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Squeeze the Numbers: A Lemonade Math Investigation

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by Elizabeth McClenaghan

"Cooking requires confident judgment and quick experimentation, not rigid adherence to strict math, but mathematics forms the backbone of the recipes we follow." — Unknown

Introduction and Rationale

Student Demographics

With twenty-five years of experience teaching grades 4–8, I have dedicated my career to advancing equitable, engaging, and rigorous mathematics instruction. My teaching journey began in Columbus, Ohio, where I taught middle school mathematics, and has since extended across urban public and charter schools in Ohio, Kansas, Missouri, and Delaware. Throughout my career, I have served as an elementary teacher, a middle school teacher of mathematics, science, and social studies, an instructional coach, and an interventionist. These experiences have provided me with a strong understanding of diverse student learning needs and the importance of designing instruction that is both meaningful and accessible.

I joined Skyline Middle School in the Red Clay Consolidated School District in 2018, where I taught 7th-grade general and Honors Mathematics. I currently teach 8th Grade Pre-Algebra, Algebra I, and Geometry. Skyline Middle School serves approximately 400 students, with 53% identifying as African American, 25% Hispanic or Latino, and the remaining students identifying as Caucasian or Asian American. Within our population, 35% of students have an Individual Education Plan (IEP) on file for special education services in math and/or reading. Many students come from low-income households and perform below grade level academically. According to the 2024–2025 Smarter Balanced assessment, only 12.28% of students demonstrated proficiency in mathematics, while i-Ready diagnostic data indicate that 63% of students are performing two or more grade levels below proficiency.

My unit aligns closely with several Common Core State Standards, particularly in Ratios and Proportional Relationships and The Number System. Students address standards, including CCSS.MATH.CONTENT.6.RP.A.1–3 by understanding ratios, unit rates, and solving real-world ratio problems.

The activities also support CCSS.MATH.CONTENT.7.RP.A.1–3, as students recognize and represent proportional relationships and solve multistep ratio and percent problems. Fraction and decimal operations align with CCSS.MATH.CONTENT.6.NS.A.1 and 6.NS.B.3, while real-world problem solving connects to CCSS.MATH.CONTENT.7.EE.B.3–4. Additionally, the unit incorporates the Standards for Mathematical Practice by encouraging students to model with mathematics, attend to precision, construct viable arguments, and persevere in solving problems.

This unit develops students' understanding of fractions, ratios, proportions, unit rates, measurement, and real-world problem solving through hands-on cooking and lemonade-based investigations. Students practice scaling recipes, solving missing-value proportion problems, comparing equivalent ratios, analyzing unit rates, and interpreting mathematical relationships using tables, graphs, tape diagrams, and equations. Throughout the unit, students strengthen mathematical communication, reasoning, estimation, and precision while applying mathematics in authentic contexts such as recipe adjustments, financial literacy, and business planning.

The progression of student learning throughout this unit is intentionally designed to move students from a foundational understanding of ratios and proportions toward deeper application, analysis, and real-world problem solving. Students begin with the Sweetness Scale Experiment, in which they develop an introductory understanding of ratios by comparing sugar-to-lemon ratios across different lemonade recipes. Through hands-on investigations, students learn to recognize equivalent ratios, interpret proportional relationships, and analyze how changes in quantities affect outcomes. By using ratio tables, graphs, and visual models, students build conceptual understanding in a meaningful and engaging context.

As students gain confidence, they transition into more collaborative, problem-solving-focused activities such as Ratio Relay and Mix It Up! In Ratio Relay, students apply their understanding of proportions to solve real-world problems on task cards that involve serving sizes, missing values, and equivalent ratios, while strengthening their communication and teamwork skills. Mix It Up! extends this learning by requiring students to solve incomplete recipe problems using multiple mathematical representations, including tape diagrams, double number lines, equations, and ratio tables. These activities encourage flexibility in thinking and help students compare strategies while deepening procedural fluency and mathematical reasoning.

Students then apply their growing understanding of ratios and proportional reasoning in authentic, real-world contexts through The Ultimate Lemonade Taste Test and the Lemonade Stand Challenge. In The Ultimate Lemonade Taste Test, students design and justify their own lemonade recipes, combining creativity with mathematical precision as they defend their ingredient choices using ratios, proportions, and unit rates. The Lemonade Stand Challenge further extends these concepts by integrating financial literacy and entrepreneurship. Students scale recipes, calculate costs, determine pricing, and analyze profit while maintaining proportional consistency in their recipes. These experiences help students recognize the practical value of mathematics in decision-making and business applications.

The unit culminates with Lemonade Around the World, where students broaden their understanding by exploring how ratios and proportions are used in recipes across different cultures. Students compare ingredient relationships, percentages, and flavor variations in international lemonade-inspired drinks while reflecting on the universal role of mathematics in food preparation and daily life. By the end of the unit, students have progressed from building foundational ratio concepts to applying mathematical reasoning in complex, authentic, and culturally relevant situations that promote both conceptual understanding and real-world connections.

This unit was designed to address these learning gaps through engaging, real-world mathematical experiences that connect directly to students' lives. Mathematics is often approached with anxiety or low confidence, particularly among students who have struggled academically. By integrating food-focused, hands-on activities into instruction, this unit seeks to increase engagement, strengthen conceptual understanding, and help students view mathematics as practical, relevant, and accessible.

