarios?	
<u>Extension Ideas</u> 1. **Steel wool and mass:** Different scales allow for different levels of significant figures (precision) to be determined. A triple beam balance might allow for estimation of mass to the hundredths place, whereas an analytical scale might read to the ten-thousandth place. When steel wool is held over a flame (bunsen burner) it oxidizes and the iron undergoes a chemical change as shown by the following equation: $4Fe\ (s) + 3O_2\ (g) \rightarrow 2Fe_2O_3$. Students should obtain the mass of the steel wool on the different scales to the highest degree of precision before and after burning over a bunsen burner. The steel wool should be burned for a significant amount of time in order to allow for a significant amount of oxygen molecules to be “deposited” on the steel. The steel wool almost shows a change in color when it has been burned sufficiently. a. ***Full lab-safety precautions should be taken*** b. Materials: i. Scales (triple beam balance, analytical scale) ii. Steel wool iii. Bunsen burner iv. Striker v. Lab attire (closed-toed shoes, hair up, long pants, goggles) c. Key points/ideas before activity: i. Law of conservation of mass ii. Lab safety	

d. Reflection questions:
    i. What did you observe? increase in mass (ideally more than one group will engage with this and the average/different values can be seen)
    ii. How did that happen? (something was added)
    iii. What do you think was added? (something from the air; oxygen)

2. **Mystery metals and density:** Density is an intensive property (meaning no matter how much of a sample is present, the same value will be calculated). Students can be challenged to determine the identity of various unknown metals such as aluminum, steel, brass, copper, acrylic, nylon, poplar, oak, willow and polyethylene. Flinn scientific and other science education stores have density cube sets that include these and other metals. This could be prefaced as an official class activity with scaffolding or posed as an ongoing challenge throughout the year.
    a. Materials:
        i. Samples of metal
        ii. Water
        iii. Volume device
        iv. Scale
        v. List of known density values (optional, students could Google this information if minimal scaffolding is desired)
        vi. *Students might have other ideas for how to determine the identity; materials within the scope of the classroom should be made available for use within reason.
    b. Key points before activity: do not damage the metal samples
    c. Reflection questions:
        i. How did you determine the identity? (density/other)
        ii. If the property of density was used to determine the metals' identities, if I gave you a sample three times as heavy, what would the density be? (the same as the sample)
    d. Key points following activity: density is an intensive property
3. **Significant figures:** Engage students with conversation on the general idea of significant figures and why it is inaccurate/not precise to include too many when taking measurements. The general rule of thumb when measuring is to include one estimated digit.

Differentiation

- **Emergent multilingual students:** Instead of having students make the table in their own lab notebooks, a handout (Appendix A) can be provided that already lists the names of the lab equipment. This could also be turned into a flip table in which the drawings are on the outside and students test themselves by remembering the name. This should be made available to students preceding this lesson.
- **Gifted students:** Either extension activity could be made available for students to engage with.
- **Students with learning disabilities:** Students will complete this activity in a blend of heterogeneous and homogeneous pairs/groups. Students will receive assistance from the teacher as needed.

Assessment/Check for Understanding

- **Formative:**
    - The teacher will circulate the room during discussions and whiteboarding to assess students' level of understanding.
    - Throughout the year, provide students the autonomy to use the volume device or piece of lab equipment they deem appropriate. When allowing students to engage with lab materials, ask students for justification for their lab equipment selection.
- **Summative:** On a future test/quiz, ask students to choose which piece of lab equipment is appropriate for a certain scenario, such as the scenarios listed. Students should provide justification for their selection

Required resources

- "Accuracy vs Precision!" introduction video
    - https://www.youtube.com/watch?v=qBDg2hTxtAw
    - Channel: Robin Reaction
    - This video provides a brief overview of the definitions of the words 'accuracy' and 'precision' by utilizing a bow and arrow shooting target. This lesson suggests watching from 0:00-1:18 minutes and then allowing

students to whiteboard and engage with the material presented in the video rather than watching the entire thing

- Accuracy and Precision for Data Collection
    - https://www.youtube.com/watch?v=EeHtK5UYEMM
    - Channel: Professor Dave Explains
    - This video provides a brief overview of accuracy and precision in the context of the scientific community. Students who were absent from the lesson or who need a follow up on this material will benefit from watching this video.

Supplemental resources

Whiteboarding is a technique promoted by the American Modeling Teachers Association (AMTA) and argumentative-driven inquiry (ADI). Utilizing whiteboards in small groups and pairs allows students a low-risk environment to engage with material, express their thoughts, and potentially present their ideas to their peers. More resources about AMTA can be found at https://www.modelinginstruction.org/. More resources about ADI can be found at https://www.argumentdriveninquiry.com/.

