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Beyond Ranch: The Science of Mixtures and Solutions with Salad Dressing

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by Beth Sawyer

Introduction

I currently teach grades K–5 STEAM (Science, Technology, Engineering, Arts, and Mathematics) at an urban elementary school in Richmond, Virginia. I also teach 5th grade science classes. This unit, *Beyond Ranch: The Science of Mixtures & Solutions with Salad Dressing*, is designed for my 5th grade students. My students thrive during hands-on investigations and collaborative learning experiences, especially when activities connect to their daily lives. They are often willing to try new foods, ideas, and challenges when they feel ownership over the process, particularly when they have grown or created something themselves. My STEAM classroom is intentionally designed to support inquiry-based learning, with flexible spaces and materials that allow students to work collaboratively through experiments, design challenges, and scientific investigations.

While my students are highly engaged in active learning environments, there are also instructional challenges I hope to address through this unit. Some students struggle with productive collaboration and effective communication during small-group work. To support growth in these areas, I plan to intentionally model cooperative learning strategies, assign clear group roles, and provide sentence stems that help students participate in discussions. Additionally, many students read below grade level, so I intend to incorporate scaffolded reading passages, accessible scientific articles, visual recipes, and supported writing activities that allow all learners to successfully engage with the content. By integrating science, food systems, collaboration, and real-world problem solving, this unit aims to make science both academically rigorous and personally meaningful for my students.

Demographics

Bellevue Elementary School is located in the East End community of Richmond, Virginia, and is one of twenty-five elementary schools within the Richmond Public Schools system. The school is a smaller elementary school serving approximately 200 students in kindergarten through fifth grade. The student population has approximately 70.4% of students identifying as African American, 10.7% as White, 10.2% as multiracial, 6.3%

as Hispanic/Latino, and 1.9% as Asian. The school community includes a range of student needs and backgrounds. Approximately 64.6% of students are identified as economically disadvantaged, 14.6% receive special education services, and 3.4% are identified as English learners.[1]

Rationale

One important aspect of my students' lived experiences is access to healthy and affordable food. Many of the neighborhoods my students come from, including areas of Church Hill in Richmond, VA, can be considered food deserts, where access to fresh produce and affordable grocery options are limited. To help address this, I maintain two hydroponic garden systems at school where students grow lettuce, herbs, and other vegetables throughout the year. At the end of each harvest cycle, we hold a "Salad Celebration" where students harvest, wash, prepare, and eat the produce they have grown themselves. Although students are offered a variety of salad dressing choices, the overwhelming favorite is always ranch dressing. This observation inspired the idea for this unit: using students' interest in food and cooking as an entry point into Virginia's 5th grade science standards on matter, mixtures, and solutions. Because students are often more open to trying unfamiliar foods when they create them independently, this unit will encourage students to experiment with new salad dressing combinations while exploring scientific concepts such as mixtures, solutions, emulsions, ratios, and the physical properties of matter through meaningful, hands-on experiences.

Content

This unit is built around the students taking on the role of a food scientist. Food scientists apply principles of chemistry and engineering to develop, improve, and test food products, ensuring they are safe, nutritious, appealing, and consistent in quality.[2] Throughout this unit, students will think like food scientists as they investigate mixtures and solutions, test ingredients, and use evidence to design and improve a healthy salad dressing.

The scientific content described below extends beyond the expectations of the Virginia Grade 5 Science Standards. It is included to provide teachers with background knowledge about the chemistry of salad dressings and the behavior of mixtures and solutions. A deeper understanding of these concepts will help teachers answer student questions, facilitate meaningful scientific discussions, and increase the rigor of classroom investigations while maintaining age-appropriate instruction.

