Estimating How Big:

The Metric Estimation Game



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Cover: Metric Estimation Game facilitator demonstrates unit symbol writing style to participants as they stand in front of a white board that displays the game score. Credit: NIST

Summary



Audience

Educators

Keywords

Activity; Base Unit; Classroom; Collaboration; Defining Constant; Derived Unit; Education; Estimation; Formal; Game; Hybrid; Individual; Informal; In-person; International System of Units; Measurement; Metric System; Play; Prefix; Proportion; Quantity; Scale; Sense-making; STEM; Team; Virtual.

Subjects

Biology, Chemistry, Earth Science, Engineering, Environmental Science, Life Science, Mathematics, Physical Science, Physics, and STEM.

Activity Includes

Instructions, presentation template, and supporting resources.

Education Standards

Review education standards in **Appendix A - Education Standards**.

- **Time: 50 minutes**

Abstract

The ability to interpret measurement scales and approximate a quantity are essential Science, Technology, Engineering, and Mathematics (STEM) competencies. The Metric System Estimation Game is a fun, hands-on activity that helps participants become familiar with SI measurements by practicing estimation skills.

During this activity, participants will become familiar with using the metric system (International System of Units, SI) measurements on common, everyday objects. About how many grams does a baseball weigh? Approximately how many centimeters long is a pencil? How many liters are in that water bottle? Participants will work in small groups and earn points during this interactive, hands-on measurement game. With multiple game variations, the activity may be differentiated for instructional and skill levels.

Game	Delivery Method	Grade Level			
		K to 2nd	3rd to 5th	6th to 8th	9th+
Everyday Objects (Option 1)	In-person		✓	✓	✓
Metric Meal (Option 2)	In-person Hybrid Virtual	✓	✓		

Introduction

While the International System of Units (SI), commonly known as the metric system, is the measurement standard used in Science, Technology, Engineering, and Mathematics (STEM), many participants have limited opportunities to gain experience in its use.

- **Practice making measurements and developing reference points builds proficiency and confidence working with metric measurements.**
- **Estimations are valuable when developing a hypothesis and determining if resulting experimental data are reasonable.**

Everyday Objects (Option 1)

During this activity, participants will collaborate in small groups to earn points as they become familiar with metric (SI) mass, length, and volume measurement units.

This game is designed for in-person learning. Each team will determine a quantity estimate for each game item, which is compared to a verified value. Multiple measurement methods may be used to verify results **(Figure 1)**. Some estimations are determined using basic math formulas and use a standard set of game objects **(Appendix C - Game Boards)**.

Metric Meal (Option 2)

The Metric Meal (option 2) focuses exclusively on length measurements and uses a multidisciplinary approach to build measurement skills.

This game is designed for in-person, hybrid, and virtual learning. Connections may be made to health, nutrition, and life skills. Game objects include a plate, eating utensils, and everyday food items, such as fruits, vegetables, and special treats. Participants may apply art techniques, such as coloring their set before gameplay begins, allowing participants to express their creativity and improve hand-eye coordination, fine motor skills, and focus.



Figure 1. Use multiple measurement methods to determine the perimeter of the heart candy box. Credit: NIST

Learning Objectives

The Metric Estimation Game is designed to develop and reinforce estimation skills, select and use appropriate measurement tools, and determine measurement unit quantity, scale, and magnitude.

- **Measure the diameter, circumference, and perimeter of objects.**
- **Use basic math formulas to calculate the area of a square and the volume of a cube.**
- **Use three SI prefixes: milli, centi, and kilo.**
- **Apply measurement writing style requirements for unit symbols.**

Skills

Although this activity is designed for a middle school audience, it can be modified to accommodate elementary or high school learners. Extensions include updating the game board to focus on only one measurement parameter during a game session (e.g., mass, length, or volume).



Figure 2. Use a diverse collection of length measuring tools during gameplay. Credit: NIST

Participants will be able to:

- **DEMONSTRATE** metric system (SI) measurement estimation skills.
- **APPLY** the SI to quantify the length, mass, and volume of everyday household objects at multiple magnitudes.
- **SELECT** and **EMPLOY** appropriate length measurement tools (fit for purpose).
- **DEVELOP** quantity benchmarks that facilitate the sense-making of 1 kilogram, 1 liter, and 1 meter.
- **APPROXIMATE** measurement scale using at least three SI prefixes.
- **LIST** one SI measurement example.

Visit the activity webpage for additional resources.

https://www.nist.gov/pml/owm/metric-estimation-game-sp-1336

Materials, Tools and Game Objects

One recommended education best practice is to teach the SI by using the SI. Participants must build proficiency and confidence working with metric measurements before they can effectively make comparisons with other measurement systems.

- **Develop a classroom set of metric measuring devices, including meter sticks, rulers, flexible measuring tapes (Figure 2), kilogram or gram scales, and Celsius thermometers to evaluate game objects (Figure 3).**
- **Use SI only, single-system measurement tools whenever possible. Using dual-unit measuring equipment can confuse learners because it is easy to select and use the non-SI scale.**
- **If dual-unit measurement tools are used (e.g., those using U.S. customary units), block the non-metric units from view. For example, use opaque painters' tape to cover up inches on a dual unit ruler (Appendix B - Measurement Tool and Game Objects).**

Materials

- Projector and computer
- Chalk board and chalk, dry erase board and markers, or flip chart paper
- Clock or timing device displaying seconds
- Freezer storage bags or large manila envelopes
- Scissors and wax pencils
- Tent cards, index cards, and printer paper
- Presentation Game Board **(Appendix C - Game Boards)**



Figure 3. Sample Everyday Objects (Option 1) Game Objects and unit symbol cards. Credit: NIST



Figure 4. Assemble the Everyday Objects (Option 1) materials and tools for each team. Credit: NIST

Tools (Figure 4)

Everyday Objects (Option 1):

- Meter sticks
- Metric rulers
- Metric flexible measuring tapes
- **Resources - Job Aids**
- Dry-erase paddle and marker
- Reference points
  - Liter cube model
  - Two 500 mL bottled water per participant
  - Five cubic centimeter math manipulatives per participant

TABLE 1			
MASS	**LENGTH**	**AREA**	**VOLUME**
kg	m	m^2	m^3
g	dm	dm^2	L (dm^3)
	cm	cm^2	mL (cm^3)

Table 1. Everyday Objects (Option 1) units. Credit: NIST

Tools

Metric Meal (Option 2):

- Metric rulers
- Metric flexible measuring tapes
- Dry-erase paddle and marker
- Reference points
  - Five cubic centimeter math manipulatives per participant

TIPS

- **Create a team toolkit. Place the materials and tools in a freezer bag to make Everyday Objects (Option 1) set-up and clean-up fast and easy.**
- **Print the Unit Symbol Cards (Resources - Unit Symbol Cards) that will be used during the game (Table 1) .**

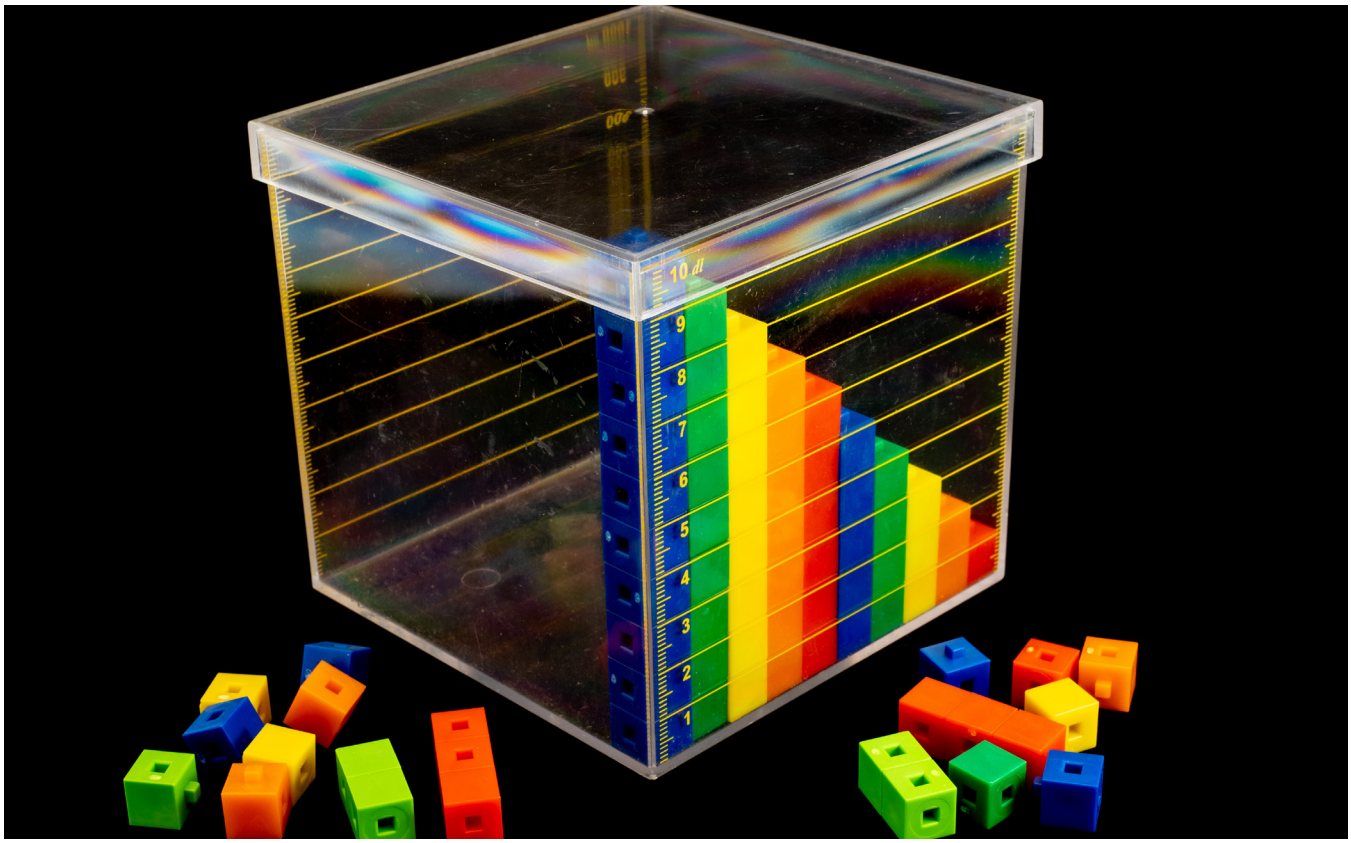


Figure 5. Cubic decimeter (dm^3) or Liter (L) model and cubic centimeter (cm^3) or mL manipulatives. Credit: NIST

TIP

- **U.S. educators may obtain a free set of metric education classroom resources. Contact the NIST Metric Program at TheSI@nist.gov and include your name, school, subject, grade level, phone number, and U.S. mailing address.**

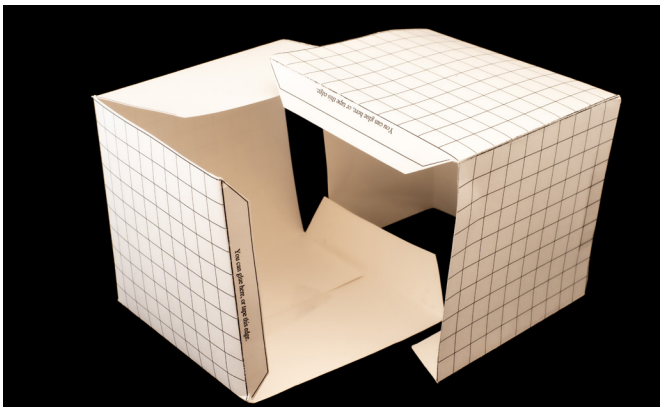


Figure 6. Partially assembled cubic decimeter (dm^3) or Liter (L) model. Credit: NIST

TIPS

- **Metric rulers are available from many retail vendors, which can be identified by using search terms such as "metric rule," "meter stick," or "metric stick." Printable rulers[1] such as the centimeter Color-square rules[2], can be color printed on to overhead transparency sheets to make inexpensive metric rulers.**
- **Use a volume liter cube model[3] per team to illustrate one cubic decimeter (dm^3), also known as one liter (L). When a template[4,5] is printed on cardstock and assembled, the two sheets create a cube 10 cm on each side with a volume of 1000 cm^3 (Figure 5 and 6).**



Figure 7. Assemble the Metric Meal (Option 2) materials and tools for each team. Credit: NIST

Game Objects

Everyday Objects (Option 1):

- Gather inexpensive objects from recycling, garage sales and thrift stores
- **Appendix A - Education Standards** provides length, mass, and volume objects
- Verify the measurements of your objects and customize the presentation answers as needed

TIPS

- **Encourage students to contribute Game Objects.**
- **When designing your game include objects with varying:**
  - geometric shapes, for example rectangles, cubes, pyramids.
  - scales such as small, medium, and large, for example, table tennis ball, softball, and basketball.

Game Objects

Metric Meal (Option 2, Figure 7):

- Apple, banana, beans, carrot, orange, and watermelon
- Cupcake and pizza
- Fork, knife, and plate

TIPS

- **Prepare game object sets in advance and organize each set in a manila envelope to make the set-up fast and easy.**
- **Laminate the game object sheets before cutting to increase the lifespan.**
- **Prepare extras to replace lost pieces, as needed.**



Figure 8. During gameplay use caution when handling heavy objects. Participants should use both hands to avoid dropping and injury. Credit: NIST

TIPS

- **Some objects will be shown to students, but they are not permitted to touch it. Instead they may hold the measurement tool near the item to make their estimation (Figure 8).**
- **Some "hot potato" objects should be safely passed around for all participants to observe or feel the quantity (Figure 9).**

Safety Considerations

- Some objects selected for the game may be sharp or heavy.
- As a precaution, participants must be seated, to avoid dropping and injuring themselves or property.
- Hold one game item at a time. Always use two hands when holding a heavy item.
- Do not balance multiple heavy objects in participants hands.
- Do not consume water bottle contents.
- Consider the safety of each item. For example, a spoon may be preferred over a fork or other utensil.
- Use caution when handling paper edges and scissors to prevent injury. Keep fingers clear of cutting areas.



Figure 9. Participants compare game objects and tools without touching. Credit: NIST

Background

SI Basics

Play activities are an easy way to motivate students to learn, build self-confidence, and transfer SI measurement skills to new situations. Familiarity with the elements and structure of the International System of Units (SI), commonly known as the metric system, will prepare students to successfully make measurements in science, technology, engineering and mathematics (STEM) applications. The major SI elements are illustrated in this model[6,7] **(Figure 10 and Figure 11)**.



Figure 10. SI logo with seven defining constants and seven base units[8]. Credit: BIPM

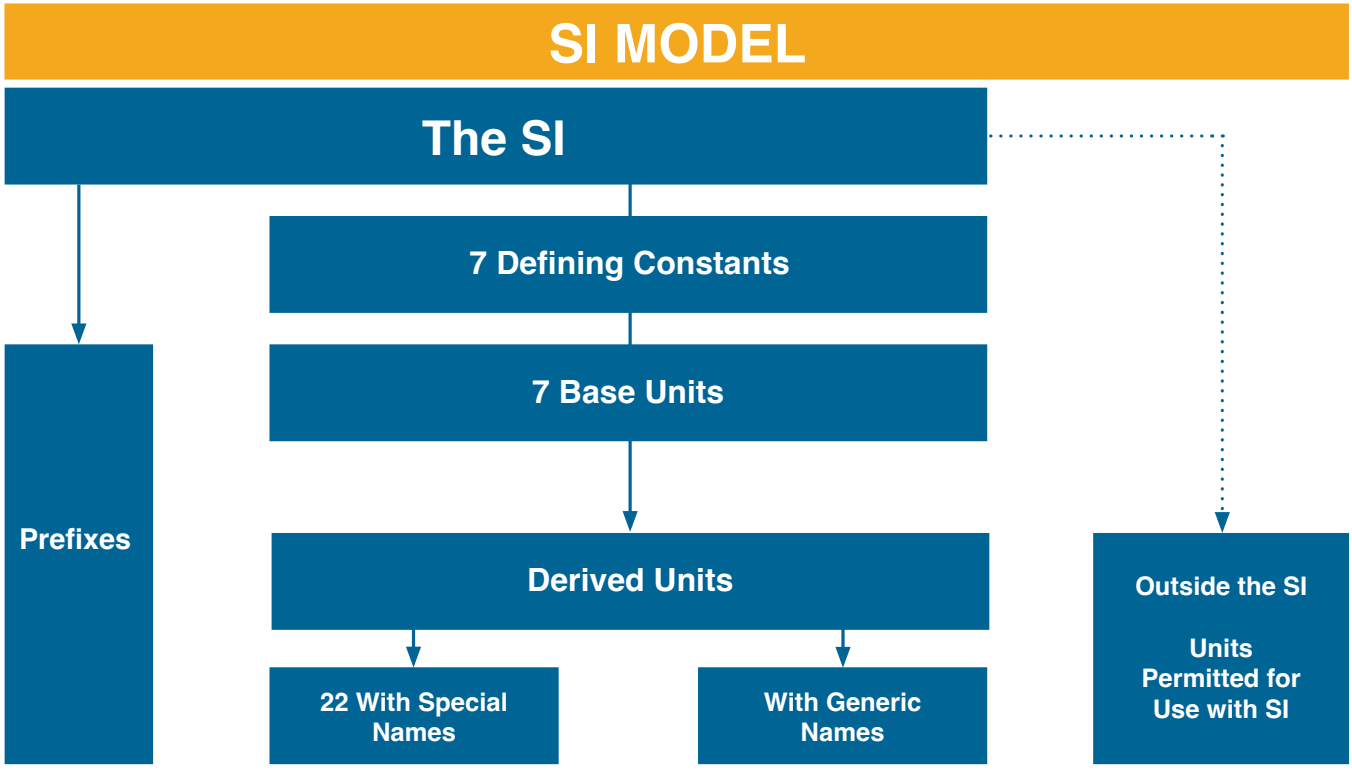


Figure 11. A graphical model of the International System of Units (SI), adapted from NIST TN 938.2. Credit: NIST

- Seven **defining constants**: the cesium hyperfine splitting frequency (ΔV_{Cs}), speed of light in vacuum (c), the Planck constant (h), elementary charge (e) (i.e., the charge on a proton), Boltzmann constant (k), Avogadro constant (N_A), and luminous efficacy of a specified monochromatic source (K_{cd}). More information on the defining constants is available on the NIST webpage (https://www.nist.gov/si-redefinition/meet-constants)[9,10].
- Seven **SI base units**: the meter (m), second (s), mole (mole), ampere (A), kelvin (K), candela (cd), and kilogram (kg). The 7 base units of the SI are used to define 22 derived units with special names and symbols (**Figure 12**)[11].
- Twenty-two **derived units with special names**, defined as products of powers of the base units **(Figure 12)**.
- Together the base units and derived units with special names (twenty-nine units) form the **core set of SI units**. All other SI units are combinations of some of these twenty-nine units. Any of the base units and derived units with special names can be constructed directly from the seven defining constants. Derived units with **generic names** reflect their mathematical derivation, such as area (m^2), volume (m^3), velocity (m/s), and acceleration (m/s^2).
- Twenty-four **prefixes** ranging from 10^{30} to 10^{-30}, are currently recognized for use. Values of quantities are expressed using Arabic symbols for numbers paired with a unit symbol, often prefix symbol that modifies unit magnitude.