Content Objectives

A Brief History of Lemonade

For more than a thousand years, people around the world have enjoyed lemonade made from the simple combination of water, sugar, and lemon juice. Whether it is sweet or tart, pink or yellow, still or sparkling, lemonade has remained a popular drink from ancient civilizations to modern celebrities like Beyoncé.[1] Although the exact origin of lemons was once uncertain, recent research has identified them as a hybrid of sour oranges and citrons. A 2018 study published in the journal *Nature* found fossilized citrus leaves in China's Yunnan province, showing that citrus fruits have existed for nearly 8 million years.[2]

The earliest version of lemonade can be traced back to medieval Egypt, where drinks called Kashkad, made from fermented barley, herbs, and citron, were consumed.[3].[4] Historical writings from the 10th century reveal that Egyptians, particularly the Jewish community in Cairo, drank and traded a sweet, lemon-based beverage called qatarmizat.[5] While citron fruits were known throughout the Mediterranean long before lemons, evidence suggests that lemons themselves did not appear there until the Islamic period. References to lemon trees first appeared in 10th-century Arabic agricultural texts, and later writings by physicians helped spread knowledge of lemons across the Mediterranean.

By the 1600s, lemonade had become fashionable in Europe, especially in Paris. Vendors sold a mixture of sparkling water, lemon juice, and honey from tanks carried on their backs. The drink became so popular that Parisian lemonade sellers formed their own guild, called the Compagnie de Limonadiers.[6] In Britain, advances in carbonation technology by scientists like Joseph Priestley and entrepreneurs like Johann Schweppe helped make fizzy lemonade widely available.[7]

Lemonade eventually spread to America with European immigrants during the 18th century. During the Victorian era, the temperance movement promoted lemonade as a substitute for alcohol. Even the White House embraced the trend when President Rutherford B. Hayes banned alcohol at official events, leading critics to nickname his wife "Lemonade Lucy".[8].[9]

The circus also played a role in the history of lemonade, especially in the rise of pink lemonade during the 19th century. Popular stories claim the drink's color was either the result of cinnamon candies accidentally falling into lemonade or, according to a less appetizing legend, wash water from pink tights used to make a new batch.[10] Regardless of its true origin, pink lemonade became a circus favorite and helped boost sales.

Over time, lemonade has come to symbolize resilience and optimism. Whether served cloudy, clear, fizzy, sweet, or sour, it continues to represent making the best out of difficult situations — the classic idea of turning life's lemons into lemonade.

The Chemistry behind Lemonade

The ingredients in lemonade are deceptively simple: lemon juice, sugar, and water. Despite containing only three primary ingredients, producing the perfect glass of lemonade involves several important chemical and culinary considerations. Which type of lemon juice produces the best flavor? Does the source or composition of the water affect the final product? Does the type of sugar influence sweetness, texture, or solubility? Exploring these questions provides an opportunity to examine how chemistry influences the taste, appearance, and quality of lemonade.

There are more than one hundred species and varieties of lemons grown throughout the world. These generally fall into two categories: true lemons, which are varieties of the *Citrus limon* species, and hybrid lemons, which result from crossing true lemons with other citrus fruits. Several varieties are commonly used for making lemonade. Lisbon lemons, grown primarily in South Asia, are the variety most often found in grocery stores. Eureka lemons, also widely cultivated in South Asia, contain relatively few seeds, making them especially well-suited for juicing. Meyer lemons, originally grown in China, have a rounder shape, thinner skin, and naturally sweeter flavor than traditional lemons. Volkamer lemons are actually a hybrid between citron and mandarin orange. Although they have a flavor similar to Eureka lemons, they are commonly grown in California and valued for their high juice yield.[11]

A lemon consists of three main layers: the flavedo, mesocarp, and endocarp, each serving a unique purpose. The flavedo, commonly known as the zest, is the colorful outer peel that contains essential oils responsible for the lemon's distinctive aroma and flavor. Beneath the flavedo lies the mesocarp, or pith, a thick, white, spongy layer that surrounds and protects the fruit's interior. Rich in carbohydrates and pectin, the mesocarp provides structural support and helps protect the delicate inner tissues.[12]

The endocarp, commonly referred to as the pulp, is the segmented interior of the lemon and accounts for most of its weight. It is composed of wedge-shaped compartments called carpels, which contain both seeds and thousands of tiny juice vesicles. These juice vesicles are elongated, thin-walled cells filled primarily with water, citric acid, sugars, and other dissolved compounds that give lemons their characteristic tart flavor. When the fruit is squeezed, the juice vesicles rupture, releasing lemon juice.[13]

The tart or sour nature of lemons is due to their acidity. An acid is any molecule that can easily lose a hydrogen ion and has a pH level less than 7.[14] The pH scale measures how acidic or alkaline a solution is, ranging from 0 to 14. A pH of 7 is neutral, values below 7 are acidic, and values above 7 are alkaline. Even though the numbers only change by one, each step on the pH scale means the solution is 10 times more or less acidic than the previous one. For example, a substance with a pH of 5 is 10 times more acidic than one with a pH of 6 and 100 times more acidic than one with a pH of 7. Lemons contain a high concentration of citric acid, giving lemon juice a pH of approximately 2 to 3.[15] Even though the pH numbers don't seem very far apart, lemon juice is 10,000 to 100,000 times more acidic than water. That's what gives lemons their strong sour taste.