Food Science

Food science is an interdisciplinary field that combines knowledge from biology, chemistry, engineering, and biochemistry to understand how food is produced, processed, and preserved. Food scientists investigate the physical, chemical, and biological properties of foods to better understand how ingredients interact and how food changes during preparation and storage. They use this knowledge to develop foods that are safe, nutritious, high quality, and sustainable, while also designing innovative packaging that helps maintain freshness and reduce waste.[3]

Food scientists work in many different specialties, each contributing to the development of safe, healthy, and appealing foods. Food microbiologists study microorganisms to help ensure that foods are safe to eat and free from harmful bacteria. Food chemists investigate how ingredients interact and how food changes during cooking, processing, and storage to improve quality and develop new products. Sensory scientists evaluate characteristics such as taste, smell, texture, and appearance to better understand consumer preferences and create foods that are enjoyable to eat. Other food science careers focus on bringing food products to consumers. Food engineers design equipment and systems used to process, package, store, and transport food efficiently and safely. Product development specialists collaborate with scientists, engineers, and marketing professionals to create new foods. Food marketing and sales professionals communicate the features and benefits of food products to manufacturers, retailers, and consumers while helping connect new products to the marketplace.[4]

Mixtures and Solutions

Substances can be mixed together without changes in their physical properties. Components can be combined to form more complex substances known as mixtures and solutions.[5] Matter can be classified as either a pure substance or a mixture. Mixtures consist of two or more substances that retain their chemical identity and individual properties. They can be separated by physical means.[6] They are classified as either homogeneous (uniform throughout, like vinegar) or heterogeneous (uneven, with visibly distinct parts, like a salad).

Salad dressings are generally considered heterogeneous mixtures because their components, such as oil and vinegar, have different physical properties and separate into visible layers. However, when an emulsifying agent such as egg yolk or mustard is added, the ingredients can become more evenly distributed. This process creates an emulsion, in which tiny droplets of one liquid remain suspended throughout another, giving the dressing a more uniform appearance and texture.

A solution is a specific type of mixture. It is a homogeneous mixture where one substance dissolves completely into another, making the composition uniform throughout.[7]

Often, one component of a solution is present at a significantly greater concentration, in which case it is called the solvent. The other components of the solution present in relatively lesser concentrations are called solutes. Sugar is a covalent solid composed of sucrose molecules, $C_{12}H_{22}O_{11}$. When this compound dissolves in water, its molecules become uniformly distributed among the molecules of water:



The subscript “aq” in the equation signifies that the sucrose molecules are solutes and are therefore *individually dispersed* throughout the *aqueous solution* (water is the solvent). Although sucrose molecules are heavier than water molecules, they remain dispersed throughout the solution; gravity does not cause them to “settle out” over time.[8]

Emulsions and Culinary Surfactants (Emulsifiers)

Emulsions occur when two liquids that do not naturally mix are combined to form a more uniform mixture. A common example in salad dressings is olive oil and vinegar, which can be temporarily mixed by shaking. Thorough mixing is essential for dispersing oil throughout a water-based liquid. Although shaking the ingredients in a jar creates a temporary mixture, using a whisk, blender, or food processor produces smaller oil droplets and a more stable mixture. Many emulsions appear white or cloudy because the tiny droplets scatter light, giving the dressing an opaque appearance.[9] Because the two liquids naturally separate over time, ingredients called emulsifiers are often added to help keep the mixture blended for a longer period, creating a smoother and more stable dressing.[10]

Combining oil and water requires energy because the molecules prefer to remain with substances that have similar properties. An emulsifier, also called a surfactant, helps overcome this barrier by allowing the two liquids to mix more effectively. Emulsifiers work at the boundary where the oil and water meet, helping to keep tiny droplets of oil suspended throughout the water-based liquid. This is the same principle that allows dish soap to lift grease from dishes. Many vinaigrette recipes naturally include ingredients that act as emulsifiers, even if they are not identified as such. For example, mustard and garlic contain substances called mucilage, a type of carbohydrate that helps stabilize the emulsion and slows the separation of the oil and vinegar.[11]

Emulsifiers in Salad Dressings

If a vinaigrette is not emulsified with a surfactant, the oil and vinegar will separate. As a result, the lettuce may become coated with oil while the vinegar collects at the bottom of the bowl, creating an uneven flavor and texture. Common kitchen emulsifiers include egg yolks, mustard, honey, and mayonnaise. These ingredients contain molecules with one end that is attracted to water (hydrophilic) and another end that is oil-loving (hydrophobic). By interacting with both liquids, emulsifiers help keep tiny droplets of oil suspended throughout the vinegar, creating a smoother, more stable dressing.[12]