Learn more about the SI in **NIST Special Publication (SP) 330, SP 811** and explore the NIST webpage[12,13] (https://www.nist.gov/si-redefinition/definitions-si-base-units).

- Length - meter (m)
- Time - second (s)
- Amount of substance - mole (mol)
- Electric current - ampere (A)
- Temperature - kelvin (K)
- Luminous intensity - candela (cd)
- Mass - kilogram (kg)

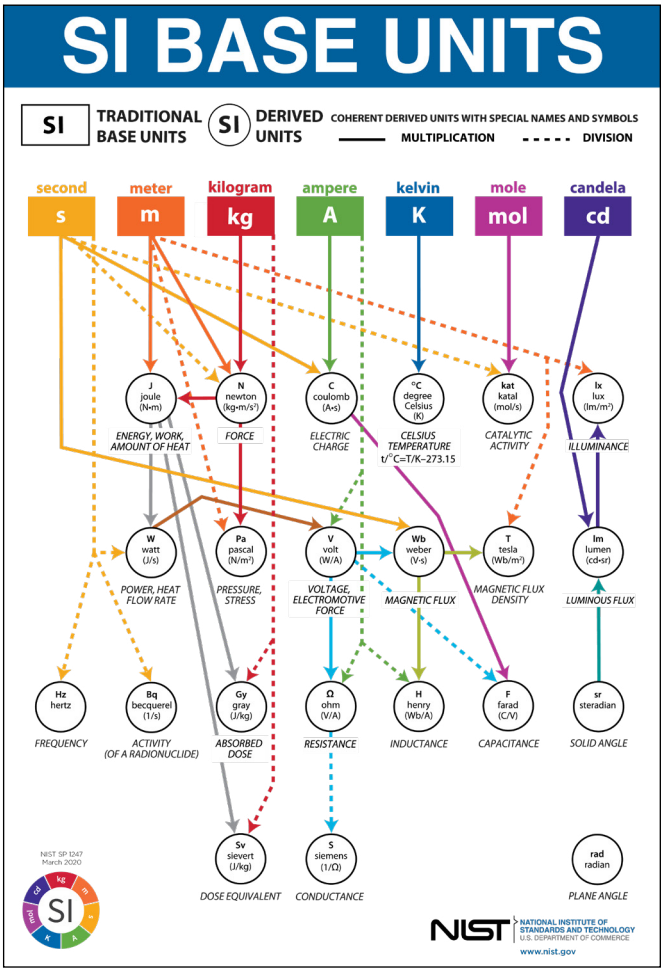


Figure 12. SI Base Units Relationships Poster (SP 1247: 2020, https://doi.org/10.6028/NIST.SP.1247). Colorful diagram illustrates the relationships between the SI derived units with special names and symbols and the seven traditional base units. Credit: NIST



Figure 13. Participants quickly estimate an umbrella segment using decimeters. Credit: NIST

Prefixes

Gameplay will help participants develop a sense of the powers-of-10 scales. Decimal subdivisions and multiples of the SI measurement units are named by combining the proper prefix with the name of the basic unit to form self-defining terms (**Resources - SI Prefixes**)[14]. The prefixes commonly used are "milli," which means the one-thousandth; "centi," which means the one-hundredth; and "kilo," which means one thousand. Some game objects are ideal for illustrating prefixes. For example, one segment of an umbrella can be used to illustrate decimeter scale **(Figure 13)**.

Applying this concept, "milliliter" means one-thousandth of a liter, "centimeter" means one-hundredth of a meter, and "kilogram" means one thousand grams. The metric system is a "decimal" system, just like the U.S. monetary system.

Review the similarities between the U.S. monetary systems and the SI prefixes **(Table 2)**.

TABLE 2

Dollars & Cents	Meters & Centimeters
$1.00 = 100¢	1 m = 100 cm
$0.10 = 10¢	0.1 m = 10 cm
$0.01 = 1¢	0.01 m = 1 cm
Meters & Millimeters	**Centimeters & Millimeters**
1 m = 1000 mm	100 cm = 1000 mm
0.1 m = 100 mm	10 cm = 100 mm
0.01 m = 10 mm	1 cm = 10 mm
0.001 m = 1 mm	0.1 cm = 1 mm

Table 2. U.S. monetary system is decimal based like the SI. Credit: NIST

The U.S. monetary system has another connection the metric system. U.S. coins are manufactured to metric specifications **(Figure 14)**[15]. During gameplay, U.S. nickels that weigh 5 g will be used **(Figure 15)**.

Denomination	Cent	Nickel	Dime	Quarter Dollar	Half Dollar	Dollar
						
Composition	Copper Plated Zinc 2.5% Cu Balance Zn	Cupro-Nickel 25% Ni Balance Cu	Cupro-Nickel 8.33% Ni Balance Cu	Cupro-Nickel 8.33% Ni Balance Cu	Cupro-Nickel 8.33% Ni Balance Cu	Manganese-Brass 88.5% Cu 6% Zn 3.5% Mn 2% Ni
Weight	2.500 g	5.000 g	2.268 g	5.670 g	11.340 g	8.1 g
Diameter	0.750 in. 19.05 mm	0.835 in. 21.21 mm	0.705 in. 17.91 mm	0.955 in. 24.26 mm	1.205 in. 30.61 mm	1.043 in. 26.49 mm
Thickness	1.52 mm	1.95 mm	1.35 mm	1.75 mm	2.15 mm	2.00 mm
Edge	Plain	Plain	Reeded	Reeded	Reeded	Edge-Lettering
No. of Reeds	N/A	N/A	118	119	150	N/A

Figure 14. U.S. Mint Coin Specifications use metric units to describe their mass and dimensions. (https://www.usmint.gov/learn/coin-and-medal-programs/coin-specifications). Credit: U.S. Mint

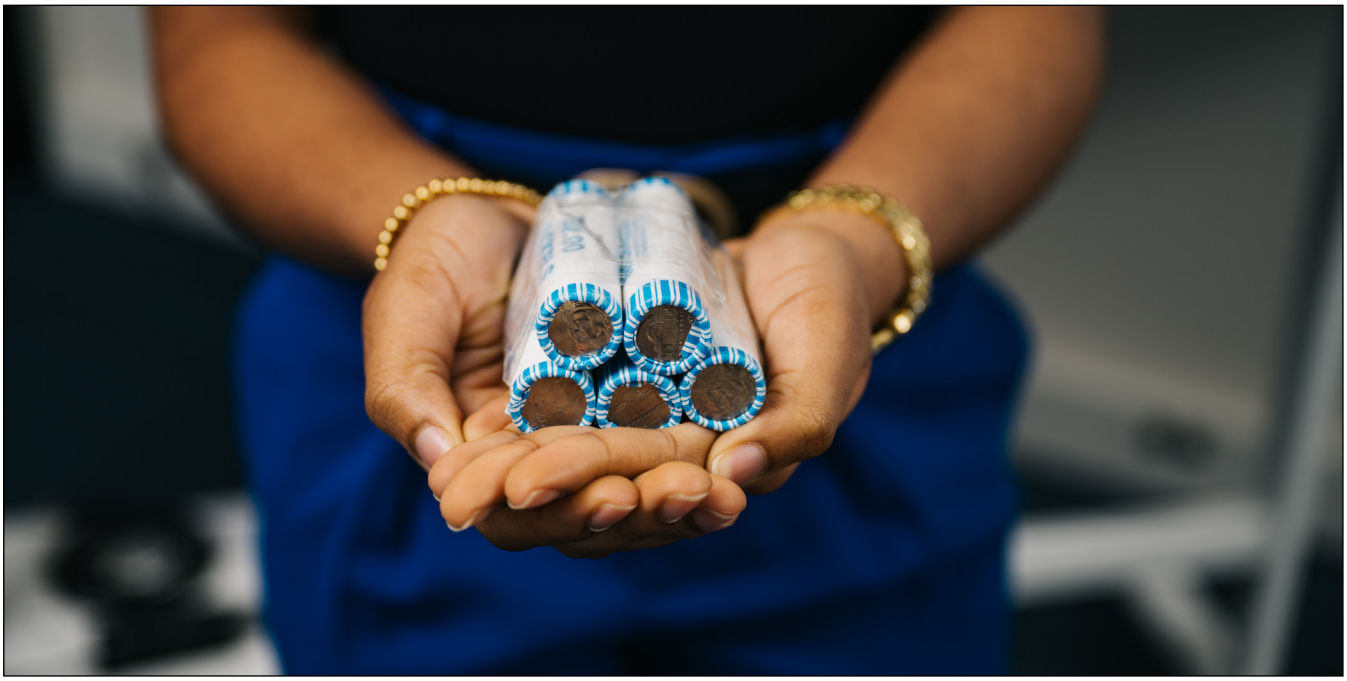


Figure 15. A five cent U.S. nickel weighs 5 g. Five rolls of U.S. nickels are taped together to illustrate 1 kg during gameplay. Credit: NIST

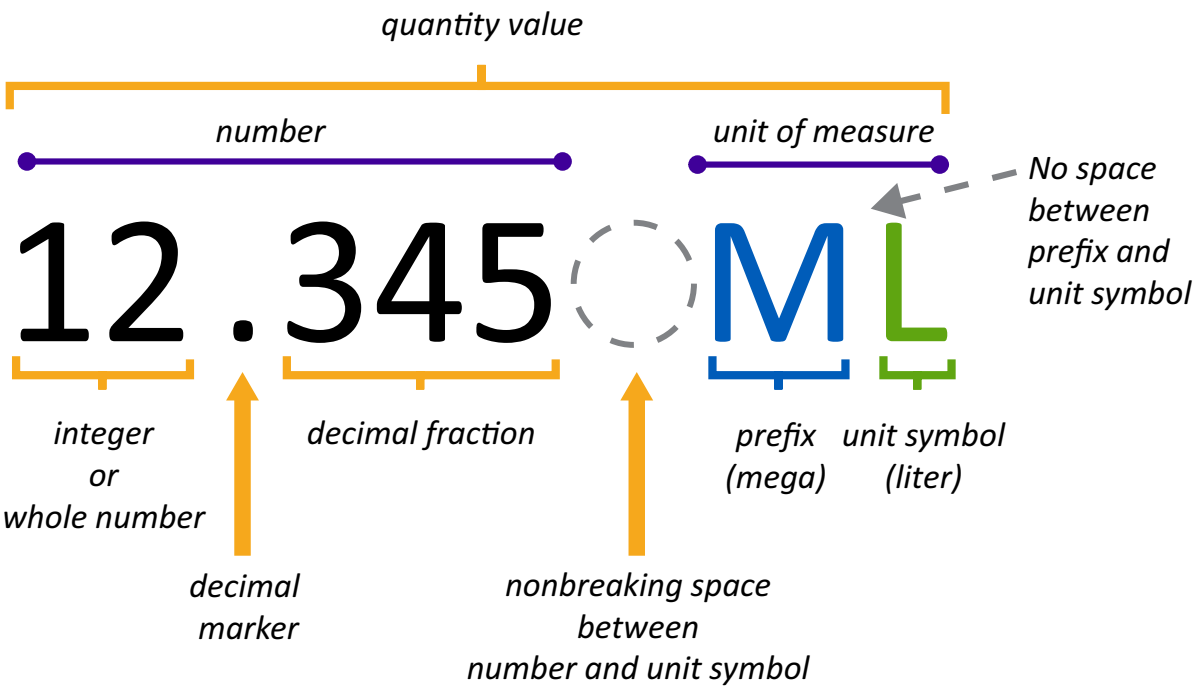


Figure 16. SI writing conventions are applied to a quantity value, which includes a number and unit of measure. Credit: NIST

Writing with the SI

A benefit of the SI is that written technical information is effectively communicated, transcending the variations of language – including spelling and pronunciation. Arabic numerals describe the quantity. A quantity is then paired with a unit symbol, often with a prefix symbol that modifies unit magnitude[16].

Write Like a Scientist, Technologist, Engineer, and Mathematician

SI writing style is an essential literacy skill used by STEM professionals and the public to interpret, evaluate, synthesize, communicate, and apply measurement information. For STEM professionals, SI skills are necessary to plan investigations, collect and document research data observations, analyze results, clearly communicate, share research, gain new information by interpreting the findings of others, develop technological solutions to improve the quality of life, design and build critical infrastructure, and develop new products for the marketplace. Using SI writing style helps prevent miscommunication, misinterpretation of data, and calculation errors. SI writing style is also important for consumers who will interpret and use quantities to make daily life decisions.

Learning new concepts requires building new vocabulary in context **(Resources - Vocabulary)**. This activity provides an opportunity for learners to apply, practice, and reinforce writing quantity values, unit symbols, prefixes and capitalization rules frequently within a short period of time.

Communicating Estimation Results

Measurement estimation results must be clearly reported to earn game points. SI writing conventions are important to ensure the comprehension of quantitative information and understandability of quantity values. A quantity is a property that often consists of an Arabic number paired with a unit of measure. For example, megaliter (ML) is made up of the prefix “mega” (M) and unit “liter” (L) **(Figure 16)**. When used in a sentence, “megaliter” becomes one word without a space between the prefix and unit symbol.



Figure 17. Measurements are used in daily life while baking, interpreting nutrition labels, determining the outside temperature, and sewing. Credit: Adobe Stock

Similarly, the prefix symbol and the unit symbol are written without any space between to form a single symbol.

SI unit symbols are the same in every language. Because word spelling varies among different languages, abbreviations may also vary. For this reason, abbreviations are not used in technical communications **(Table 3)**. For example, the permitted unit symbol for the second is s, but the unacceptable abbreviation sec should not be used.

TABLE 3		
UNIT	**SYMBOL (permitted)**	**ABBREVIATION (unacceptable)**
second	s	sec
ampere	A	amp
cubic centimeter	cm^3	cc

Table 3. Use SI symbols and do not use abbreviations.