Acidic foods typically taste sour unless their acidity is balanced by sugar, as in lemonade. Sugar is a general term for a family of naturally occurring compounds in the carbohydrate group.[16] During digestion, many carbohydrates, such as starch, are broken down into glucose, a monosaccharide (simple sugar) commonly known as blood sugar because it circulates through the bloodstream and provides energy to the body's cells.[17]

When two simple sugars bond together, they form a disaccharide, or double sugar.[18] Granulated sugar

(sucrose) is a disaccharide composed of approximately 50% glucose and 50% fructose. Brown sugar has the same chemical composition but retains some of the molasses from the refining process, giving it its characteristic color and flavor. Powdered (confectioners') sugar is finely ground granulated sugar. Because sugar is hygroscopic—meaning it readily absorbs moisture—a small amount of cornstarch is added to powdered sugar to prevent clumping and maintain its fine texture.[19]

Most table sugar is produced from sugar cane, a bamboo-like grass grown in tropical regions. Sugar cane is harvested when it reaches approximately 10 feet in height and about 1 inch in diameter. After harvesting, the stalks are transported to a mill, where they are shredded and pressed to extract the juice. The juice is clarified by adding lime, allowed to settle, and then heated under partial vacuum. This process evaporates water, concentrates the sugar, and promotes crystal formation.[20]

The sugar crystals are separated from the remaining molasses in a centrifuge and then sent to a refinery for further purification. There, the sugar is repeatedly washed, dissolved, boiled, recrystallized, and centrifuged to increase its purity.[21] Once refined, the finished sugar is packaged or distributed to manufacturers for use in a wide variety of food products and beverages.

Bees produce honey to preserve their food supply for times when flowers are scarce. By converting nectar into honey, they create a stable food source that can be stored in the hive, and used when needed. If nectar were stored without this transformation, it would eventually ferment and spoil.[22] Bees rely on two primary food sources obtained from flowers: pollen, which supplies protein, and nectar, which provides carbohydrates. Nectar is a sugar-rich liquid produced by plants, with sucrose as its main carbohydrate. After bees collect nectar, enzymes in their honey stomachs convert the sucrose into the simpler sugars, glucose and fructose. In addition to these sugars, honey contains small amounts of vitamins, minerals, amino acids, enzymes, and plant compounds. The flavor, aroma, and color of honey vary depending on the types of flowers from which the nectar was gathered.[23]

Agave syrup is a sweetener made from the agave plant, a succulent native to the dry regions of Mexico. Its primary components are fructose, glucose, and water, along with small amounts of other carbohydrates, fats, polyols, vitamins, and minerals. The sugars in agave syrup consist of approximately 80% fructose and 20% glucose, making it sweeter than traditional table sugar.[24]

Water, the third ingredient in lemonade, is considered by many to be one of the most remarkable substances found naturally on Earth. It is the only substance that naturally exists in all three states of matter: solid (ice), liquid (water), and gas (steam or water vapor). A water molecule is made up of two hydrogen atoms and one oxygen atom, represented by the chemical formula H_2O . These atoms are connected by covalent bonds, and the water molecules are held together by electrostatic forces because hydrogen has a slightly positive charge and oxygen has a slightly negative charge.[25] Since opposites attract, water molecules are drawn to one another. The slightly positive hydrogen side of one water molecule is attracted to the slightly negative oxygen side of another, forming a special connection called a hydrogen bond. These bonds allow water molecules to stick together and contribute to many of water's unique properties.[26] Water is most commonly observed in its liquid state, but specific conditions determine whether it remains liquid or changes into another state of matter. For water to remain a liquid, its temperature must stay between 32°F and 212°F. When the temperature drops below 32°F, water freezes and becomes solid ice. When the temperature reaches 212°F or higher, water changes into a gas called steam or water vapor. Water covers approximately 80% of Earth's surface and plays a critical role in supporting life and allowing organisms to grow and thrive.[27]

Water has been essential to human civilization since prehistoric times, with early societies settling near rivers,

lakes, and other freshwater sources. When surface water was unavailable, people relied on groundwater obtained through wells. As populations grew, civilizations developed increasingly sophisticated methods for storing and transporting water, beginning with channels carved into sand and rock before progressing to hollow palm trunks, bamboo, clay pipes, wood, and eventually metal.[28] Ancient cultures also recognized the importance of clean drinking water and used methods such as boiling, straining, settling, and filtering through sand and gravel to improve water quality. Greek physician Hippocrates even recommended boiling and straining rainwater through a cloth filter, later known as the "Hippocrates' sleeve," demonstrating one of the earliest documented efforts to protect public health through water treatment.[29]

As towns and cities expanded, providing safe drinking water became increasingly important because contaminated public water supplies contributed to widespread disease. In 1854, Dr. John Snow's investigation of a cholera outbreak in London provided the first convincing evidence that contaminated drinking water could transmit disease, laying the foundation for modern epidemiology.[30] During the late nineteenth century, scientists such as Louis Pasteur and Robert Koch established the germ theory of disease, leading to major improvements in water treatment. Engineers developed more effective filtration systems, including sand filters and chemical coagulation, which significantly reduced harmful bacteria and dramatically lowered cases of cholera and typhoid fever.[31] By the early 1900s, filtration had become a standard practice in many cities throughout Europe and the United States, greatly improving public health.