Author comments

Sources

Robin Reaction. (2018). *Accuracy Vs Precision! YouTube*. Retrieved June 21, 2022, from https://www.youtube.com/watch?v=qBDg2hTxtAw.

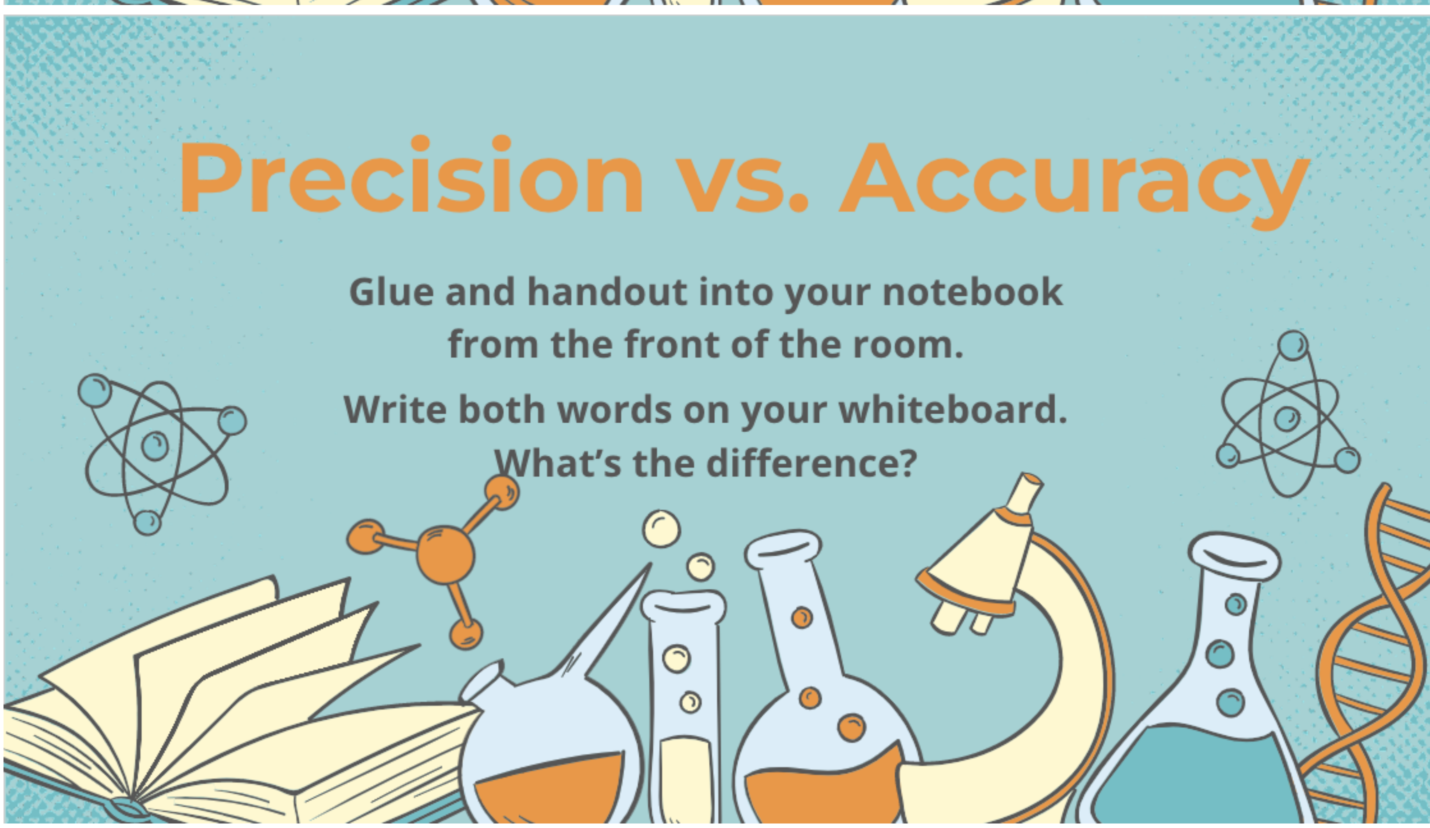
Appendix

Appendix A: “Lab Equipment - Volume” table

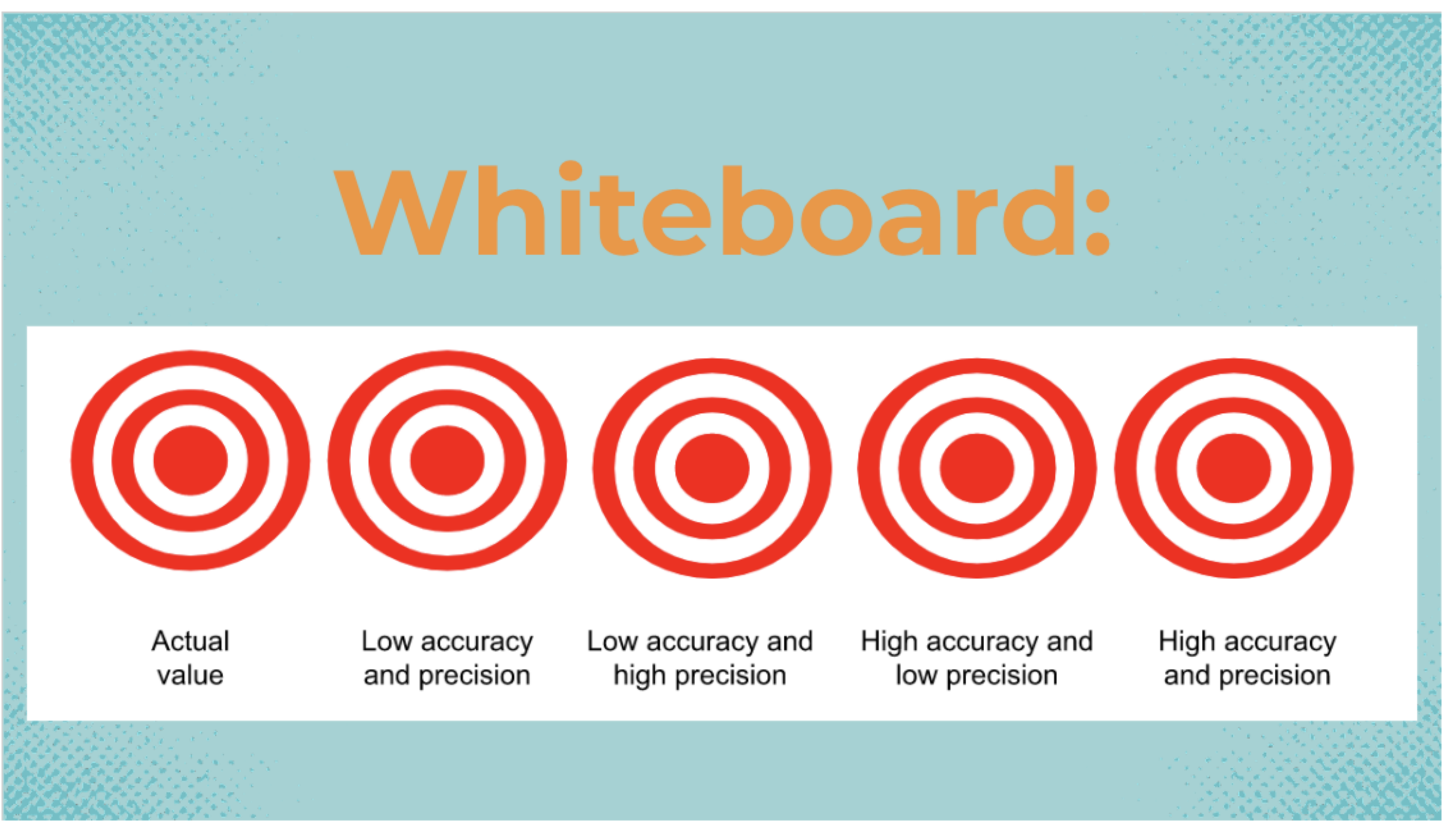
Name and Description	Drawing
Volumetric flask	
Pipette	
Graduated cylinder *Meniscus:	
Beaker	
Erlenmeyer flask	
Burette	

[PowerPoint:](#)


Lab Equipment
Exploration


Precision vs. Accuracy
Glue and handout into your notebook
from the front of the room.
Write both words on your whiteboard.
What's the difference?

https://www.youtube.com/watch?v=qBDg2hTxtAw (0-1:18)