Using the SI

For use in daily life, participants will need to learn about ten units and get used to a few new temperatures. There are some metric units with which learners are likely already familiar: Where might participants observe SI measurements in daily life? Use of SI measurements includes areas such as media reports (e.g., military deployments using kilometers), time (second), electric current (ampere, volt, ohm & watt), sports (track and field, cycling, international competitions), package labeling (especially beverages), healthcare (blood pressure, cholesterol levels, glucose measurements, prescription and over-the-counter medicines, and dietary supplement dosages), automotive (engines, tires, navigation systems, speedometers), and other consumer products (cameras, film, pens) **(Figure 17).**

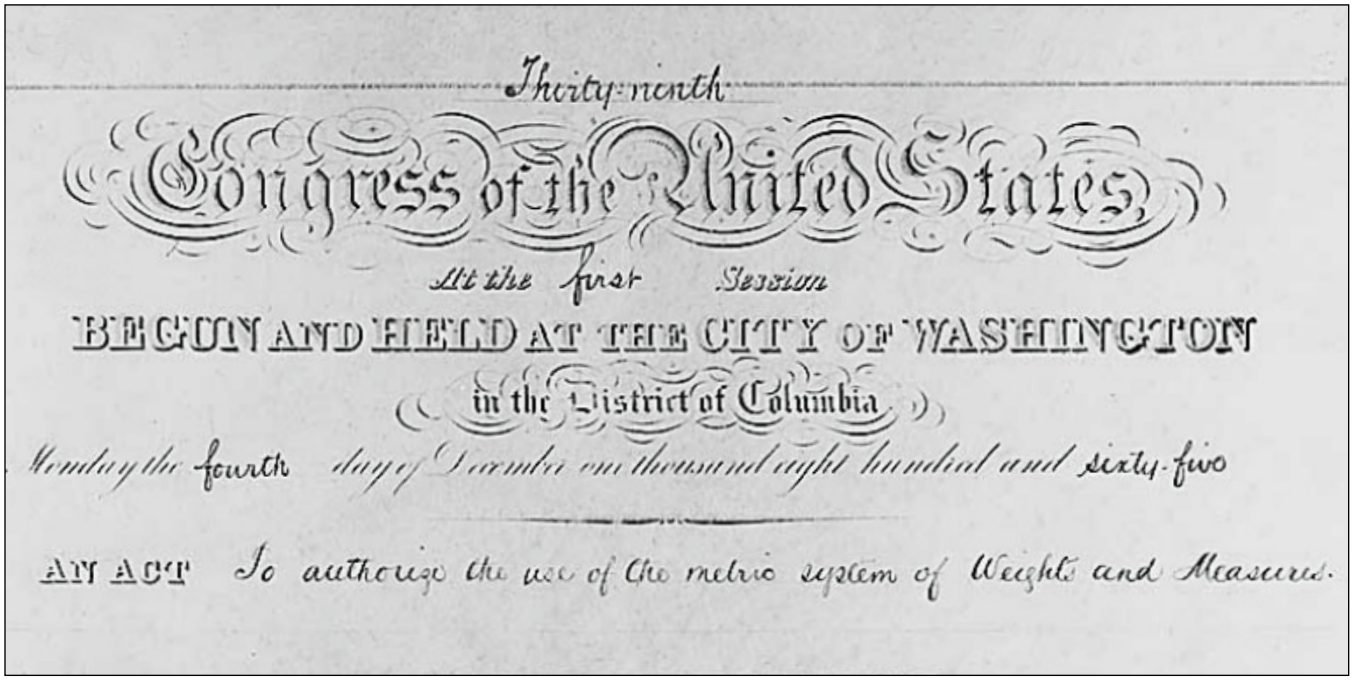

Thirty-ninth
Congress of the United States
At the first Session
BEGUN AND HELD AT THE CITY OF WASHINGTON
in the District of Columbia
Monday the fourth day of December one thousand eight hundred and sixty-five
AN ACT To authorize the use of the metric system of Weights and Measures.

Figure 18. Metric Act of 1866, also known as the Kasson Act. Credit: National Archives

U.S. consumers are becoming more familiar with grams and milligrams through information provided on mandatory nutritional labeling. Advertising, coupons, and consumer product packaging are increasingly found using metric units exclusively. U.S. currency and coinage are designed according to metric system design specifications **(Figure 18**).

Because of the importance of the SI as an international standard, its use in product design, manufacturing, marketing, and labeling is essential for U.S. industry's success in the global marketplace. The NIST metric program encourages the use of the SI in all facets of education, including honing of worker skills.

U.S. Metrication

What countries have not adopted the SI? Many mistakenly think of countries like the United States, Liberia, and Myanmar (Burma). Some are surprised to learn that all countries have adopted the SI, including the U.S.; metric use is either mandatory or permissible. The U.S. has a long history using the metric system, including being one of the original 17 countries that signed the Treaty of the Meter in 1875, which is now celebrated as **World Metrology Day** (May 20th)[17]. It has been legal to use the metric system in the U.S. since 1866[18]. The SI later became the preferred system of weights and measures for U.S. trade and commerce in 1988.

Becoming metric is not a one-time event that has either happened or not. It is a process that happens over time. Every international economy is positioned somewhere along a transition continuum represented by various stages of the metric transition journey. In nearly all countries, people often use traditional units, at least in colloquial expressions. Processes and legacy infrastructure designed with U.S. customary measurement practices often continue to be maintained and supported until the product life cycle ends or it is no longer fit for purpose. For instance, municipal utility infrastructure requires maintenance over many years and replacement represents considerable financial investment. More information about U.S. metrication can be found in the NIST blog, Busting Myths about the Metric System[19] (https://www.nist.gov/blogs/taking-measure/busting-myths-about-metric-system).



Figure 19. Gamification of Learning. Credit: Adobe Stock

The Gamification of Learning

Integrating metric measurements into play activities motivate students to learn more, build self-confidence and transfer metric measurement skills to other situations. Games provide a low-risk opportunity to experience success applying metric measurements. The gamification of learning provides classroom benefits, including application and the practice of new skills. Learner's interest is captured as they engage in the activity. Competition motivates. High interactivity and engagement with learning content. Immediate feedback. Promotes persistence. Facilitator observes, monitors and evaluates progress during the activity **(Figure 19**).

TIPS

- **Multiple teams can be awarded points for close estimates to the same question.**
- **Extremely inaccurate estimates are not awarded points.**
- **If a team(s) is far behind, offer them a challenge. Award triple points to any team that guesses the item's value exactly as displayed on the game board.**
- **Recognize the success of all teams with a round of applause at the end of the game.**



Figure 20. Participants are encouraged to write all calculations. This is helpful to identify calculation errors during gameplay. Credit: NIST

Estimation Skills and Math Review

Estimation is more than taking a guess. Developing approximation skills helps interpret the world around us. Building estimation skill proficiency is important for:

- Making comparisons to determine relative size or quantity.
- Evaluating the magnitude of small and large numbers.
- Ordering objects.
- Spatial reasoning.
- Applying mental math to quickly calculate and determine a reasonable solution.
- Sense-making, including determining if a numerical result sounds reasonable when solving a mathematical equation, formulating a hypothesis, interpreting research data, and refining or rejecting a hypothesis.

During gameplay, some object measurements will be determined using basic math formulas, such as the area of square (L x W) and volume of cube (L x H x W) **(Resources - Job Aids)**. Review the terms diameter, circumference, and perimeter. Emphasize that to make quick math estimations (e.g., they only have 30 seconds to estimate and write down the team answer) it is best to avoid making unit conversions between U.S. customary units and making long math calculations.
Use rounding to generate a quick answer that is in the "ball park."

To help identify calculation errors during gameplay, participants are encouraged to write all calculations. This is helpful to identify calculation errors during gameplay (**Figure 20**).

"A sense of numerical quantity is an important part of the general "numeracy" (mathematics literacy)." — National Academies of Sciences, Engineering, and Medicine.

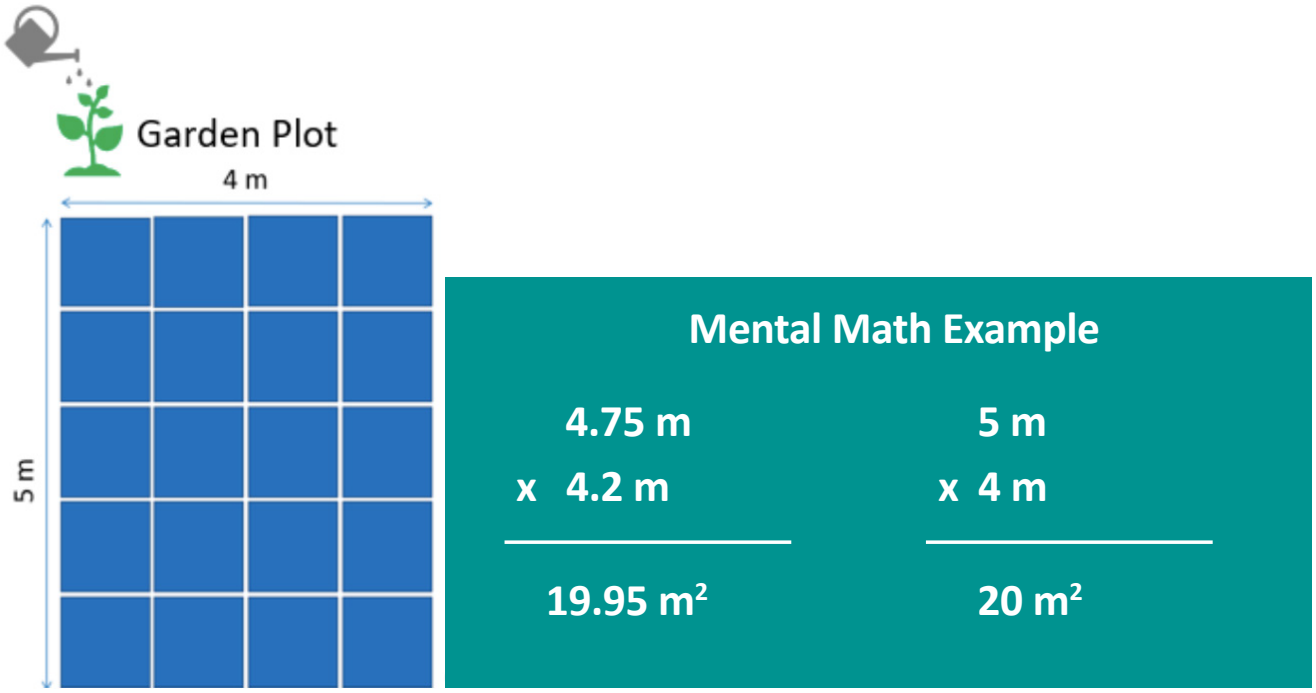


Figure 21. Apply mental math to quickly estimate a garden perimeter. Credit: NIST

Calculation versus Estimation Example

This example may be used to demonstrate that by rounding a measurement up or down to the nearest whole number will generate a number similar to one that takes significantly more time to calculate. For many applications, estimation is fit for purpose. Refining estimation skills will improve accuracy and build confidence.

A school club is developing a garden and needs to determine the boundary of the new garden **(Figure 21)**. Two approaches for determining the proposed perimeter include:

Option 1 – Take the time using a trundle wheel or 30 m tape measure to make measurements (length = 4.75 m, width = 4.2 m), followed by a mathematical computation to get an exact answer (19.95 m^2).

Option 2 – Pace out the space and make a rough estimate. By quickly rounding up (4.75 m becomes 5 m) and down (4.2 m becomes 4 m), a mental math calculation achieves a very similar result in less time (20 m^2).

Strategies

Participants should practice their measuring skills before the game. It is important that they are familiar with using a metric ruler. Review the various length measurement tools, pointing out a meter, centimeter, and millimeter. Practice measuring a common object in the classroom, such as a table or chair. The facilitator may assign a measurement unit to each team (e.g., Team 1 – measure the object in meters; Team 2 – measure the object in cm; Team 3 – measure the object in mm). As an alternative, each participant measures a common item using all three measurement units, as time permits. If the game session is being conducted in a short time period, consider reviewing these measurements prior to the game.

It is helpful to emulate a round to illustrate the game rules. Choose a low point value example or an item with a common reference point to illustrate the game process (e.g., a 1 kg item).

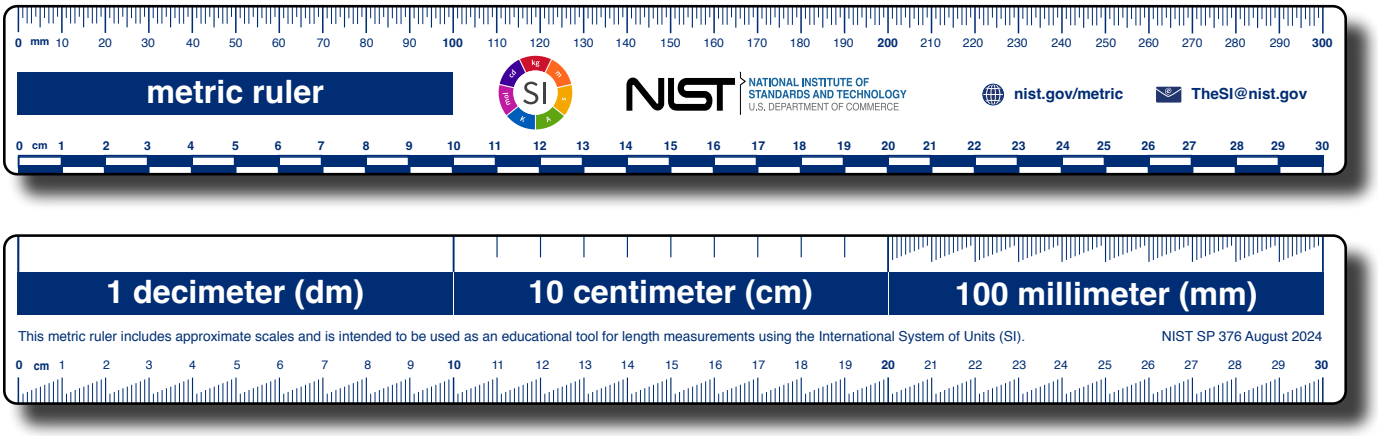


Figure 22. NIST metric ruler special publication 376. Credit: NIST

Participants often struggle with dual-unit tools like rulers marked in both inches and centimeters, frequently confusing the units. To enhance learning, NIST recommends teaching solely in SI units. Learners need to develop confidence and proficiency in metric measurements before comparing them with other systems.

Use single system measurement tools whenever possible. Using dual unit measuring equipment can confuse learners because it is easy to select and use the wrong scale. When possible, acquire metric measuring devices (meter sticks, kilogram or gram scales, and Celsius thermometers). For example, Special Publication (SP) 376 is a metric ruler **(Figure 22**). If dual unit measurement tools are used (e.g., those using U.S. customary units), block the non-SI units from view. For example, use opaque tape, an index card, or paint to cover up inches on a dual unit ruler.

TIPS

- **Prepare students for the activity by introducing and reviewing the background information prior to gameplay.**
- **Teach the SI using an interdisciplinary approach to avoid isolating SI measurements within the math and science curriculum.**
- **Customize the game for your classroom using ideas within the Extension section.**

"Understanding scale requires some insight into measurement and an ability to think in terms of orders of magnitude—for example, to comprehend the difference between one in a hundred and a few parts per billion. At a basic level, in order to identify something as bigger or smaller than something else—and how much bigger or smaller—a student must appreciate the units used to measure it and develop a feel for quantity."

— National Research Council.

Gameplay Everyday Objects (Option 1)



Everyday Objects (Option 1) is designed to develop and reinforce estimation skills, select and use appropriate measurement tools, and determine measurement unit quantity, scale, and magnitude. During the activity, participants will:

- **Develop a feel for quantities experienced in daily life.**
- **Apply orders of magnitude. For example, participants will comprehend the difference between meters and centimeters (one hundredth), liters and milliliters (thousandth), and grams and kilograms (thousand).**
- **Participants will evaluate length, volume, and mass quantity estimates.**

Everyday Objects (Option 1): Preparation

Prior to the activity, the facilitator will select all game objects and customize the presentation file **(Appendix A - Education Standards and Appendix B - Measurement Tools and Game Objects)**. The activity may be designed to focus on a variety of everyday measurement parameters and units **(Table 1)**. The facilitator will share the background section within the presentation prior to gameplay.

Visit the activity webpage for additional resources. https://www.nist.gov/pml/owm/metric-estimation-game-sp-1336

Roles: Facilitator, Teams, Participants, and Scribe. The facilitator will:

- Keep score on the board (or assign a scorekeeper).
- Reveal the game object.
- Distribute the game object to teams.
- Keep time (or assign a timekeeper).
- Reveal the correct estimate.
- Write correct answers on the board.
- Award points.

Gameplay

On game day, the facilitator will assemble the game objects, ensure all teams have the measuring materials and tools, and open the presentation from their computer on a large screen. The game objects should be placed in a prominent location, such as on a table in the front of the classroom. The facilitator will share the activity learning objectives, review the formulas **(Resources - Job Aids)**, SI writing style conventions used to report estimations, and scoring rules immediately before playing the game.

1. Distribute participants into small teams, preferably 3 to 5 persons per team. For mixed age or grade levels, the facilitator should ask participants their grade and briefly get a feel for their experience with measurements and the metric system.

2. The facilitator will ask each team to select a team scribe to write down the official team estimate and speak for the team. Encourage creative team names and reject derogatory team names. Each scribe will write the team's name on a two-sided tent card so that the facilitator can refer to the team names as they move throughout the room.

3. During each round, a Unit Symbol Card is displayed to participants to ensure the correct measurement unit is used (**Resource - Unit Symbol Cards**). Instruct participants to write estimation results with a complete quantity that includes both a number and unit symbol. If the unit is not included with the value, no points will be awarded. This practice reinforces proper SI writing style. Prefix capitalization matters. For example, mL = milliliter, while ML = Megaliter **(Figure 23)**.

4. The facilitator will select a team to start the first round. This team will view the presentation game board and pick one game item from one of four categories: mass, length, volume, and wild. For example, "mass for 1000 points" **(Figure 24)**.

5. The facilitator clicks on that game item box to reveal the object and the unit symbol, announcing both to the classroom. For example, "The Metric Maestros have selected mass for 1000 points, where the estimation object is a bowling ball, and the result will be reported in kilogram, represented with the unit symbol kg" **(Figure 24)**.