The most significant advancement in modern water treatment came with the introduction of chlorination in the early twentieth century.[32] In 1804, John Gibb designed the first municipal water system to provide disinfected water to the city of Paisley, Scotland, and cities such as Paris soon adopted large-scale filtration systems using sand and charcoal.[33] However, routine chlorination revolutionized drinking water safety when Jersey City, New Jersey, became the first U.S. city in 1908 to disinfect its public water supply with chlorine. Because chlorination was inexpensive, highly effective, and easy to implement, communities across the country quickly adopted the practice.[34] Combined with filtration, chlorination led to dramatic reductions in typhoid fever and other waterborne diseases and laid the foundation for modern drinking water systems, which are today considered among the safest in the world.

In today's market, several types of drinking water are available, and differentiating between them can be challenging. Tap water is the primary source of drinking and household water for most people in North America and is supplied through public water systems that must meet strict safety standards established by the U.S. Environmental Protection Agency (EPA).[35] The EPA is responsible for setting legal limits on more than 90 contaminants in drinking water. These limits are based on what protects human health while also considering what water systems can achieve using the best available technology.[36] The EPA also establishes water-testing schedules and methods that public water systems must follow. Although the Safe Drinking Water Act (SDWA) allows individual states to set and enforce their own drinking water standards, those standards must meet or exceed the minimum EPA requirements. The EPA's regulations cover chemical contaminants, such as arsenic, lead, copper, and radionuclides, as well as microbial contaminants.[37] Because of these strict guidelines, tap water is tested more frequently than bottled water, making it a safe and affordable drinking option for most communities. For these reasons, tap water is the recommended water source for all activities in this unit.

Other types of drinking water include mineral water, which comes from natural mineral springs and contains minerals such as calcium, magnesium, and iron. Although these minerals may provide health benefits, mineral water is usually more expensive than tap water.[38] Spring or glacier water is another bottled water option that is marketed as coming directly from a natural source. However, it can also be costly and is often less

regulated than tap water. Sparkling water is infused with carbon dioxide, giving it a carbonated, or fizzy, texture. Its popularity increased in the United States in 1976 when Perrier, a French brand of naturally carbonated water, was advertised as a sugar-free alternative to tap water, soda, and fountain drinks.[39] Today, sparkling water is available in a wide variety of flavors, often with natural fruit flavors.

Purified water is tap water or groundwater that has been treated to remove contaminants such as bacteria, fungi, parasites, and other impurities.[40] This can be accomplished through commercial purification processes or by using home filtration systems, such as Brita pitchers or faucet filters, which filter local tap water before it is consumed.

Teaching Strategies

Inquiry-Based Learning: Students investigate, predict, test, analyze, and draw conclusions through hands-on experiments and authentic problem-solving. This approach is incorporated in the Sweetness Scale Experiment, Mix It Up!, The Ultimate Lemonade Taste Test, and Lemonade Stand Challenge, where students explore proportional relationships, evaluate multiple solution strategies, and apply mathematics to real-world decision-making.

Hands-On Learning: Students manipulate ingredients, measure quantities, prepare recipes, and conduct taste tests to make abstract math concepts concrete through activities such as Recipe Remix, Perfect Ratio Investigation, Sweetness Scale Experiment, The Ultimate Lemonade Taste Test, and the Lemonade Stand Challenge. These hands-on experiences allow students to apply fractions, ratios, proportions, measurement, and unit rates in meaningful real-world contexts.

Collaborative & Cooperative Learning: Students work in pairs and groups, participate in discussions, complete relay activities, and collaborate on business proposals through activities such as Ratio Relay, Mix It Up!, The Ultimate Lemonade Taste Test, and the Lemonade Stand Challenge. Cooperative learning structures, including team roles, relay competitions, shared problem-solving, and group decision-making, encourage accountability, communication, and teamwork while students apply mathematical reasoning to real-world challenges.

Real-World Problem Solving: Students use authentic contexts such as cooking, budgeting, shopping, nutrition, and entrepreneurship through activities like Recipe Remix, Sweetness Scale Experiment, The Ultimate Lemonade Taste Test, and the Lemonade Stand Challenge. Students apply skills in fractions, ratios, proportions, measurement, and financial literacy while scaling recipes, analyzing costs, and creating business plans.

Mathematical Discourse: Students explain, justify, compare, and defend their reasoning verbally and in writing, using academic vocabulary through activities such as Perfect Ratio Investigation, Mix It Up!, The Ultimate Lemonade Taste Test, and the Lemonade Stand Challenge. Students communicate their mathematical thinking by explaining recipe choices, defending proportional relationships, comparing results, and supporting business decisions with evidence.

Classroom Activities

Squeeze the Numbers: A Lemonade Math Investigation uses cooking and lemonade-themed investigations to help students apply fractions, ratios, proportions, measurement, and problem-solving skills in authentic contexts. Through collaborative tasks and inquiry-based activities, students strengthen mathematical reasoning while also developing communication, teamwork, and critical thinking skills. When using fresh-squeezed lemon juice, it is recommended to strain the juice through a fine-mesh sieve to remove the pulp. Doing so allows students to focus on differences in flavor rather than texture, which some students may find distracting or unappealing. If lemons are being squeezed by hand rather than with a juicer, rolling them firmly on a hard surface, then microwaving them for approximately 10–15 seconds before juicing, can increase juice yield by softening the fruit and allowing the juice to flow more freely.[41]

Throughout all of the activities, I will circulate among groups, asking probing questions that encourage mathematical discourse and deeper reasoning. Rather than providing answers, I prompt students to explain their thinking, justify why their calculations are reasonable, and clear up any misconceptions. I will conclude each lesson by leading a reflective discussion or administering a brief exit ticket. Students summarize the mathematical strategies they used, explain why proportional consistency is important when modifying recipes, and describe how the skills learned during the lesson apply to everyday situations beyond the classroom.