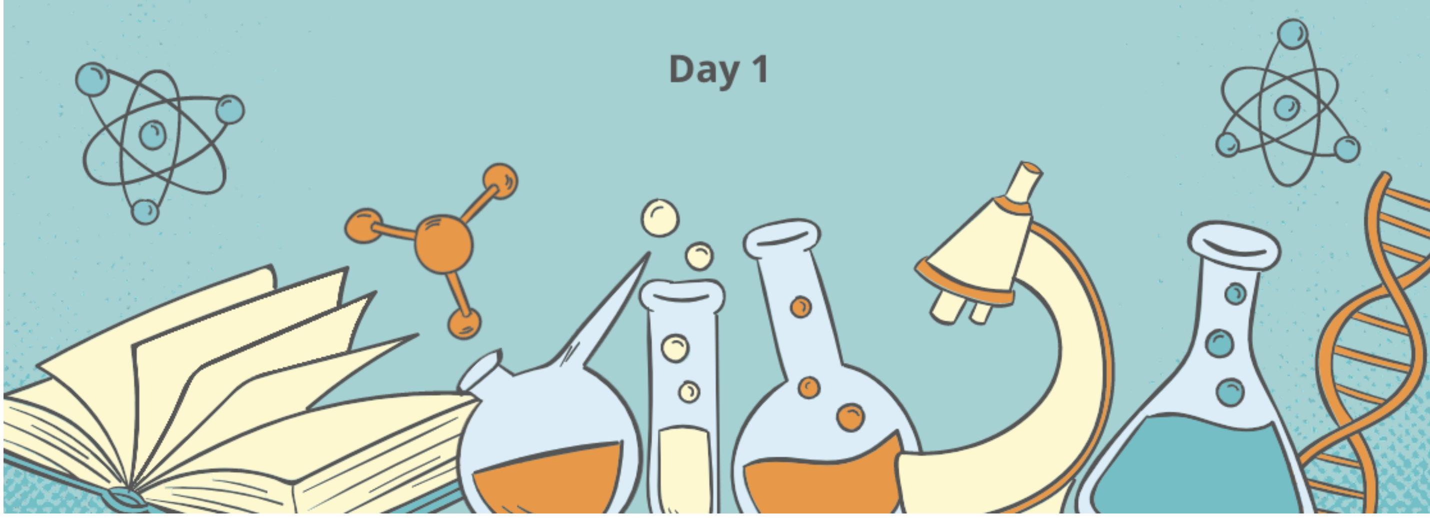


Discuss with your Partner

1. Why do we use the metric system (meters, liters, grams etc.) in science instead of the imperial system (cups, ounces, pounds, miles, etc)?
2. Which piece of equipment from around the room would give the lowest margin of error (most accurate AND precise) to measure volume?

Volume

Day 1



Lab Equipment Used to Measure Volume

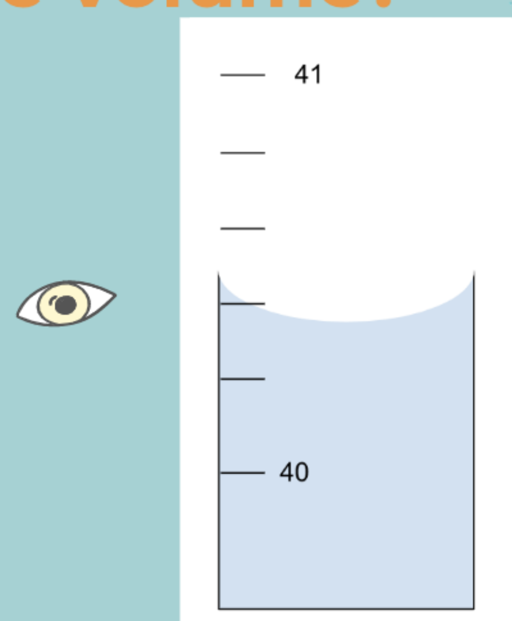
- Volumetric flask
- Pipette
- Graduated cylinder
- Beaker
- Erlenmeyer flask
- Burette

What is the volume?

Meniscus: concave curve at the surface of a liquid in a container; always read the bottom part

Steps:

1. Flat surface
2. Get on the same level
3. Read/record bottom of meniscus
4. Can add one estimated digit



in mL

Challenge Time!

The Challenge

Get as close to 25 mL (according to this volumetric flask) as possible using a piece of equipment from the front.

- Each piece of equipment can only be used by one group.
- You will select the piece of equipment your group will use by lottery.
- Use a piece of tape to put your group name and then bring to the front

Timer Starts Now!

Use a piece of tape to put your group name on and then bring to the front

Determining the Winner

Which group do you think got the closest?

Which group do you think is the furthest?

Reflection

Which volume device was the easiest to get to 25 mL? Which was the hardest? Why?

slidesgo

This PowerPoint was designed by Allison Kauffman to fulfill the lesson development requirement for the RTNN RET program and accompanies a lesson plan entitled “Hitting the Bullseye: Measuring Volume with Precision and Accuracy.”