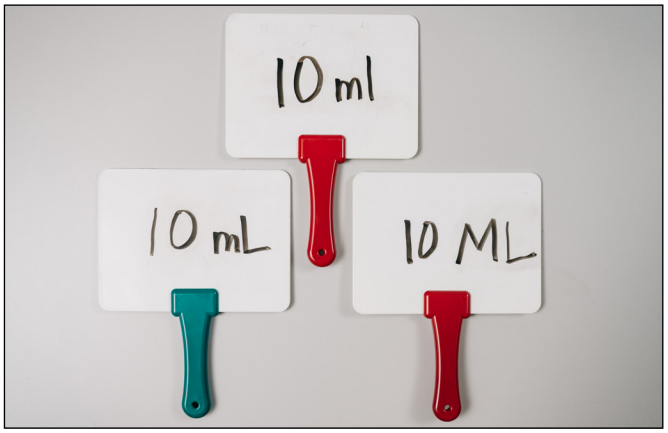
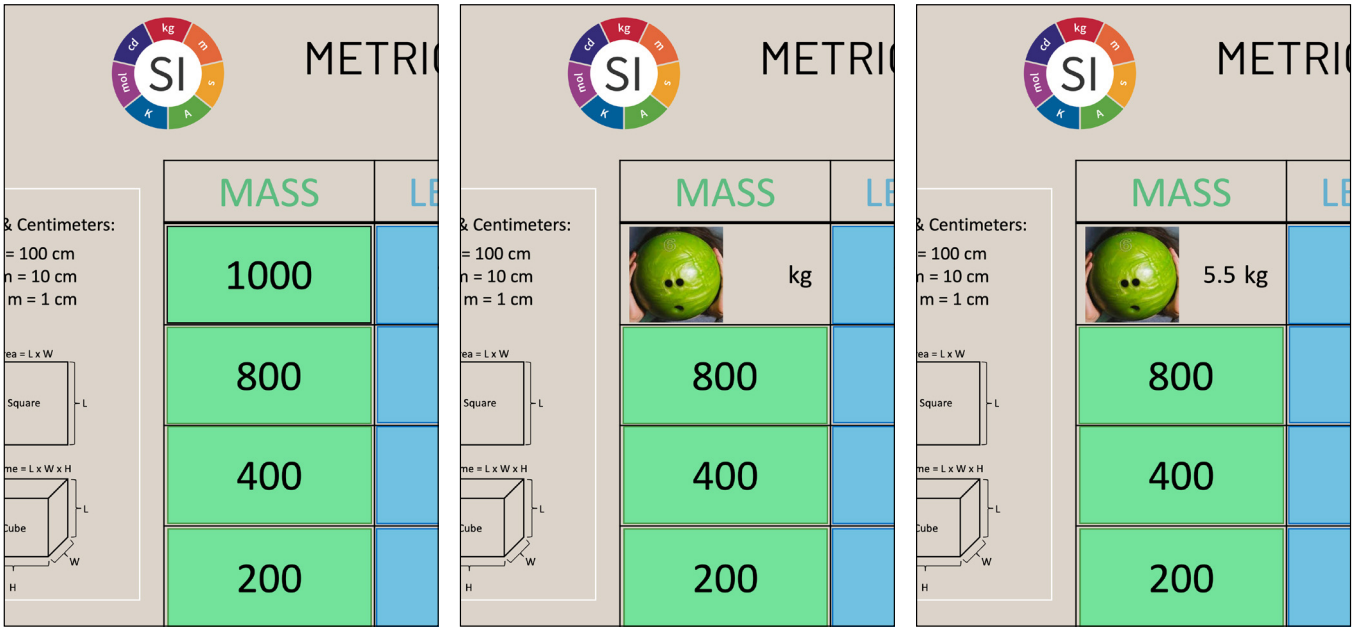


Figure 23. SI writing conventions are applied during gameplay to determine if points are earned. For example, the correct estimate is 10 mL. The green paddle uses the correct format and unit symbol for milliliter (left), lowercase m and uppercase L (mL). The 10 ml is incorrect because lowercase l may be misinterpreted as the number one (center top). The 10 ML incorrectly represents megaliters (right). Credit: NIST

6. Provide learners with the opportunity to examine the game object (**Background - Strategies**).



Step 1 *Step 2* *Step 3*

Figure 24. Step 1: In presentation mode, a team will select a category and point value (e.g., mass for 1000 points). Step 2: The facilitator selects the point box to reveal the item and unit symbol (e.g., bowling ball, kg). Step 3: After the teams determine their estimate the facilitator records them on the board, and then selects the box to reveal the answer (e.g., 5.5 kg). Credit: NIST

7. Once all learners have examined the game object, start a 60-second timer (or however long is deemed necessary) to determine the quantity value estimation that will be reported for the team. Reinforce that the participants just used the metric system – the second (s) is the base unit of time (every second of every day)!

8. Each team will determine a consensus estimate and the scribe will write the agreed-upon answer on a dry-erase paddle and raise it in the air (facing down) to indicate to the facilitator the team is ready.

9. After the time has elapsed, the facilitator will announce "time's up" and instruct any remaining teams to hold up their paddles with the estimated measurement and unit symbol.
   - Encourage the scribe to always write the unit symbol on the dry-erase paddle first so it is not forgotten.
   - Responses without unit of measure are ineligible for points.
   - Any scribes that continue writing are ineligible for points.
   - As a reminder, a complete response is a quantity number and the designated unit symbol. For example, a game board object noted a quantity estimate to be reported in kilograms (kg). The correct estimation is 1 kg, which is the response necessary to be awarded points. If a team responds with the quantity "1" without any unit symbol, or 1000 g (incorrect unit symbol), the facilitator will note that the estimate is ineligible for points.

10. The facilitator will record each team's estimate (quantity and unit symbol) on the classroom whiteboard and observe any patterns or trends among the responses.

11. The facilitator then clicks on the same box on the gameboard to reveal the correct estimate answer (**Figure 24**).

12. The facilitator will analyze team responses to determine which are correct (close to the official measurement) or incorrect (too far from the official measurement). Teams with correct estimates are awarded the point value, which is recorded on the classroom whiteboard. Points are recorded for each round and tallied at the end of the game.

13. Next, begin round 2. Ask a different team to select a category and point value from the game board presentation. For example, a softball is selected where the teams estimate the perimeter (**Figure 25**). Repeat this process until all the Game Objects are revealed or until time runs out! When available, an aid will help the facilitator bring Game Objects between each team throughout the game when large, bulky, or heavy Game Objects are used (**Safety Considerations**).

14. As the rounds progress:
   - Note that through application and practice, participants are improving measurement tool techniques. Recognize participants and celebrate as success builds their confidence. The facilitator will reflect with participants to process emotions, such as frustration, and provide the opportunity to share insightful "ah ha" moments when they occur during the game. For example, "What did you find frustrating with that item? What did you discover during that round?" **(Discussions and Extensions)**.

TIPS

- **Recognize when teams make similar estimates for a given game object.**
- **Practice increases the opportunity to work through challenges with multiple attempts, to adjust and overcome difficulties.**

- Observe which teams have not earned points. Challenge teams by increasing the opportunity to earn points and "catch up." Triple the points for each item when a team exactly estimates the game object quantity value. For example, a 1000 points object would earn 3000 points.

15. At the end of gameplay, add up the points for each team on the board to determine the winner(s). Some teams may tie (**Figure 26**).

16. The facilitator will lead a discussion where participants reflect and identify lessons learned. For example, "What would you do differently if you played this game again? What new measurement skills did you develop?" (**Discussions and Extensions)**.



Figure 25. Use a flexible tape to estimate the perimeter of a ball. Credit: NIST



Figure 26. Answer key. Credit: NIST

Gameplay Metric Meal (Option 2)

The Metric Meal (Option 2) focuses on length measurements and uses a multidisciplinary approach to build measurement skills. During the activity, participants will:

- **Identify game objects as bigger or smaller than something else—and how much larger or smaller.**
- **Order game objects from smallest to largest; evaluate their length using measurement tools.**
- **Develop a feel for quantities at the centimeter scale.**

Metric Meal (Option 2): Preparation

Prior to the activity, the facilitator will print and cut out all game objects and customize the presentation file **(Appendix C - Game Boards and Appendix D - Activity Design**). The facilitator will share the background section within the presentation prior to gameplay.

Visit the activity webpage for additional resources. https://www.nist.gov/pml/owm/metric-estimation-game-sp-1336

Roles: Facilitator, Teams, Participants, and Scribe. The facilitator will:

- Distribute the game objects.
- Keep score on the board (or assign a scorekeeper) and award points.
- Reveal the game object and correct estimate.
- Keep time (or assign a timekeeper).
- Write correct answers on the board.



Figure 27. Demonstrate unit symbol. Credit: NIST

TIPS

- **Avoid isolating SI measurements within the math and science curriculum.**
- **Include health, nutrition, and life skills. Game objects include a plate, eating utensils, and everyday food items, such as fruits and vegetables and special treats that are eaten infrequently.**
- **Practice art. Coloring their set before gameplay begins allows participants to express their creativity and improve hand-eye coordination, fine motor skills, and focus.**

Gameplay

On game day, the facilitator will distribute game objects sets and measurement tools to all participants.

1. Open the presentation from a computer and display on a large screen. The facilitator will share the activity learning objectives, review the SI writing style conventions used to report estimations (**Figure 27**), and scoring rules immediately before playing the game.

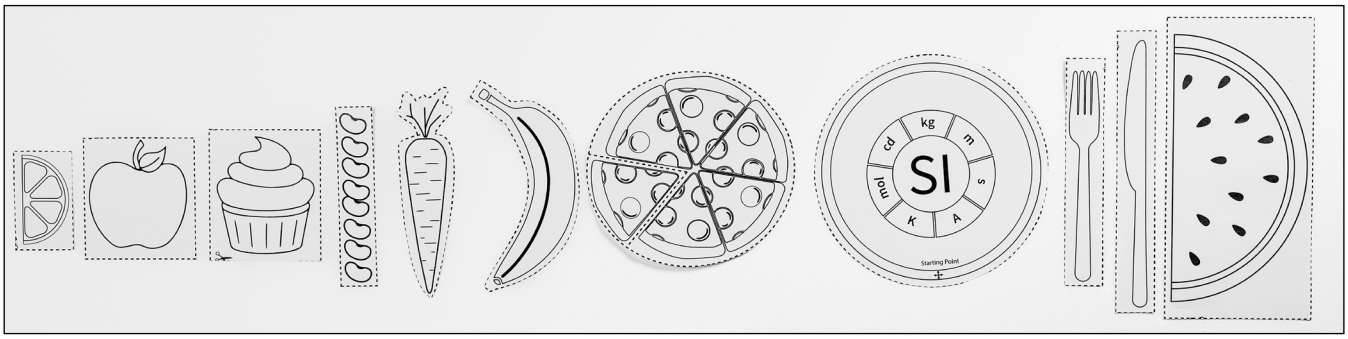


Figure 28. Place metric meal game objects from smallest to largest. Credit: NIST

2. The facilitator may choose that participants make measurements within teams (3 to 5 persons), independently, or a combination of both. For mixed age or grade levels, the facilitator should ask participants their grade and briefly get a feel for their experience with measurements and the metric system. If a virtual or hybrid mode is used, breakout groups may be used for team collaboration.

   - When teams are used, the facilitator will ask each team to select a team scribe to write down the official team estimate and speak for the team. Encourage creative team names and reject derogatory team names. Each scribe will write the team's name on a two-sided tent card so that the facilitator can refer to the team names as they move throughout the room.
   - Provide young learners an opportunity to compare each item and evaluate relative size before estimation. Each participant will place game objects in order from smallest to largest (**Figure 28**).

TIPS

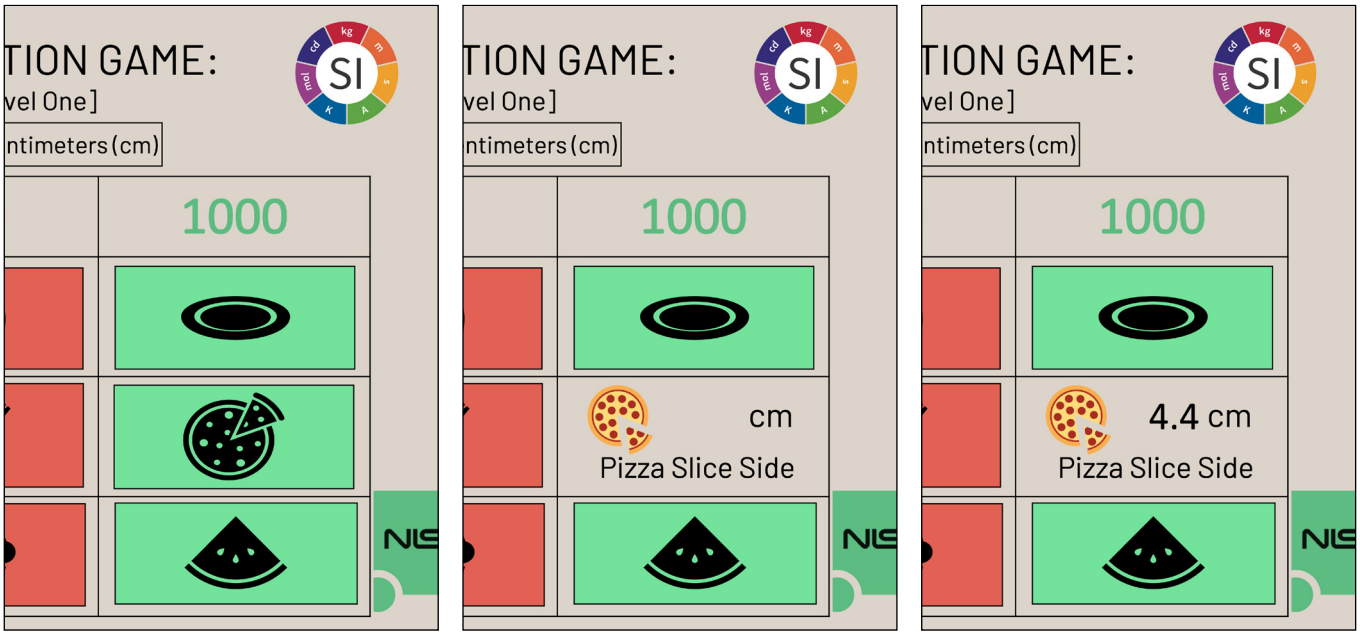
- **Encourage participants to creatively customize their game objects with wax pencils.**

   Walking among the participants, observe any sequences that may be out of increasing size sequence. The facilitator will ask for volunteer participants to explain why they selected a specific order. Provide participants the opportunity to adjust the sequence of their game objects.
   - Participants will arrange them around the edge of the "SI" plate game object. Note that the "Start Here" arrows on the SI plate game object will help all participants to identify a consistent starting point for the circumference measurement. Centimeter cubes or a ruler may be used, based on instructional level (**Figure 29**).





Figure 29. During gameplay, young learners may use math manipulatives (centimeter cubes) to help make their initial estimations. Follow each round by verifying their estimates using a ruler or flexible measuring tape. Credit: NIST



Step 1 *Step 2* *Step 3*

Figure 30. Step 1: In presentation mode, a team will select a category and point value (example pizza slice side for 1000 points). Step 2: The facilitator selects the point box to reveal the item and unit symbol (example pizza slice side, cm). Step 3: After the teams determine their estimate the facilitator records them on the board. Then selects the box to reveal the answer (example 4.4 cm). Credit: NIST

3. The facilitator will select a team (preferred) or individual to start the first round. This team will view the presentation game board and pick one game item from the game board presentation. The facilitator clicks on that game item box to reveal the object and the unit symbol, announcing both to the classroom. For example, "The Metric Maestros have selected pizza slice side for 1000 points, where we will estimate one side of the pizza slice and report the answer in cm, or centimeters (**Figure 30)**.
   - The facilitator will ask a volunteer to describe what tool they would select for this game object. For example, "Would you select a ruler or a flexible tape measure? Please explain why."
4. Provide learners with the opportunity to examine and measure their game object **(Figure 29) (Background - Strategies)**.
5. Once all learners have examined the game object, start a two-minute (120 s) timer (or however long is deemed necessary) to determine the quantity value estimation that will be reported for the team. Reinforce that the participants just used the metric system – the second (s) is the base unit of time (every second of every day)!
6. Each team will determine a consensus estimate and the scribe will write the agreed-upon answer on a dry-erase paddle and raise it in the air (facing down) to indicate to the facilitator the team is ready.
7. After the time has elapsed, the facilitator will announce "time's up" and instruct any remaining teams to hold up their paddles with the estimated measurement and unit symbol. Any scribes who continue writing are ineligible for points.
8. The facilitator will record each team's estimate (quantity and unit symbol) on the classroom whiteboard and observe any patterns or trends among the responses.
9. The facilitator then clicks on the same box on the gameboard to reveal the correct estimate.

Discussions and Extensions



In-person

The facilitator asks participants to write *one thing they learned from the game* about the SI on a blank index card (self-reflection time, 90 seconds). Then ask participants to volunteer and share their answers verbally and facilitate the discussion with a written summary of the responses on the board or flipchart or collect the index cards and compile the responses and evaluate.

Hybrid or Virtual

Write responses in the chat or other technology.

Debriefing Discussion Questions

- What was challenging/easy about this activity?
- Describe one example of how you use the SI in daily life?
- Why are measurements important in our daily life?
- Explain why it is important to choose the right measurement tool for the job?
- What could happen if an incorrect measurement is made? Describe the potential negative consequences. The facilitator provides scenarios as necessary; a manufacturing plant, hospital pharmacy, gas pump, bakery, grocery store deli, electricity or water meter.

Extensions

- Focus on only one measurement parameter in a game session, such as mass, length, or volume.
- Develop an estimation or measurement station where participants measure objects that periodically change. Measure each sample item and write the measurement on the back of the object using a note card or a piece of masking tape. Participants will have the opportunity to practice their measurement techniques by measuring the Game Objects and confirming their value.
- Reinforce measurement estimation skills by setting up 3 to 4 objects during beginning of class for participants to estimate. This is also a good opportunity to practice estimation skills for an exam.
- Challenge participants to bring in an item from home to add to the game.