Activity 1: Recipe Remix

Students begin the unit with *Recipe Remix*, in which they modify recipes by doubling, halving, or tripling, or by adjusting serving sizes for different numbers of people. I begin the lesson by introducing a simple recipe that serves a specific number of people and present a real-world scenario requiring the recipe to be adjusted, such as doubling the recipe for a larger gathering or reducing it for fewer servings. Through guided questioning, I activate students' prior knowledge by asking how ingredient amounts should change and why accurate measurements are important in cooking. I introduce the lesson objective, explaining that mathematicians and chefs use fractions, multiplication, division, and proportional reasoning to maintain the quality of a recipe while changing its yield.

Students examine the recipe card and identify the number of servings, ingredient amounts, and the types of measurements used. They distinguish between whole numbers, fractions, mixed numbers, and decimals and discuss which ingredients may be easiest or most challenging to adjust. Working collaboratively, students make initial predictions about how the ingredient amounts will change when the recipe is scaled.

Next, I assign each group a new serving size, such as doubling, halving, tripling, or adjusting the recipe to serve a different number of people. I model one example of scaling an ingredient using multiple representations, including equations, fraction models, ratio tables, or number lines, before allowing students to work independently or in cooperative groups.

Students calculate the new amount for each ingredient using appropriate fraction operations and proportional reasoning. As they work, they record their calculations, show their mathematical thinking using models and equations, and verify that every ingredient has been adjusted by the same scale factor. Students discuss their strategies with group members, compare different solution methods, and revise any errors they discover through peer discussion.

Once students have completed the recipe modifications, I introduce measurement conversions by reviewing common cooking equivalents, such as cups, tablespoons, and teaspoons. I demonstrate how equivalent measurements can be represented using fractions while maintaining the same quantity.

Students then convert selected ingredient measurements into different units and explain how the numerical values change while the actual quantity remains constant. They use conversion charts, fraction reasoning, and mathematical models to support their work and discuss how measurement conversions are used in real kitchens.

Following the calculations, I facilitate a whole-class discussion in which groups present their scaled recipes and explain the mathematical reasoning behind their solutions. I encourage students to compare multiple strategies, identify similarities and differences among solution methods, and evaluate the efficiency of various approaches. Throughout the discussion, I emphasize academic vocabulary such as *equivalent fractions*, *mixed numbers*, *scaling*, *proportion*, *conversion*, and *unit rate*.

Students actively participate in the discussion by presenting their work, defending their reasoning, asking questions of their classmates, and reflecting on how accurate measurements contribute to successful cooking.

To extend learning, I challenge students to create their own recipes using fractional measurements and exchange them with classmates for scaling practice. Alternatively, I may provide a "Mystery Recipe" activity in which students determine missing ingredient amounts using fraction operations and proportional reasoning. For students ready for additional challenge, I incorporate recipe conversions involving decimals, percentages, unit rates, or ingredient costs.

Activity 2: Ratio Relay

The unit then transitions into a series of cumulative lemonade-themed activities designed to strengthen students' understanding of ratios and proportional reasoning. In *Ratio Relay*, I begin the lesson by reviewing the concepts of ratios, equivalent ratios, unit rates, and proportions using examples from lemonade recipes and ingredient comparisons. I explain that students will participate in a collaborative "Ratio Relay" in which they will solve a series of real-world ratio and proportion problems while working together as a team. Before beginning the relay, I model how to solve one sample problem using multiple representations, such as ratio tables, double number lines, tape diagrams, graphs, and equations, emphasizing that there are often multiple valid solution strategies.

Students are organized into groups of 2 or 3 and receive their first relay task card. Each group reads the problem together, identifies the known and unknown quantities, and determines an appropriate strategy for solving it. Students collaborate to solve problems involving missing values, equivalent ratios, recipe scaling, serving-size adjustments, and multistep proportion situations. As they work, students record their mathematical reasoning using models, equations, and academic vocabulary while discussing and justifying their thinking with teammates.

As groups complete each task, I signal students to rotate to the next relay station or distribute a new task card. During timed relay rounds, I encourage each student to contribute by solving one portion of a problem before passing the work to the next teammate. This structure promotes individual accountability while reinforcing teamwork and mathematical communication.

Students rotate through each relay station, building upon the work of their teammates. After completing each

problem, they explain their reasoning either verbally or in writing, compare their solution strategies with those of other groups, and revise their work, when necessary, based on class discussion or peer feedback.

Following the relay, I facilitate a whole-class discussion in which groups present selected solutions and explain the mathematical reasoning behind their approaches. I encourage students to compare multiple representations, discuss the advantages of different strategies, and identify common misconceptions that arose during the activity. Academic vocabulary, including *ratio*, *proportion*, *equivalent ratios*, *unit rate*, *scale factor*, and *proportional relationship*, is reinforced throughout the discussion. Students actively participate by presenting solutions, asking questions, defending their reasoning, and evaluating the methods used by their classmates.

To extend learning, I invite students to create their own Ratio Relay task cards using original lemonade recipes or authentic real-world scenarios. Students exchange their problems with classmates, solve one another's challenges, and provide constructive feedback on the clarity and accuracy of each task.

Activity 3: Sweetness Scale Experiment

I begin the *Sweetness Scale Experiment* reintroducing the concept of ratios through a discussion of how the balance of ingredients affects the flavor of lemonade. I display several lemonade recipes with different sugar-to-lemon and sugar-to-water ratios and ask students to predict which recipes will taste sweeter, sourer, or more diluted. Through guided questioning, I help students recognize that changing the ratio of ingredients changes the concentration and overall flavor of the lemonade. I explain that they will investigate how proportional relationships influence taste while collecting and analyzing mathematical data.

Students examine the sample recipes and identify the ratios between sugar, lemon juice, and water. Working in small groups, they compare the ingredient amounts and make predictions about the expected flavor of each recipe. Students justify their predictions using ratio language and prior knowledge of proportional relationships before recording their hypotheses.

Next, I provide each group with a set of ingredients and explain the investigation procedures. Students will compare different types of sweeteners, including granulated sugar, simple syrup, brown sugar, honey, and agave syrup. They may also investigate different sources of lemon juice, such as freshly squeezed lemons, bottled lemon juice, lemonade concentrate, or flavored lemon varieties, as well as different types of water, including still, sparkling, flavored, or infused water. Before students begin, I review expectations for safely measuring ingredients, recording observations, and maintaining consistent procedures throughout the investigation.

Students prepare several lemonade samples by following assigned recipes and carefully measuring each ingredient. As they create each mixture, they maintain accurate measurements and record the quantities used. Students observe the appearance of each sample, taste the lemonade when appropriate, and describe the flavor using agreed-upon descriptive terms such as sweeter, sourer, more diluted, or more concentrated. The overall goal is for students to gain an understanding about the impact that changing one ingredient affects the overall ratio and flavor. As students work, I will prompt students to use mathematical evidence to explain whether the recipes remain proportional after ingredient substitutions.

Students organize their results by creating ratio tables, double number lines, graphs, and other visual models to compare the relationships among sugar, lemon juice, and water in each recipe. They analyze how proportional changes affect flavor intensity and determine whether equivalent ratios produce similar taste

profiles, even when different sweeteners or liquids are substituted. Students compare their mathematical models with their observational data to identify patterns and explain how ratios influence the consistency of the lemonade. Students actively participate by presenting their data, defending their conclusions, comparing solution strategies with classmates, and discussing how proportional reasoning helped explain differences in flavor.

Following the investigation, I facilitate a whole-class discussion in which students share their findings and compare the results of different ingredient combinations. I guide students in identifying trends across the class data and encourage them to evaluate whether their original predictions were supported by the evidence. Throughout the discussion, I continue to reinforce academic vocabulary, while encouraging students to explain their reasoning using mathematical representations and evidence from the investigation

Activity 4: Mix It Up!

I begin the *Mix It Up!* activity by reviewing the concepts of ratios, equivalent ratios, and proportions using examples from lemonade recipes. I explain that students will solve a series of missing-value proportion problems by maintaining the same ingredient ratios while adjusting recipes for different situations. Before students begin working independently, I model a sample problem using several mathematical representations, including a ratio table, tape diagram, double number line, and proportion equation. I emphasize that there are multiple valid strategies for solving proportional reasoning problems and encourage students to select the method that best supports their thinking.

Students examine an incomplete lemonade recipe and identify the known and unknown quantities. Working independently or in collaborative groups, they determine the missing ingredient amounts by applying proportional reasoning and using one or more mathematical models. As they solve each problem, students record their work, explain their reasoning using academic vocabulary, and compare different solution methods with their peers. They verify that the completed recipe maintains equivalent ratios and discuss how proportional relationships preserve the flavor of the lemonade.

Throughout the activity, I guide students to recognize patterns, evaluate the reasonableness of their solutions, and compare multiple representations. I monitor student understanding, provide additional support when needed, and differentiate instruction by providing problems of varying complexity involving whole numbers, fractions, decimals, and mixed numbers.

Once students have successfully completed several missing-value problems, I extend the activity by inviting them to create their own incomplete lemonade recipes. I model how to design a proportion problem by removing one or more ingredient quantities while ensuring that the remaining values maintain equivalent ratios.

Students design original lemonade recipes with missing ingredient amounts and exchange their problems with classmates. They solve one another's challenges using ratio tables, tape diagrams, double number lines, equations, or other appropriate mathematical models. After solving the problems, students explain and justify their reasoning, compare different solution strategies, and provide constructive feedback to their classmates.

To deepen students' understanding of proportional reasoning, I introduce recipe-scaling challenges that require students to adjust recipes for different serving sizes while maintaining the original flavor ratio. I present authentic scenarios, such as preparing lemonade for a small family gathering, a classroom celebration, or a large community event, and encourage students to consider how changing the scale factor

affects every ingredient in the recipe.

Students solve the scaling problems by determining the quantities needed for each new serving size. They work with whole numbers, fractions, decimals, and mixed numbers while applying proportional reasoning to maintain equivalent ratios. As students compare their solutions, they discuss the efficiency of different scaling strategies and explain why each method produces equivalent results.