Example Feedback

1. **I love making measurements.**
2. **It is fun to measure with metric and I like that you use it for everything.**
3. **I like this game because it helped me learn how to use metric units.**
4. **Estimating is very important.**
5. **I like having the option to choose which ruler I use to measure.**
6. **The U.S. nickel is 5 g.**
7. **I enjoyed working on my team to earn points.**
8. **The more I practice, the better I get at measuring.**
9. **We can use two different methods to measure an object and compare our answers.**
10. **Everything can be measured with the metric system, including food I eat.**

References



1. Vendian, *Some Printable Paper Ruler, Meter Sticks, and Color-square Rules,* http://www.vendian.org/mncharity/dir3/paper_rulers/
2. Vendian, *A Printable Decimeter Box, 10 cm Cube*, http://www.vendian.org/mncharity/dir3/dm_box/
3. National Institute of Standards and Technology (NIST), *SI Units-Volume*, https://www.nist.gov/pml/owm/si-units-volume
4. Vendian, *A How Big Are Things Cube,* http://www.vendian.org/howbig/cube/
5. Benham, E. (2022). *Top 10 TIPS for Teaching the Metric System*, National Institute of Standards & Technology (NIST) Taking Measure blog. https://www.nist.gov/blogs/taking-measure/top-10-TIPS-teaching-metric-system
6. Milton, Hans J. National Bureau of Standards (NBS) Technical Note (TN) 938 (1977). *Recommended Practice for the Use of Metric (SI) in Building Design and Construction.* https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote938.pdf
7. BIPM (2019). *SI Brochure, The International System of Units (SI).* https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-EN.pdf
8. International Bureau of Weights and Measures (BIPM), *Promotion of the SI,* https://www.bipm.org/en/measurement-units/si-promotion
9. NIST, *Meet the Constants,* https://www.nist.gov/si-redefinition/meet-constants
10. NIST, *SI Base Units*, https://www.nist.gov/pml/weights-and-measures/metric-si/si-units
11. Tiesinga, E., Dill, K.A., Newell, D. (2020). *SI Base Units Relationships Poster*. NIST SP 1247. https://doi.org/10.6028/NIST.SP.1247
12. Newell, D. and Tiesinga, E. (2019). *The International System of Units (SI)*. NIST Special Publication (SP) 330. https://www.nist.gov/pml/special-publication-330
13. Thompson, A. and Taylor, B. N. (2008). *Guide for the Use of the International System of Units (SI)*. NIST SP 811. https://www.nist.gov/pml/special-publication-811
14. NIST, *Prefixes*, https://www.nist.gov/pml/owm/metric-sports
15. United States Mint, *Coin Specifications,* https://www.usmint.gov/learn/coin-and-medal-programs/coin-specifications
16. NIST, *Writing with SI,* https://www.nist.gov/pml/owm/writing-si-metric-system-units
17. BIPM, *World Metrology Day*, http://www.worldmetrologyday.org
18. *Metric Act of 1866* (14 Stat 339), also known as the Kasson Act (15 USC 204 et seq.12.), https://www.nist.gov/system/files/documents/2017/05/09/HR-596-Metric-Law-1866.pdf
19. Benham, E. (2020). *Busting Myths about the Metric Syste*m, National Institute of Standards & Technology (NIST) Taking Measure blog. https://www.nist.gov/blogs/taking-measure/busting-myths-about-metric-system
20. Common Core Standards National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics.* Washington D.C. http://corestandards.org/
21. National Academies of Sciences, Engineering, and Medicine. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

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Contributions

Elizabeth Benham: Project Administration, Supervision, Resources, Conceptualization, Investigation, Instructional Design, Validation, Writing-Original Draft Preparation, Writing-Reviewing and Editing. Kristen Dill: Graphic Design, Visualization, Writing-Reviewing and Editing. Dinelka Jagoda: Conceptualization, Graphic Design, Writing-Reviewing and Editing. Maryanne Amanze: Writing-Reviewing and Editing, Photography Model. Yoon Thwel: Writing-Reviewing and Editing. Isabel Chavez Baucom: Photography Model.

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Appendix A – Education Standards

Common Core State Standards[20], ELA-Literacy

Use knowledge of the International System of Units and its conventions when writing, speaking, reading, and listening.

Educators should carefully examine local and state frameworks and curriculum guides to determine the best method for integrating this activity into their school's programs. Appropriate placement within the scope and sequence of a school's curriculum will optimize the interdisciplinary connections and enhance the ability of a student to learn key concepts related to measurement science.

English Language Arts	
Use knowledge of the English Language, including the International System of Units, and its conventions when writing, speaking, reading, and listening. [https://www.thecorestandards.org/ELA-Literacy/W]	
Instructional Level	**Writing**
Grade 5	**CCSS.ELA-LITERACY.W.5.2.D.** Use precise language and domain-specific vocabulary to inform about or explain the topic.
	CCSS.ELA-LITERACY.W.5.3.D. Use concrete words and phrases and sensory details to convey experiences and events precisely.
Instructional Level	**Speaking and Listening. Comprehension and Collaboration**
Grade 5	**CCSS.ELA-LITERACY.SL.5.1.** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.
	CCSS.ELA-LITERACY.SL.5.1.A. Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.
	CCSS.ELA-LITERACY.SL.5.1.B. Follow agreed-upon rules for discussions and carry out assigned roles.
	CCSS.ELA-LITERACY.SL.5.1.C. Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
	CCSS.ELA-LITERACY.SL.5.1.D. Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

Mathematics

Mathematically proficient learners consider the available tools when solving a mathematical problem (e.g., centimeter cube math manipulative, flexible metric measuring tape, rigid metric ruler, or liter cube model). Proficient learners are sufficiently familiar with tools appropriate for their grade or course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations. They detect possible errors by strategically using estimation and other mathematical knowledge.

[https://www.thecorestandards.org/Math/Practice/MP5/]

Instructional Level	Measurement & Data [https://www.thecorestandards.org/Math/Content/MD/]
Grade Kindergarten Describe and compare measurable attributes.	**CCSS.MATH.CONTENT.K.MD.A.1.** Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.
	CCSS.MATH.CONTENT.K.MD.A.2. Directly compare two objects with a measurable attribute in common, to see which object has “more of”/”less of” the attribute, and describe the difference.
Grade 2 Measure and estimate lengths in standard units.	**CCSS.MATH.CONTENT.2.MD.A.1.** Measure the length of an object by selecting and using appropriate tools such as rulers, meter sticks, and measuring tapes.
	CCSS.MATH.CONTENT.2.MD.A.1. Measure the length of an object by selecting and using appropriate tools such as rulers, meter sticks, and measuring tapes.
Grade 3 Solve problems involving measurement and estimation. Geometric measurement: recognize perimeter.	**CCSS.MATH.CONTENT.3.MD.A.2.** Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (L).
	CCSS.MATH.CONTENT.3.MD.D.8. Solve real world and mathematical problems involving perimeters of polygons, including finding the perimeter given the side lengths, finding an unknown side length, and exhibiting rectangles with the same perimeter and different areas or with the same area and different perimeters.
Grade 4 Solve problems involving measurement and conversion of measurements.	**CCSS.MATH.CONTENT.4.MD.A.1.** Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; L, mL. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit.
	CCSS.MATH.CONTENT.4.MD.A.3. Apply the area and perimeter formulas for rectangles in real world and mathematical problems.

Mathematics	
Instructional Level	**Measurement & Data** [https://www.thecorestandards.org/Math/Content/5/MD/]
Grade 5 Geometric measurement. Understand concepts of volume. Recognize volume as an attribute of solid figures and understand concepts of volume measurement.	**CCSS.MATH.CONTENT.5.MD.C.3.** Recognize volume as an attribute of solid figures and understand concepts of volume measurement.
	CCSS.MATH.CONTENT.5.MD.C.3.A A cube with side length 1 unit, called a "unit cube," is said to have "one cubic unit" of volume, and can be used to measure volume.
	CCSS.MATH.CONTENT.5.MD.C.3.B A solid figure which can be packed without gaps or overlaps using n unit cubes is said to have a volume of n cubic units.
	CCSS.MATH.CONTENT.5.MD.C.4 Measure volumes by counting unit cubes, using cubic centimeter (cm^3).
	CCSS.MATH.CONTENT.5.MD.C.5 Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume.
	CCSS.MATH.CONTENT.5.MD.C.5.A Find the volume of a right rectangular prism with whole-number side lengths by packing it with unit cubes, and show that the volume is the same as would be found by multiplying the edge lengths, equivalently by multiplying the height by the area of the base. Represent threefold whole-number products as volumes, e.g., to represent the associative property of multiplication.
	CCSS.MATH.CONTENT.5.MD.C.5.B Apply the formulas V = l × w × h and V = b × h for rectangular prisms to find volumes of right rectangular prisms with whole-number edge lengths in the context of solving real world and mathematical problems.

Mathematics	
Instructional Level	**Number & Operations in Base Ten** [https://www.thecorestandards.org/Math/Content/NBT/]
Grade 4 Generalize place value understanding for multi-digit whole numbers. Use place value understanding and properties of operations to perform multi-digit arithmetic.	**CCCSS.MATH.CONTENT.4.NBT.A.1.** Recognize that in a multi-digit whole number, a digit in one place represents ten times what it represents in the place to its right.
	CCSS.MATH.CONTENT.4.NBT.A.2. Read and write multi-digit whole numbers using base-ten numerals, number names, and expanded form.
	CCSS.MATH.CONTENT.4.NBT.B.5. Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers, using strategies based on place value and the properties of operations.
Grade 5 Understand the place value system.	**CCSS.MATH.CONTENT.5.NBT.A.1.** Recognize that in a multi-digit number, a digit in one place represents 10 times as much as it represents in the place to its right and 1/10 of what it represents in the place to its left.

Next Generation Science Standards[21]	
[https://nap.nationalacademies.org/read/13165/chapter/7#52]	
Science and Engineering Practices	
Using Mathematics and Computational Thinking	SI units provide a standardized way to quantify and compare data.
Analyzing and Interpreting Data	Consistent measurement units ensure that data is reliable, comparable, and meaningful across investigations and disciplines.
Planning and Carrying Out Investigations	Accurate measurement using SI units is critical to experimental design and reproducibility.
Obtaining, Evaluating, and Communicating Information	To apply these ideas, measurements of mass, volume, temperature, time, force, and energy, expressed in SI units, are required.
Crosscutting Concepts	
Scale, Proportion, and Quantity	Understanding and using SI units teaches students how to work with different scales (e.g., micrometers or kilometers), proportions, and quantities, which is key to modeling and interpreting scientific phenomena. In this activity, learners directly observe, see, touch, feel, and manipulate objects from daily life on the macroscopic scale to develop their understanding of magnitude.
Systems and System Models	Measuring in SI units allows a consistent description and analysis of systems, whether biological, chemical, or physical.
Disciplinary Core Ideas	
Across physical, Earth, and life sciences, SI units are used to express quantities related to: • PS1: Matter and its interactions. • PS2: Motion and Stability: Forces and Interactions • ESS1-3: Earth and Space Sciences • LS1-4: Life Sciences Examples. Natural objects range from the very small to the immensely large. SI units measure and describe physical quantities, such as mass, length, and volume.	
Nature of Science	
Science investigations use a variety of methods and tools to make measurements and observations.	Learners use a variety of measurement instruments, including math manipulatives, rigid rulers, and flexible tapes, to measure length variables represented by a continuous numerical scale.
Scientific knowledge is based on empirical evidence.	Scientists look for patterns and order when making observations about the world. Scientists use tools and technologies to make accurate measurements and observations.
College and Career Readiness	
Learners should be prepared for real-world applications of science. Since the SI is the globally accepted measurement system, it is critical for STEM literacy, collaboration in international scientific efforts, and careers in science and engineering. Learning the SI is about developing a scientifically literate mindset. SI units support collaboration and clarity in communications, which are essential to engage in meaningful NGSS-aligned learning experiences.	

Appendix B – Measurement Tools and Game Objects

Everyday Objects (Option 1)

MASS		
Game Object	**Official Measurement**	**Comments**
Bowling Ball	5.5 kg	
5 - Rolls of Nickels	1 kg	
Fork	83 g	
Plastic Produce Bag	2.5 g	
Cell Phone	135 g	
Butter Knife	108 g	
Spoon	66 g	
Golf Ball	49.5 g	
Spoon	32 g	
Foam Rocket Toy	11.5 g	
Wax Pencil	5 g	
Pencil	5 g	
Sugar Sweetener Package	1 g	
Cotton Ball	585 mg	
LENGTH		
Game Object	**Official Measurement**	**Comments**
Classroom Length	9 m	
Jump Rope - Plain	2.8 m	
Jump Rope - Purple	2.1 m	
Flag Length	2 m	
Beach Ball (Circumference)	1.05 m	
Umbrella (Perimeter)	311 cm	
Candy Box Heart (Perimeter)	80.5 cm	
Small Ball (Circumference)	32 cm	
Softball (Circumference)	27.5 cm	
Hockey Puck (Circumference)	24 cm	
Fork	210 mm	
Knife	0.23 m	
Pencil	190 mm	
Spoon	180 mm	
Golf Ball (Circumference)	135 mm	
Wax Pencil	92 mm	
Hockey Puck (Diameter)	75 mm	
Golf Tee	55 mm	
Door Key	55 mm	

Everyday Objects (Option 1)

VOLUME		
Game Object	**Official Measurement**	**Comments**
Classroom Volume	172.5 m^3	
Beach Ball	22.4 L	
Hand Soap Bottle	5 L	
Water Jug	3L	
Hand Sanitizer Bottle	2 L	Reference Point
Orange Juice Bottle	1.75 L	
Bubble Bath Bottle	1 L	Reference Point
Ice Cream (Gelato) Container	1 L	Reference Point
Milk Bottle Volume	201 mL	
Juice Box	200 mL	
Toothpaste Box	173 cm^3	
Ice Cream Scoop	61 mL	
Thimble	25 mL	
Lipstick Box	23 cm^3	
Eye Drop Bottle	15 mL	
Baby Medicine Syringe	3 cm^3	

AREA		
Game Object	**Official Measurement**	**Comments**
Classroom Area	TBD m^2	
Table Surface Area	4 m^2	
Flag Area	2.14 m^2	
Sheet of Office Paper	616 cm^2	
Ruler	150 cm^2	
Bookmark	80 cm^2	
Business Card	45 cm^2	
Sugar Sweetener Package	22.4 cm^2	
Postage Stamp	528 mm^2	

Metric Meal (Option 2)

Game Object	Official Measurement	Comments
Plate Perimeter (inner circle)	32.7 cm	
Plate Diameter (inner circle)	8.6 cm	
Plate Radius	5.1 cm	
Fork Length	10.9 cm	
Knife Length	13.7 cm	
Carrot Length (excluding leaf)	8.1 cm	
Banana Width	2.1 cm	
Banana Stalk	1.8 cm	
Watermelon Length	13.8 cm	
Watermelon Outer Curve	22.4 cm	
Orange Wedge Length	4.7 cm	
Orange Wedge Outer Curve	8.1 cm	
Row of Beans	8.7 cm	
Bean Length (horizontal)	1.3 cm	
Pizza Slice Perimeter	13.4 cm	
Pizza Slice Side	4.4 cm	
Pizza Slice Crust (width)	4.7 cm	
Cupcake Height	6.2 cm	
Apple Length (including stem)	5.5 cm	
Apple Width	5.0 cm	

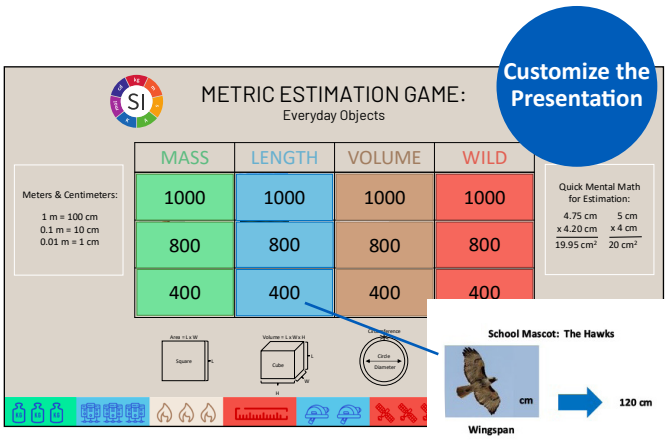
Appendix C – Game Boards

The game animation will allow the user to click on the topic and reveal the object. A second click will reveal the measurement value. **DO NOT SAVE** the file after the Point blocks have been selected or "clicked" during the game (e.g., saving the modifications will remove the animations). If you exchange an item on the game board, remember to also change it in the answer.