To further strengthen conceptual understanding, I facilitate an error-analysis activity by presenting completed proportion problems that contain common mathematical mistakes. I encourage students to examine each solution carefully, identify where the reasoning breaks down, and explain why the error occurred. Through guided discussion, I help students recognize common misconceptions and reinforce the importance of using proportional reasoning rather than relying solely on memorized procedures.

Students analyze each incorrect solution, identify the mathematical error, correct the problem, and justify their revised reasoning using appropriate models and representations. They compare their corrections with classmates, discuss alternative approaches, and reflect on how identifying mistakes strengthens their own understanding of proportional relationships.

After students complete the investigation, I bring the class together to discuss their solutions and compare the different strategies used to solve the proportion problems. I encourage students to explain their thinking, ask questions, and justify their answers using mathematical evidence while reinforcing key vocabulary such as *ratio*, *equivalent ratio*, *proportion*, *scale factor*, *unit rate*, and *proportional relationship*. As students share and reflect on their work, they develop a deeper understanding of proportional reasoning, recognize that problems can be solved using multiple strategies, and make connections between recipe modifications and other real-world applications.

Activity 5: Lemonade Around the World

I begin the *Lemonade Around the World* activity by introducing students to the idea that lemonade is prepared differently around the world. I share examples of lemonade-inspired drinks from several countries, such as Limonana, Brazilian Lemonade, Cardamom Sharbat, and French Lemonade, and facilitate a discussion about how ingredients, flavors, and preparation methods vary across cultures. I explain that, although the recipes may differ, each relies on mathematical concepts such as ratios, proportions, and percentages to achieve a balanced flavor. I review the lesson objectives and model how to compare two recipes by examining their ingredient ratios and identifying similarities and differences.

Students work individually or in small groups to research lemonade-inspired beverages from different countries or regions. As they investigate each recipe, they identify the ingredients, record the quantities used, and calculate or compare the ratios and proportions between ingredients. Students organize their findings using tables, charts, or graphic organizers and analyze how the ingredient relationships differ among the recipes.

Throughout the activity, I circulate among the groups, asking guiding questions that encourage students to think critically about the mathematical relationships within each recipe and how cultural preferences influence ingredient choices. I support students as they compare ratios, identify equivalent proportions, and explain how changes in ingredient amounts affect the overall recipe.

After students complete their research, they present their research, compare recipe ratios, ask questions, and

reflect on the similarities and differences they discovered. As a class, we discuss how mathematics is used around the world to create recipes that reflect local ingredients and cultural traditions.

To extend the lesson, I invite students to modify one of the international recipes by scaling it to serve a different number of people while maintaining the original proportions. Students calculate the new ingredient amounts, explain their mathematical reasoning, and compare their scaled recipes with those of their classmates. I conclude the lesson with a brief reflection or exit ticket in which students summarize what they learned about proportional reasoning and describe how mathematics can be used to explore cultural traditions through food.

The *Ultimate Lemonade Taste Test* begins by explaining that students will apply everything they have learned about ratios and proportional reasoning to design their own lemonade recipe. I will review the importance of maintaining balanced ingredient ratios while allowing students the freedom to experiment with different combinations of lemon juice, water, sugar, and optional flavorings. Before students begin, I model how changing one ingredient affects the overall ratio and flavor profile, emphasizing the importance of recording accurate measurements and mathematical reasoning throughout the investigation.

Students work in small groups to design an original lemonade recipe. They measure ingredients carefully, record the quantities used, and adjust their recipes as needed to create the flavor they believe is most appealing. As they experiment, students use ratios, proportions, ratio tables, equations, and unit rates to ensure their recipes remain mathematically balanced while documenting any changes they make during the process.

Once students have finalized their recipes, I facilitate a class taste test in which students evaluate each lemonade recipe using agreed-upon criteria such as sweetness, sourness, balance, and overall appeal. I guide students in collecting and organizing the class results using tables, graphs, or spreadsheets and model how to analyze the data by calculating measures of central tendency, including the mean, median, and mode.

I have students plan and organize a lemonade taste test for the remaining students in their grade level. Students present their original lemonade recipes for their peers to sample and collect feedback using a rating form that evaluates sweetness, sourness, balance, and overall appeal. After the taste test, I guide students in organizing the data into tables and graphs and analyzing the results by identifying trends and calculating measures of center. Students use the data to determine which recipes were most successful, compare the results with their original predictions, and reflect on how ingredient ratios influenced the flavor and overall appeal of each lemonade recipe.

I introduce the *Lemonade Stand Challenge* as the culminating performance task for the unit, explaining that students will apply their understanding of ratios, proportions, financial literacy, and entrepreneurship to develop a complete lemonade business proposal. I review the project expectations, assessment criteria, and timeline before modeling how mathematical reasoning supports business decisions such as scaling recipes, calculating costs, and setting prices.

Students work in collaborative teams to develop their lemonade business. They begin by analyzing the taste test data collected in the previous activity to identify the flavor profiles that were most successful. Using this feedback, teams refine their original lemonade recipe or create a new recipe by selecting ingredient combinations that produce a consistent flavor while maintaining proportional relationships. Students use the taste test results and supporting data to justify their recipe decisions before developing a business identity by choosing a company name, designing a logo, and creating promotional materials that reflect their product.

As students develop their business plans, I guide them through scaling their recipes to meet different levels of customer demand while maintaining equivalent ratios. I model how ratio tables, double number lines, equations, and other mathematical representations can be used to justify ingredient quantities for larger or smaller batches. Students use proportional reasoning to determine the quantities of lemons, sugar, water, and other ingredients needed for different batch sizes. They explain and justify their calculations using multiple mathematical models and demonstrate how maintaining equivalent ratios ensures a consistent product.

Next, I guide students through the financial planning portion of the project by providing ingredient prices and modeling how to calculate production costs, cost per serving, selling prices, projected revenue, expenses, and profit. I encourage students to use mathematical evidence to support their pricing decisions while considering realistic business scenarios. Students calculate the total cost of producing their lemonade, determine unit rates such as cost per serving, establish selling prices, and analyze projected profits under different sales scenarios. Students can consider that high prices will generate a higher profit, however, could lead to less sales, whereas a low price could lead to less profit but more sales. They use their calculations to make informed business decisions and explain how mathematics supports budgeting and pricing.

To conclude the project, teams will share their business proposals with the class. I encourage students to explain and defend their recipe choices, scaling strategies, pricing decisions, marketing plans, and projected profits using mathematical reasoning and supporting data. Students ask questions, provide constructive feedback, and evaluate each proposal using established criteria.

As a culminating extension, I may organize a simulated or real lemonade stand in which students apply their business plans by creating advertisements, preparing their lemonade, and selling their product within the school community, when appropriate. Students reflect on how mathematics, science, communication, and entrepreneurship worked together throughout the project and evaluate how proportional reasoning supported every stage of the business process. I conclude the unit with a reflective discussion or written assessment that allows students to synthesize their learning and explain how the mathematical concepts explored throughout the unit connect to authentic, real-world experiences.

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Appendix on Implementing District Standards

Ratios and Proportional Relationships

6.RP.A.1 – Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. Students develop an understanding of ratios through activities such as Perfect Ratio Investigation and Sweetness Scale Experiment, where they compare sugar-to-lemon juice-to-water relationships and describe ingredient combinations using ratio language.

6.RP.A.2 – Understand the concept of a unit rate associated with a ratio. Students calculate unit rates in activities such as Recipe Remix and Lemonade Stand Challenge by determining amounts per serving, cost per cup, and ingredient quantities needed for different batches.

6.RP.A.3 – Use ratio and rate reasoning to solve real-world and mathematical problems. Students apply ratio reasoning in Recipe Remix, Mix It Up!, and The Ultimate Lemonade Taste Test to scale recipes, adjust ingredient amounts, and maintain balanced lemonade mixtures.

7.RP.A.1 – Compute unit rates associated with ratios of fractions. Students work with fractional measurements in Recipe Remix and Lemonade Stand Challenge to determine unit costs, serving sizes, and ingredient rates when adjusting recipes.

7.RP.A.2 – Recognize and represent proportional relationships between quantities. Students identify proportional relationships in Perfect Ratio Investigation, Mix It Up!, and Sweetness Scale Experiment by creating ratio tables, double number lines, and equations to represent ingredient relationships.

7.RP.A.3 – Use proportional relationships to solve multistep ratio and percent problems. Students solve multistep problems in Lemonade Stand Challenge by calculating ingredient costs, discounts, profits, and pricing strategies using proportional reasoning.

The Number System

6.NS.A.1 – Interpret and compute quotients of fractions and solve word problems involving division of fractions. Students apply fraction division in Recipe Remix when adjusting serving sizes, converting

measurements, and determining ingredient amounts for different groups.

6.NS.B.3 – Fluently add, subtract, multiply, and divide multi-digit decimals. Students use decimal operations throughout Recipe Remix and Lemonade Stand Challenge to calculate measurements, costs, and profits.

7.NS.A.1 – Apply and extend previous understandings of addition and subtraction to add and subtract rational numbers. Students use rational number operations in Lemonade Stand Challenge when tracking expenses, revenue, and changes in business costs.

7.NS.A.2 – Apply and extend previous understandings of multiplication and division of rational numbers. Students multiply and divide rational numbers in Recipe Remix, Mix It Up!, and Lemonade Stand Challenge to scale recipes and solve real-world measurement problems.

Expressions and Equations

7.EE.B.3 – Solve multi-step real-life and mathematical problems using positive and negative rational numbers. Students solve multistep financial and measurement problems in Lemonade Stand Challenge, including calculating costs, profits, and adjustments to business plans.

7.EE.B.4 – Use variables to represent quantities and solve real-world mathematical problems. Students use variables and equations in Mix It Up! and Perfect Ratio Investigation to determine missing ingredient amounts and represent proportional relationships.

Endnotes

[1] Tatro

[2] Wu, G. A., et.al.

[3] Tatro

[4] History of Lemonade

[5] Tatro

[6] Tatro

[7] Tatro

[8] Tatro

[9] Ewbank

[10] Wikipedia

[11] <https://www.facebook.com/PlantSnap>

- [12] Lemon Parts
- [13] Lemon Parts
- [14] Field
- [15] Still
- [16] Wolke p. 5
- [17] Wolke p. 6
- [18] Wolke p. 6
- [19] Wolke p. 10
- [20] Wolke p. 8
- [21] Wolke p. 8
- [22] US, F. H.
- [23] US, F. H.
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[41] Wolke p. 283

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