Customization Instructions

Follow these steps to change an object, graphic or measurement:

1. Cut the object cover (PC: CTRL + X, Mac: Command + X).
2. When you click inside the object box the first layer will be the object measurement.
3. Highlight the number and change the text to black (to be able to see the text).
4. Modify the number to your new measurement.
5. Change the color back to its previous color (background color).
6. Change the object's measurement unit (if needed).
7. Right click on the number textbox (click the textbox outline) and send the textbox to the back. The command shown should be "Send to Back". This will give you access to the layers underneath.
8. Click on the object's measurement unit textbox and change it to match your new measurement.
9. Change the object's picture (if needed) to match your new measurement. Crop the picture to fit inside the chart box.
10. Put everything back in place.
11. **IMPORTANT:** Move the measurement number layer back on top to avoid interfering with the animations.
12. Click on where the number measurement would be; this will highlight the table outline.
13. Right click the table outline and move it to the back. The exact command shown should be "Send to Back".
14. You will now have access to the measurement number outline. Right click the textbox and move it to the front. The exact command shown should be "Send to Front".
15. Paste the object cover back into place (PC: CTRL + V, Mac: Command + V).
16. **It is important to follow these instructions to ensure the animations work smoothly.**

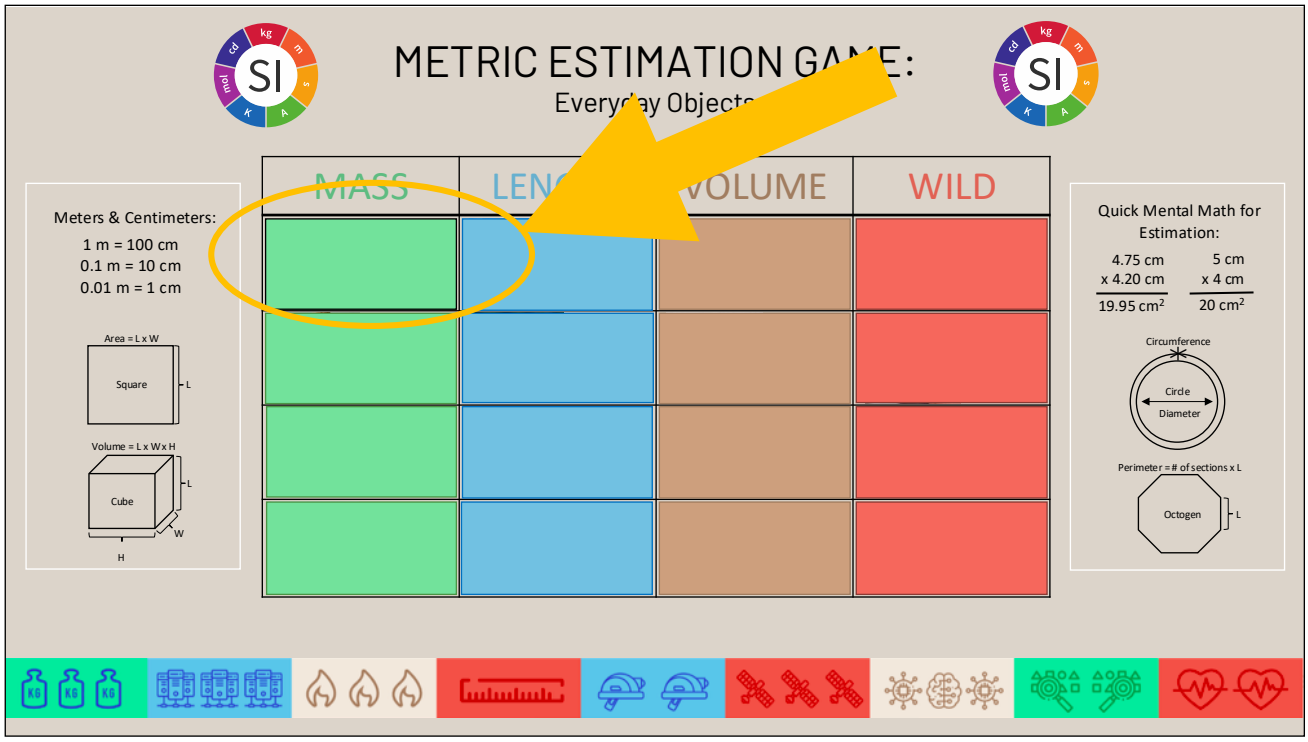


Everyday Objects (Option 1) example gameboard. Credit: NIST

TIPS

- **Ensure "Use Timings'" option (Slide Show tab) is unchecked.**
- **Change the magnitude by adjusting the measurement unit (e.g., m, cm, or mm). For example, a 5.5 kg bowling ball could also be represented in the game as 5500 g.**
- **Frequently mix or reorganize the sample's location on the board location or point value.**

Everyday Objects - Option 1: Played in classroom, in teams, in-person

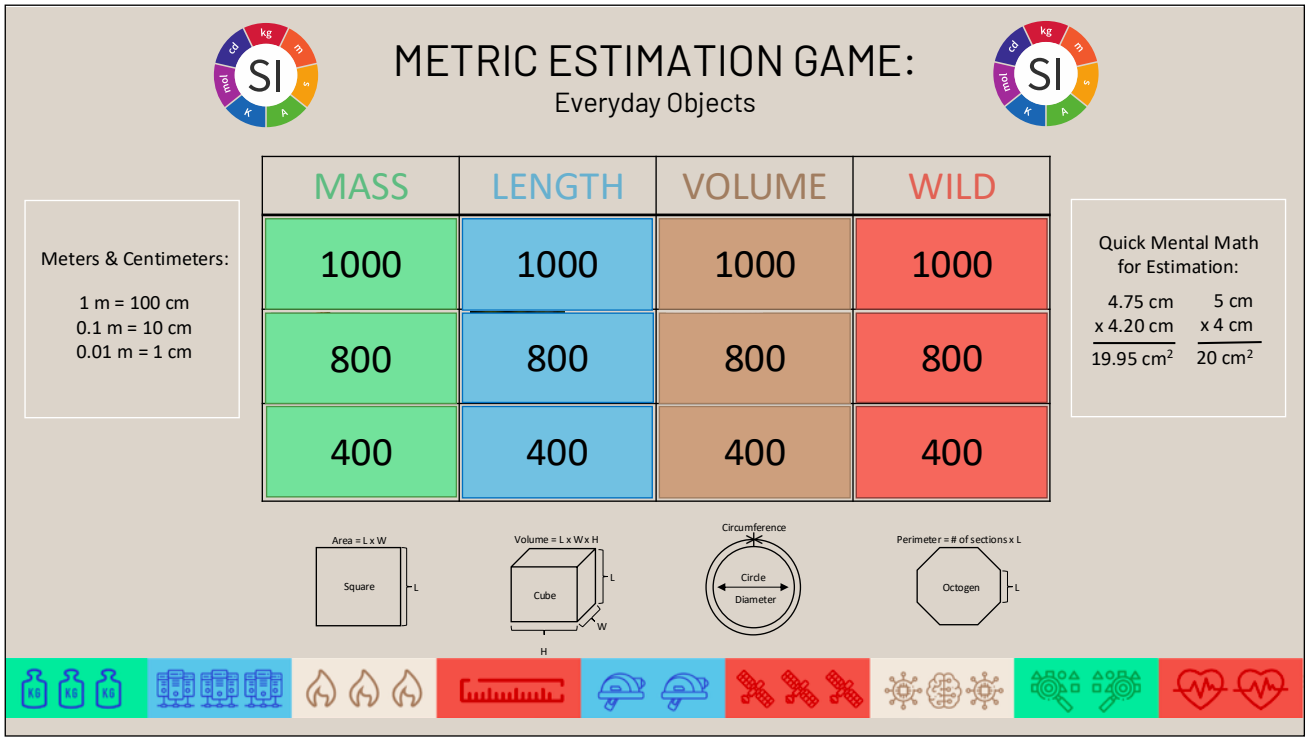


Categories at the beginning of the game. Credit: NIST

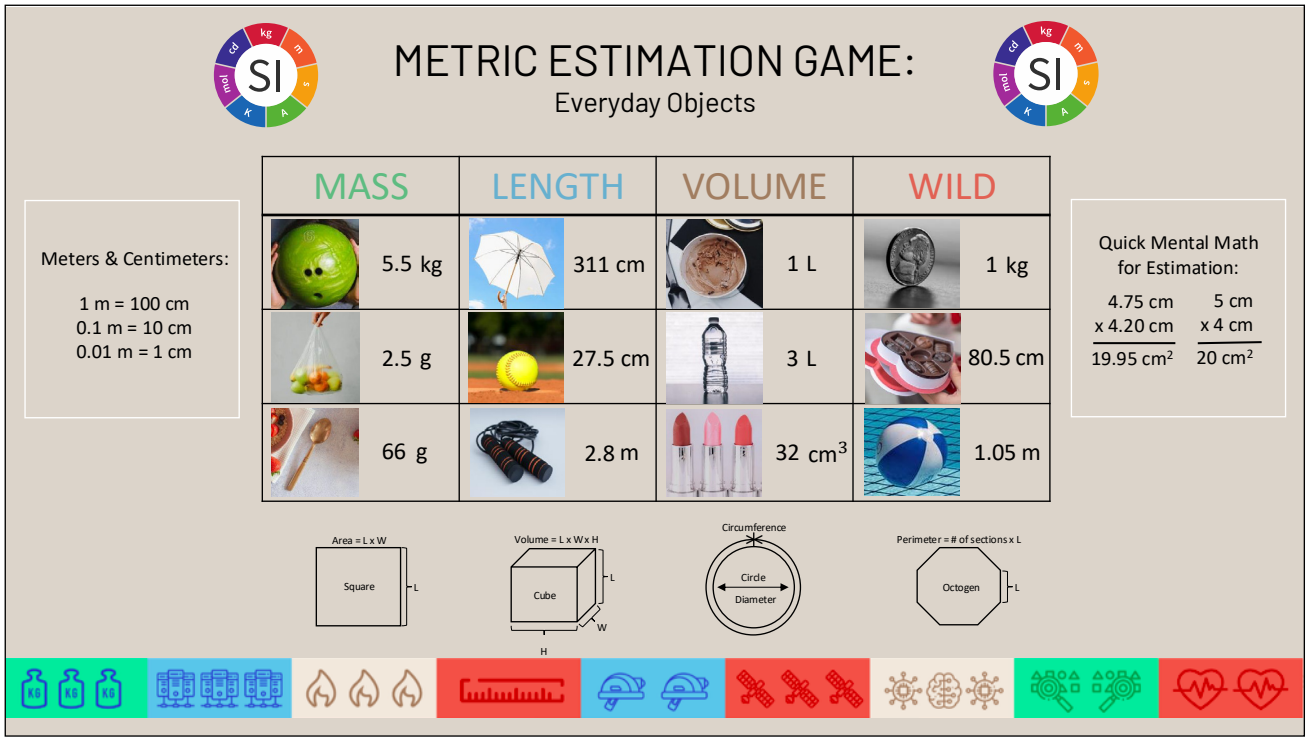


Key that reveals the answers. Credit: NIST

Everyday Objects - Option 1 (extended): Played in classroom, in teams, in-person

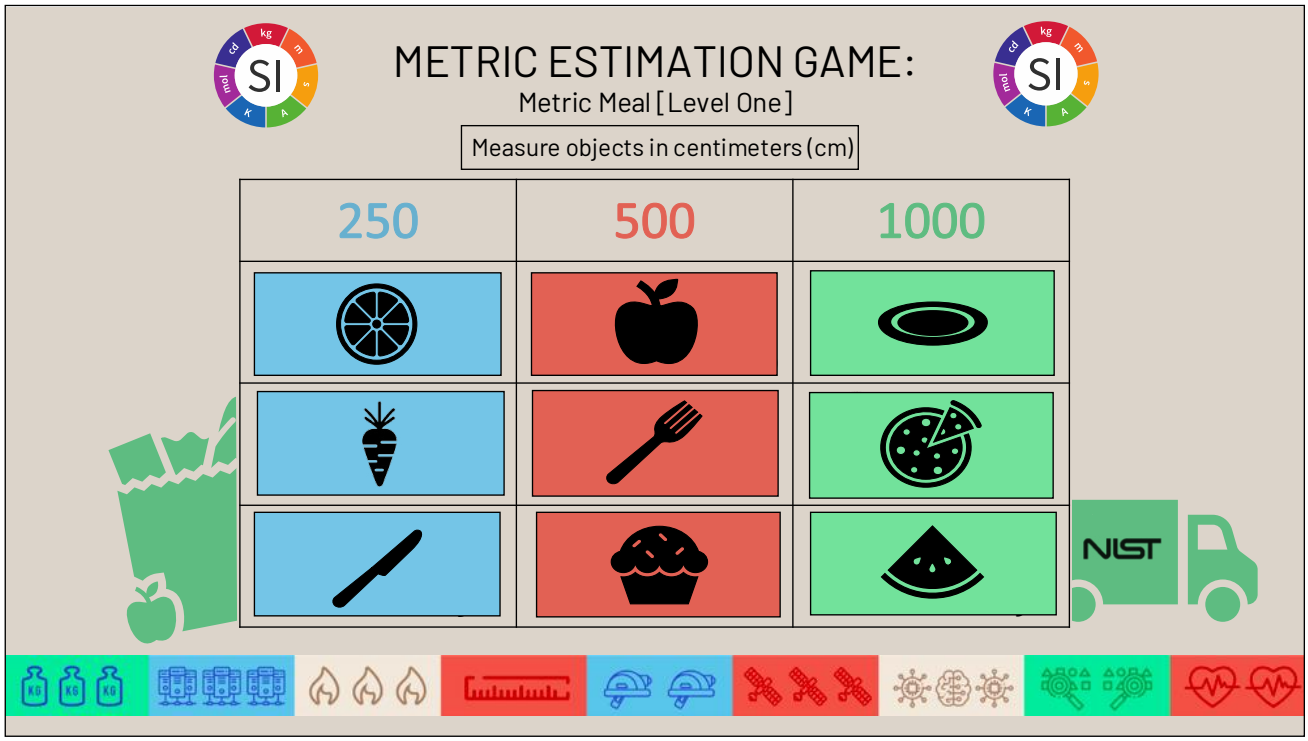


Categories at the beginning of the game. Credit: NIST

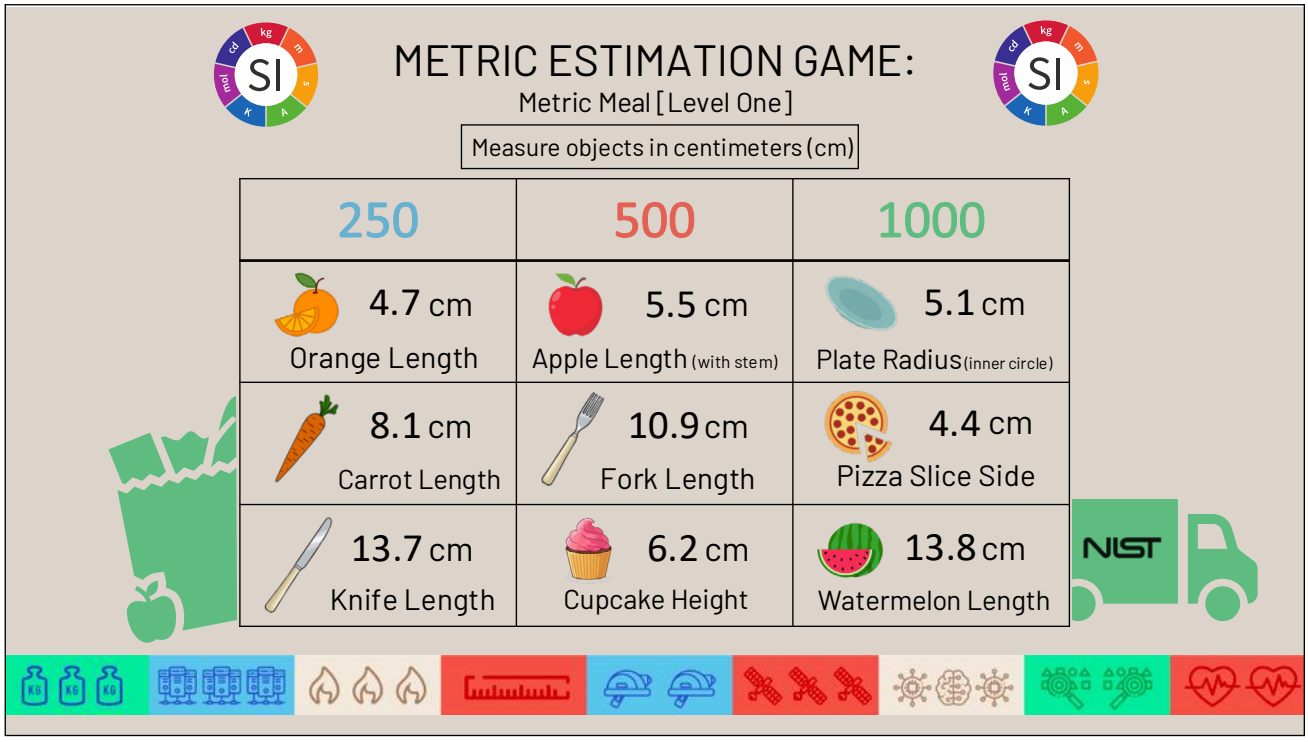


Key that reveals the answers. Credit: NIST

Metric Meal - Option 2: Played as individual, in teams, in-person or virtual, hybrid

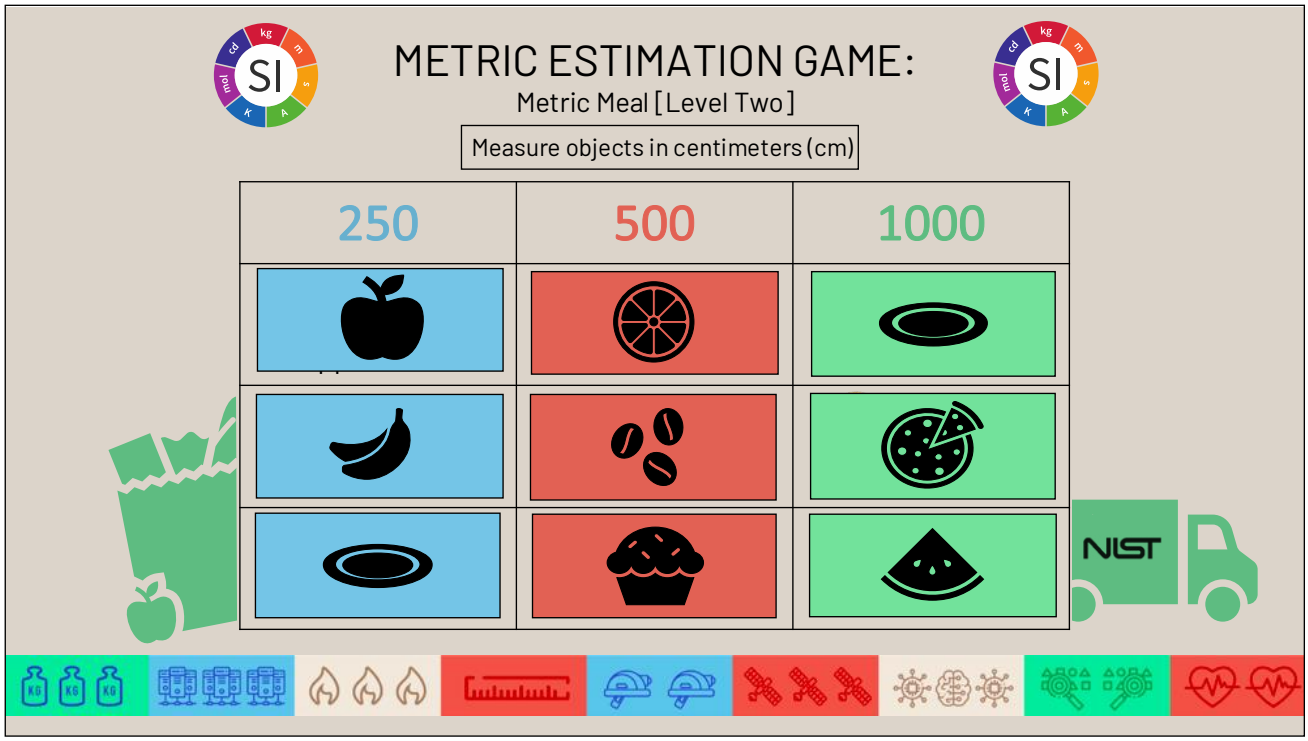


Categories at the beginning of the game. Credit: NIST

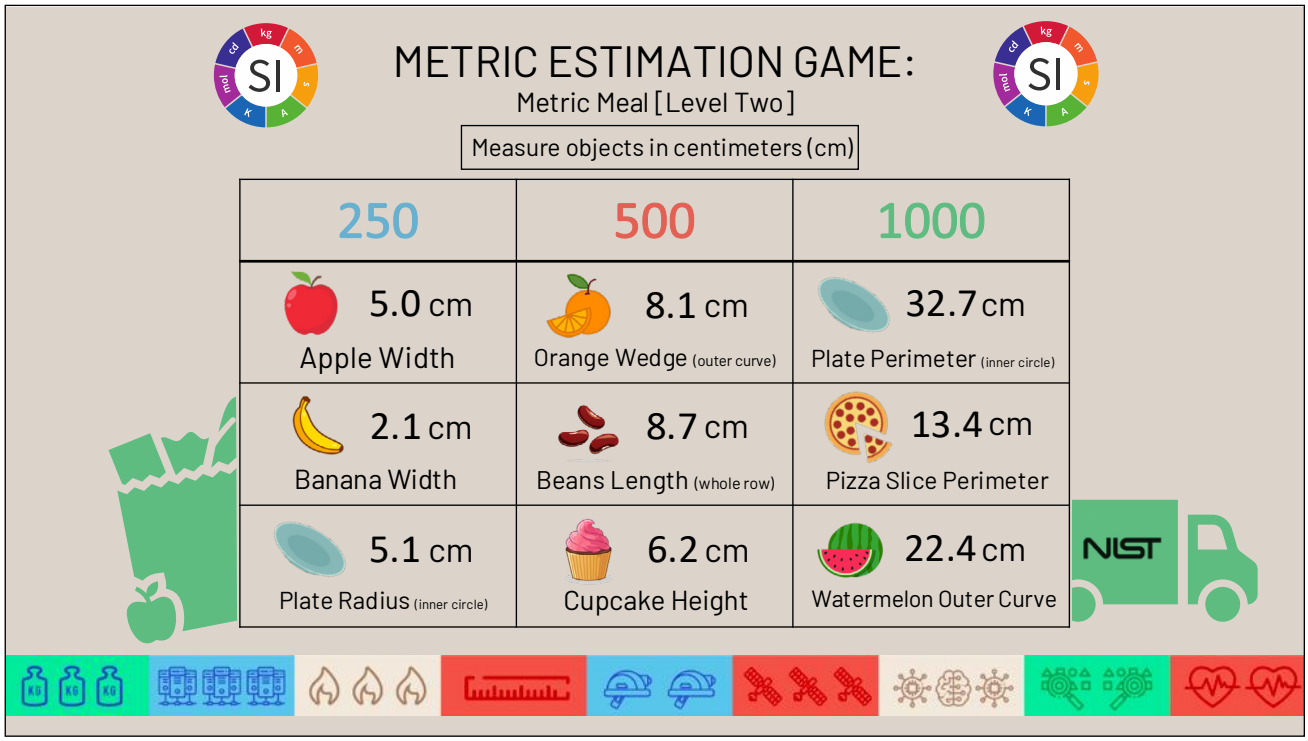


Key that reveals the answers. Credit: NIST

Metric Meal - Option 2: Played as individual, in teams, in-person or virtual, hybrid



Categories at the beginning of the game. Credit: NIST



Key that reveals the answers. Credit: NIST

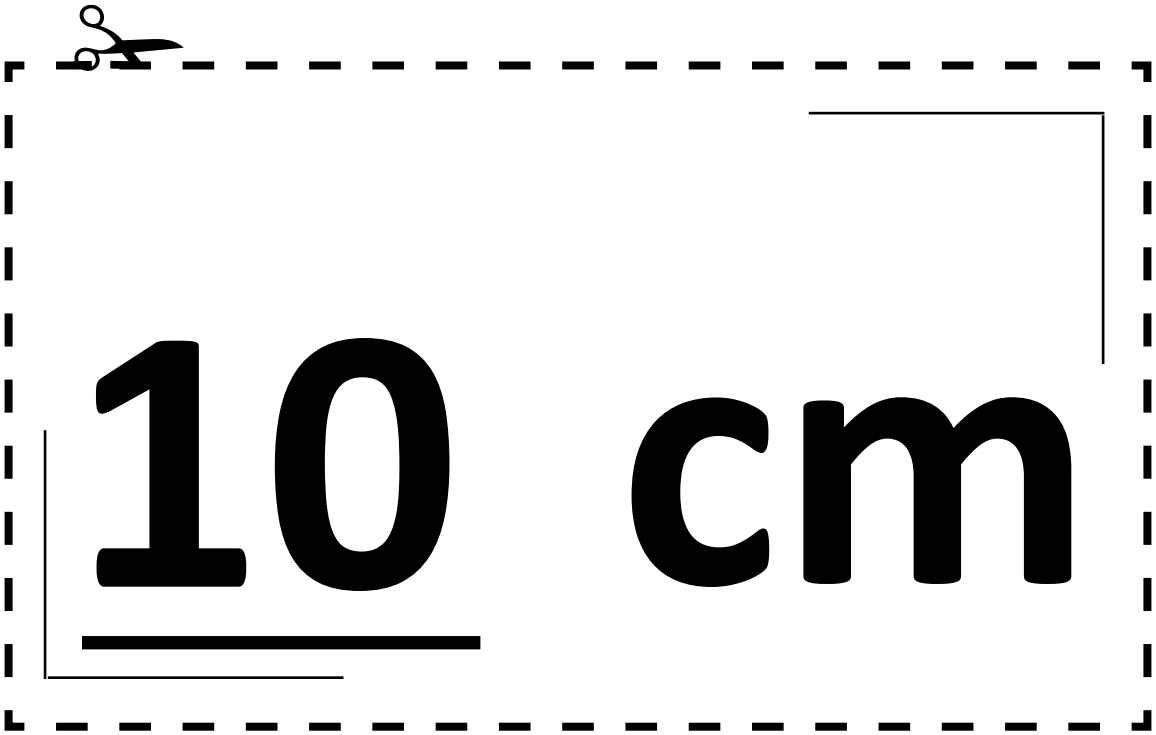
Appendix D - Activity Design

Bloom's Taxonomy	Learning Objective	Activity	Assessment
Knowledge	LIST one SI measurement example.	Lecture (PPT) – basic history, simplicity, 7 base units, common reference points. Metric Estimation Game	Participant will write one thing they learned about the metric system (SI) on a note card. Ask participants to share their answers verbally and write responses on the board. Collect the cards.
Application	APPLY SI measurements to common objects used every day. Estimate Calculate Operate SI measurement tools Illustrate SI length, mass and volume measurements	Metric Estimation Game Participants perform length, mass, area, and volume measurements by selecting and using appropriate measurement equipment, such as rigid plastic rulers, flexible measuring tapes, meter sticks, cubic centimeter manipulatives, and holding the reference objects (do not using a scale/balance) to measure a diverse group of common everyday objects (sport balls and equipment, food containers, wax pencils, cotton ball, sugar packet, coins, umbrella, flatware) during the game. Participants use SI measurement units, including mm, cm, m, g, kg, mL, L, cm^3. Some object measurements will be determined using basic math formulas. Participants may verify results using multiple methods.	Observe measurement methods, application of concepts (radius, diameter, perimeter, and circumference) and formula (area of a square and volume of a cube), and accurate math computation. Record each participant's performance or participation on a seating chart (e.g., a simple + positive, - negative, 0 neutral, with comments). **Debriefing Discussion** What was challenging/easy about this activity? Describe an example of how you use the metric system or metric measurements in your daily life?
Application	DEVELOP SI measurement reference points. Interpret estimated measurement results (Does this answer make sense?)	Participant team assigns a measurement value estimate for each item, which is compared to a verified measurement value. Each team measurement is recorded on the board as the game progresses so that participant can build on previous knowledge as additional objects are evaluated. Reference points include objects across a small (< 10 cm, < 10 gram, < 30 mL), medium (10 cm to 1 m, 10 g to 1 kg, 1 L to 2 L), and large (1m to 10 m, 1 kg to 5 kg, >3 L) range. Objects with common nominal values are used, such as 1 g, 500 g, 1 kg, 500 mL, and 1 L.	As the game progresses (with multiple rounds) observe: • Increasing agreement between team estimate and the known item value. • Decreasing variation between team estimates. **Debriefing Discussion** Explain why it is important to choose the right measurement tool for the job. Identify how important accurate measurements are in our daily life. What could happen if an incorrect measurement is made. Describe the potential negative consequences (supply example scenarios as necessary, e.g., manufacturing plant, hospital pharmacy, gas pump, bakery, grocery store deli, home electricity or water meter).

Resources - Unit Symbol Cards

Prepare before the game. Print on card stock and cut out the cards.
Use blank replacement cards as needed.





Example

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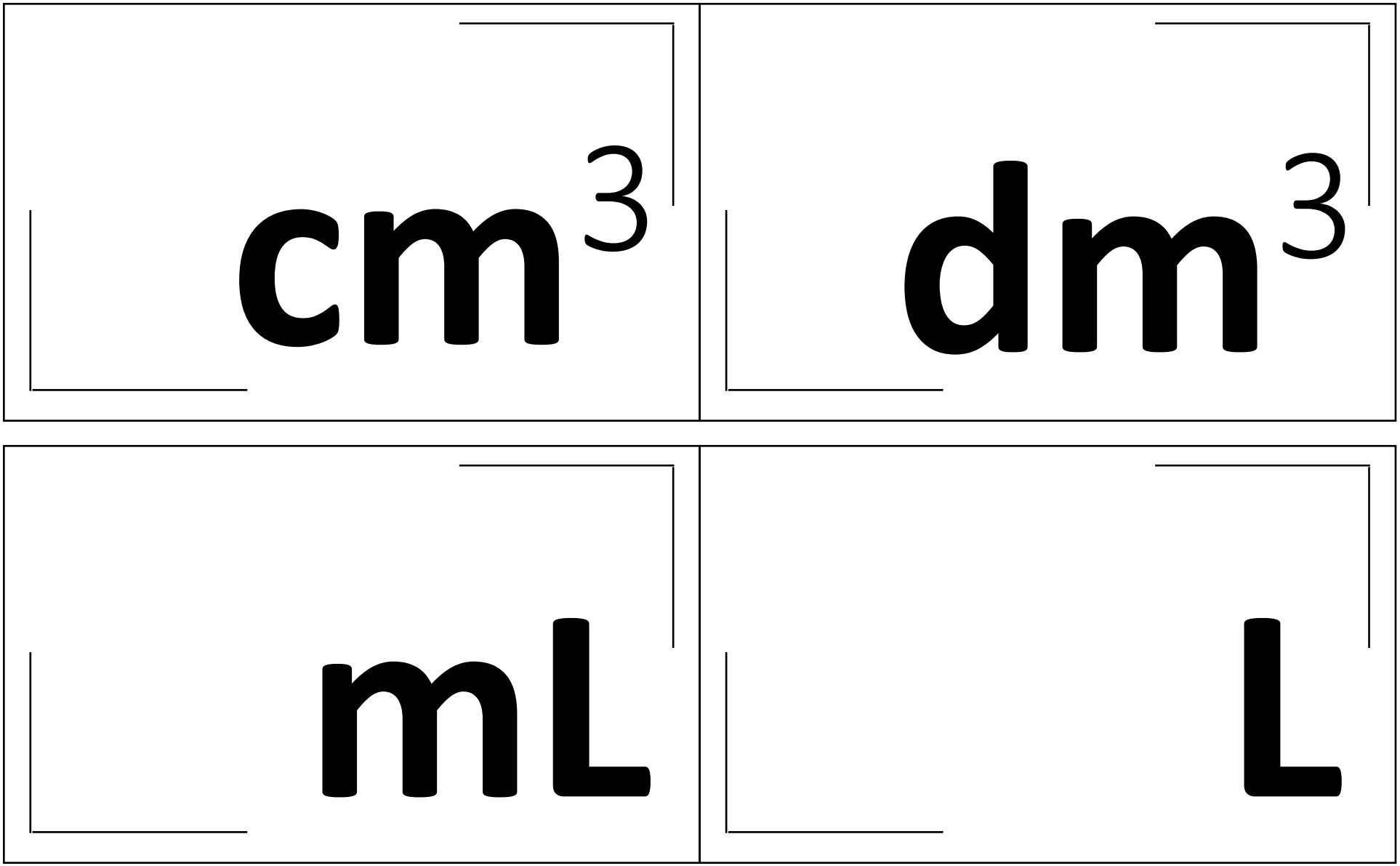
dm

mm

m

cm

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cm3
dm3
mL
L

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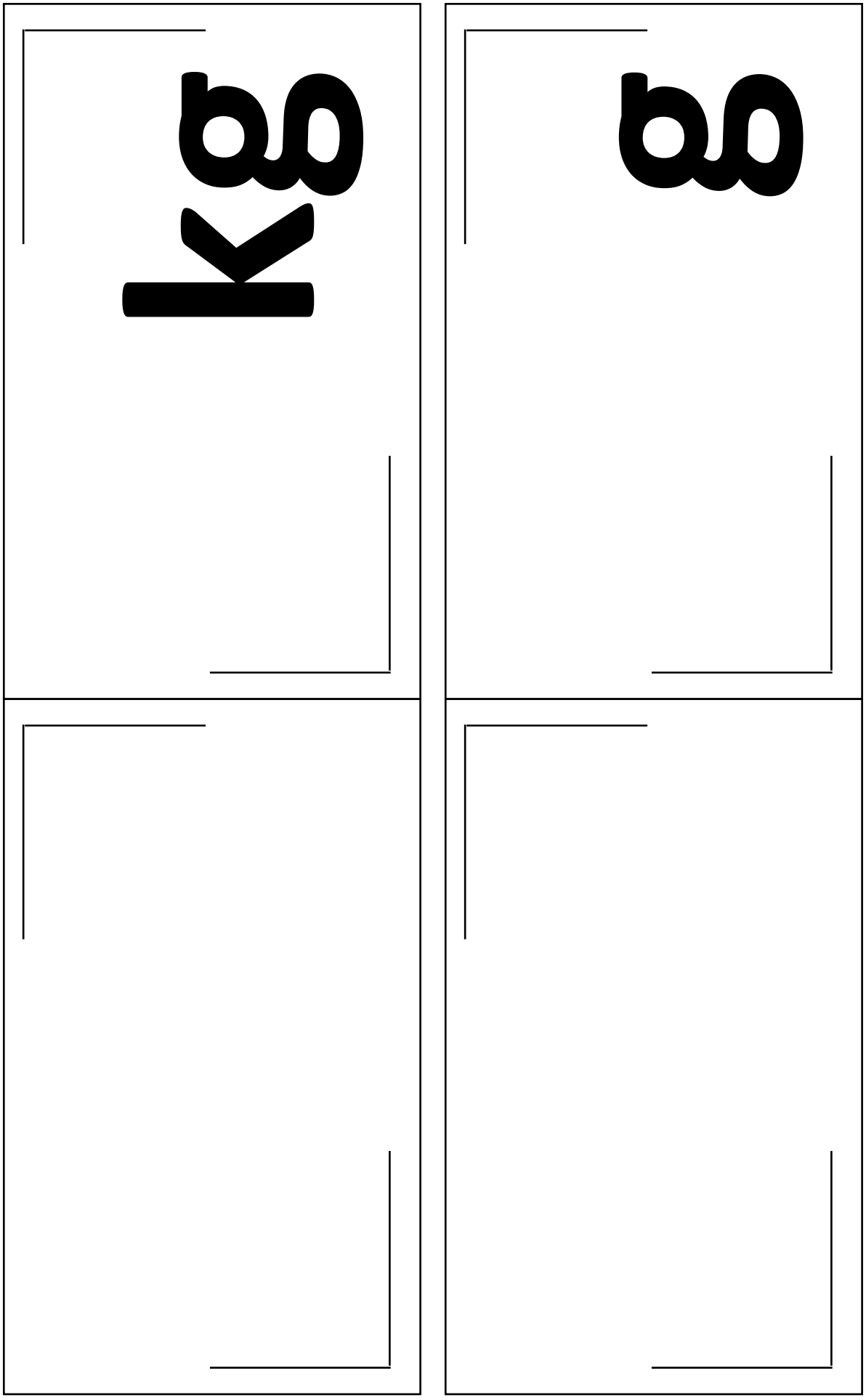
m^3

m^2

cm^2

dm^2

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kg
g

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Resources - SI Prefixes



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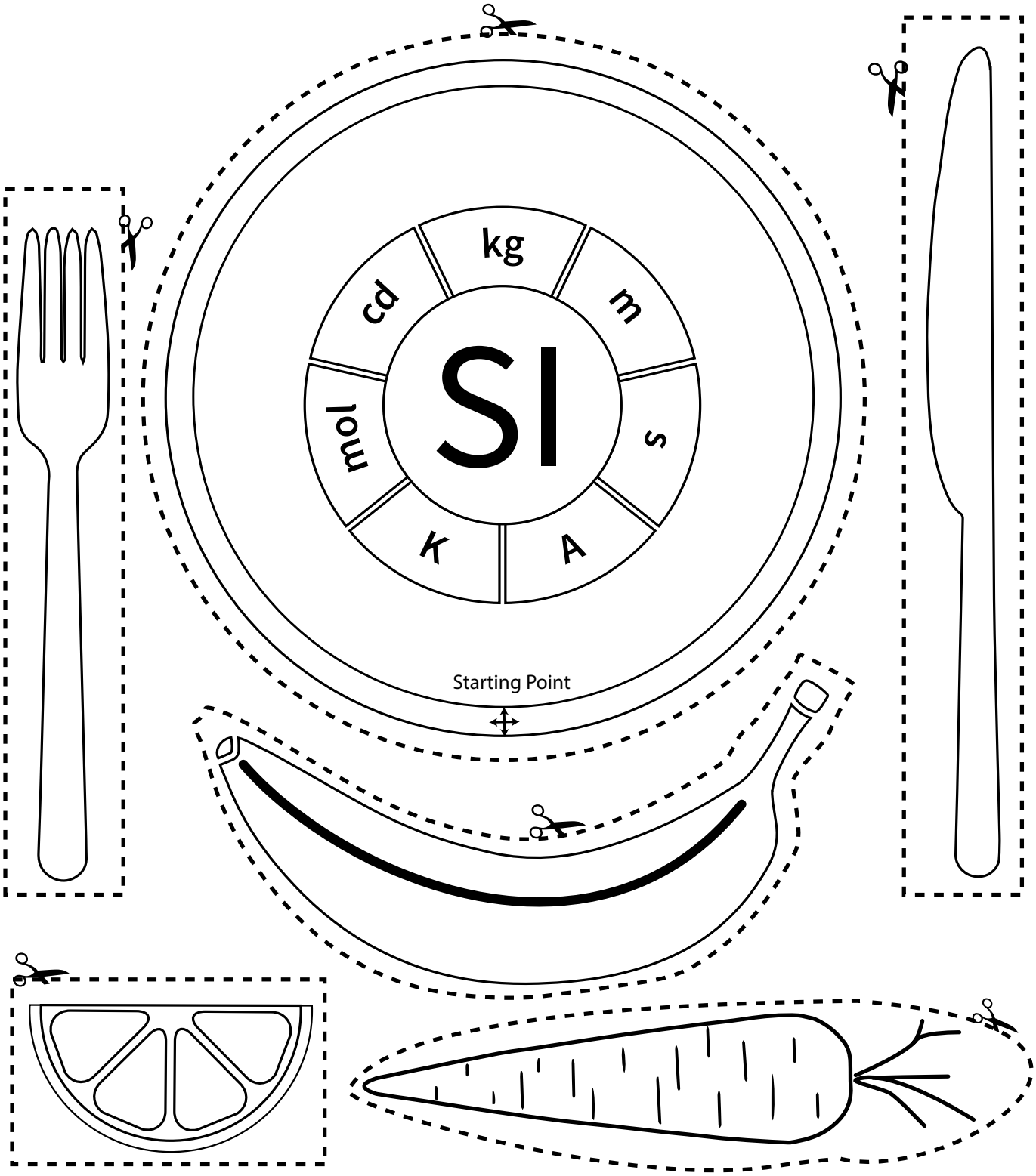
FACTOR	NAME	SYMBOL	MULTIPLYING FACTOR
10^{30}	quetta	Q	1 000 000 000 000 000 000 000 000 000
10^{27}	ronna	R	1 000 000 000 000 000 000 000 000
10^{24}	yotta	Y	1 000 000 000 000 000 000 000 000
10^{21}	zetta	Z	1 000 000 000 000 000 000 000
10^{18}	exa	E	1 000 000 000 000 000 000
10^{15}	peta	P	1 000 000 000 000 000
10^{12}	tera	T	1 000 000 000 000
10^{9}	giga	G	1 000 000 000
10^{6}	mega	M	1 000 000
10^{3}	kilo	k	1 000
10^{2}	hecto	h	100
10^{1}	deka	da	10
10^{-1}	deci	d	0.1
10^{-2}	centi	c	0.01
10^{-3}	milli	m	0.001
10^{-6}	micro	µ	0.000 001
10^{-9}	nano	n	0.000 000 001
10^{-12}	pico	p	0.000 000 000 001
10^{-15}	femto	f	0.000 000 000 000 001
10^{-18}	atto	a	0.000 000 000 000 000 001
10^{-21}	zepto	z	0.000 000 000 000 000 000 001
10^{-24}	yocto	y	0.000 000 000 000 000 000 000 001
10^{-27}	ronto	r	0.000 000 000 000 000 000 000 000 001
10^{-30}	quecto	q	0.000 000 000 000 000 000 000 000 000 001

For more information: https://www.nist.gov/pml/owm/metric-si-prefixes

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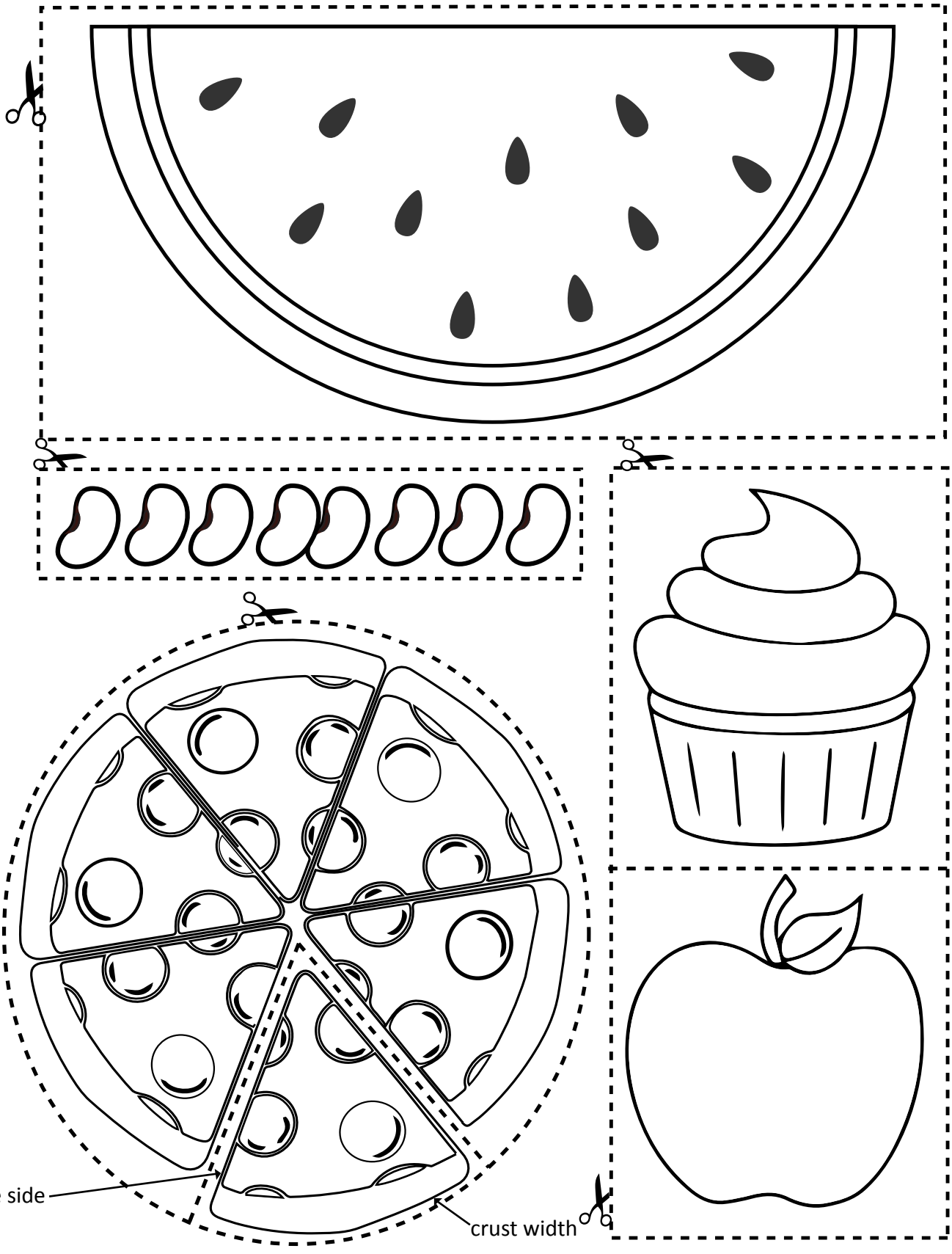
Resources - Metric Meal

- Print one sided.
- Use scissors to cut around the dotted lines around each object.



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Resources - Metric Meal



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Resources - Job Aid (English)

Reference Points:



Plastic Cube

= 1 cm^2
= 1 mL
= 1 g



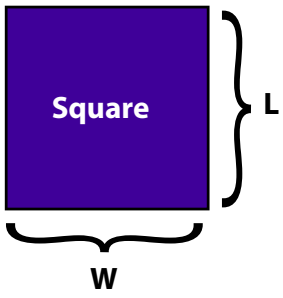
= 500 mL
= 0.5 L
= 500 g



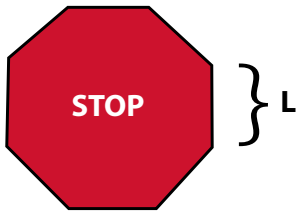
= 1000 mL
= 1 L
= 1000 g
= 1 kg

Formulas:

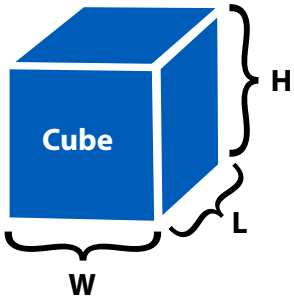
Area = L x W



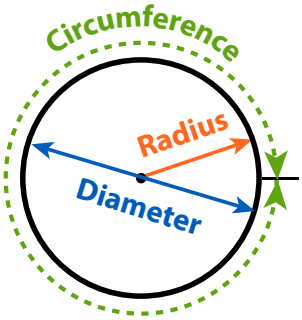
Perimeter = # of sections x L



Volume = L x W x H



Circumference = 3.1416 x D



Vocabulary: Basic definitions

Area: The size of a surface. The amount of space inside the boundary of flat shape or the surface of an object. Measured in square units.

Circumference: The distance around the edge of a circle (or any curvy shape). A type of perimeter.

Diameter: Any straight line segment between two points on the circumference of a circle that passes through the center of the circle. Twice the length of the radius of a circle.

Radius: Any straight-line segment between the center of a circle or sphere to a point on the boundary of the circle or sphere. Half the length of the diameter of a circle.

Perimeter: The continuous line forming the boundary of a closed geometric figure.

Volume: The amount of space inside a three-dimensional object. Measured in cubic units.

www.nist.gov/pml/owm/circumference-area-and-volume

Resources - Job Aid (Spanish)

Recursos - Ayuda de Trabajo (español)

Puntos de Referencia:



Cubo de plástico

= 1 cm^2

= 1 mL

= 1 g



= 500 mL

= 0.5 L

= 500 g



= 1000 mL

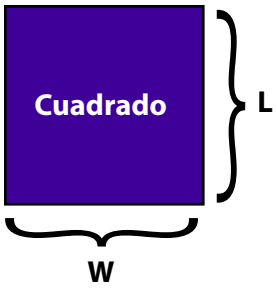
= 1 L

= 1000 g

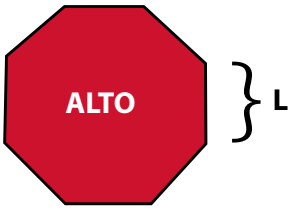
= 1 kg

Fórmulas:

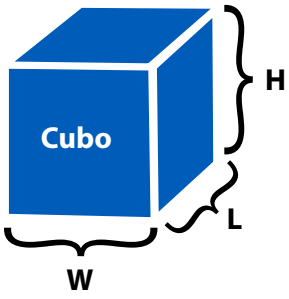
Área = L x W



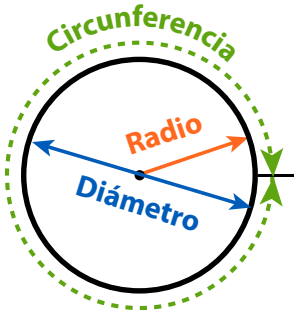
Perímetro = de # secciones x L



Volumen = L x W x H



Circunferencia = 3.1416 x D



Vocabulario: Definiciones básicas

Área: El tamaño de una superficie. La cantidad de espacio dentro del límite de una forma plana o la superficie de un objeto. Se mide en unidades cuadradas.

Circunferencia: La distancia alrededor del borde de un círculo (o cualquier forma curva). Un tipo de perímetro.

Diámetro: Cualquier segmento de línea recta entre dos puntos de la circunferencia de un círculo que pase por el centro del círculo. El doble de la longitud del radio de un círculo.

Radio: Cualquier segmento de línea recta entre el centro de un círculo o esfera y un punto en el límite del círculo o esfera. La mitad de la longitud del diámetro de un círculo.

Perímetro: Línea continua que forma el límite de una figura geométrica cerrada.

Volumen: La cantidad de espacio dentro de un objecto tridimensional. Se mide en unidades cúbicas.

www.nist.gov/pml/owm/circumference-area-and-volume

Resources - Vocabulary Words



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Communication skills are essential during the activity. Participants will apply technical vocabulary during gameplay, discussions, and written feedback to build Language Arts reading and writing proficiency. Some participants may have prior experience with math and science vocabulary, while others may be new to it. For example, the term "Metrology," the science of measurement, is often confused with "Meteorology," the science of weather. Metrology is used in within meteorology, including temperature, barometric pressure, wind speed, rain and snow depth, and hail diameter measurements.

Area – The size of a surface. The amount of space inside the boundary of a flat shape or the surface of an object. Measured in square units.

Capacity – The maximum amount that an object can contain. Measured in cubic units.

Circumference – The distance around the edge of a circle (or any curvy shape). A type of perimeter.

Diameter – Any straight-line segment between two points on the circumference of a circle that passes through the center of the circle. Twice the length of the radius of a circle.

Estimation – A rough approximation of value, number, or quantity.

International System of Units – The dominant measurement system used in science and international commerce, abbreviated SI (from the French Le Système International d'Unités). Also known as the metric system of measurement.

Metrology – The science of measurement.

Measure – To determine the dimension, quantity, or capacity.

Radius – Any straight-line segment between the center of a circle or sphere to a point on the boundary of the circle or sphere. Half the length of the diameter of a circle.

Scale – Graduated range of intervals.

Magnitude – Size or extent of an object.

Perimeter – The continuous line forming the boundary of a closed geometric figure. The perimeter of a circle is called its circumference.

Quantity – A measurable amount, characteristic, or property of an object or collection of objects.

Volume – The measurement of the amount of space occupied inside the three-dimensional space. Measured in cubic units.

Resources - NIST QR Codes



NIST OFFICE OF WEIGHTS AND MEASURES



Everyday Estimation



SI Units



SI Prefixes



Meet the Constants



Writing with the SI



SI Relationships Poster
(SP 1247)



SI Units Card Deck
(SP 1297)



The International System
of Units (SI)
(SP 330)



Metric Program



National Metric Week
(10 October)



SI Training Program
Free Professional Development



Calendar of Events



Teach the New SI



SI Redefinition



Metric Kitchen



Education

The End