Vinaigrette Ratios

Here's where the students can use their math skills. A basic vinaigrette has one part acid (usually some type of vinegar) and two-three parts of a neutral oil (canola, vegetable, grapeseed, or safflower). A flavored oil (extra-virgin olive oil, nut oils, toasted sesame oil, or pumpkin seed oil) could also be used. Emulsifiers (mustard, mayonnaise, honey, or egg yolk) should be 1/3 of dressing. Once students understand the basic ratios for vinaigrettes, then they can add other flavorings of their choice. Additional flavoring options could include minced shallots, minced garlic, ground spices, and fresh herbs (add just before serving to prevent wilting). Additionally, students should be able to scale their recipes up or down, using multiplication and division to prepare different serving sizes while maintaining the correct ingredient proportions.[13]

Conservation of Mass

Conservation of mass is a law central to chemistry. The principle is that the mass of matter, in a closed system, will always be the same no matter what type of change happens to the matter. Whether it's a change in state, or dissolving, or a chemical reaction, or any combination of these, the amount of mass will not change. The reason for this fundamental law is that the mass of the atoms stays the same during all these changes, and no atoms are gained or lost during any of

these processes—they simply rearrange, whether it be chemical or physical.[14]

When a substance such as salt or sugar dissolves in water, it may appear to disappear, but it is still present in the solution. Dissolving does not destroy or reduce the amount of matter. Instead, the particles of the solute become evenly distributed among the particles of the solvent. Because no atoms are created or lost during this process, the total mass of the system remains unchanged, demonstrating the law of conservation of mass.[15]

Physical Changes in Salad Dressing

Several physical changes occur during the preparation of salad dressings. When oil and vinegar are mixed by whisking or shaking, the liquids are broken into tiny droplets that become temporarily dispersed throughout one another, creating an emulsion. Although the ingredients appear combined, no new substances are formed during this process.[16]

When an emulsion is left undisturbed, the oil and vinegar components gradually separate due to differences in density and the effects of gravity. This separation is a physical change because the original substances remain the same and can still be identified.[17]

The texture and thickness of a salad dressing can also be physically modified by adding ingredients such as chopped herbs, spices, or starches. These additions change the viscosity of the dressing, or how easily it flows, without changing the chemical composition of the ingredients.[18]

The Chemistry of Common Salad Dressing Ingredients

Salad dressings are a subcategory of flavored sauces with more than 20% fat content and less than 30% moisture content.[19] Vinaigrettes are one of the most common types of salad dressings and provide an accessible example of how food chemistry influences everyday products. They are typically made by combining oil with an acidic ingredient, such as vinegar or citrus juice, along with seasonings and other flavoring agents. Because oil and water-based liquids naturally separate, vinaigrettes demonstrate the science of emulsions, which are mixtures where one liquid is dispersed throughout another. Through mixing and the use of emulsifying agents, these ingredients can temporarily combine to create a more uniform dressing with desirable texture, flavor, and appearance.[20]

Vinegar

“Vinegar is a solution of acetic acid and small flavor molecules in water.”[21] Most common commercial vinegars are about 5 percent acetic acid.[22] Acetic acid has a molecular formula most commonly written as CH_3COOH to show its structure as a methyl group attached to a carboxylic acid group.[23] Acetic acid inhibits fermentation and spoilage, extends the shelf life of the dressing, and enhances its flavor.[24]

Vinegar is produced through a two-step biochemical process involving fermentation and oxidation. During the first step, sugars are converted into ethyl alcohol and carbon dioxide through fermentation. In the second step, bacteria convert the ethyl alcohol into acetic acid through oxidation by combining the alcohol with oxygen from the air. This production of acetic acid gives vinegar its characteristic sour taste and acidic properties.[25]

Vinegar adds a unique flavor profile to foods and is often selected for salad dressings based on its specific

taste, aroma, and chemical properties. Common varieties of vinegar are produced from sources such as grapes, apples, malted barley, oats, and rice. Each type retains compounds from its original ingredients, contributing to its distinct flavor and scent. Unlike flavored vinegars, distilled white vinegar is highly purified and does not contain noticeable flavors from fruits or grains. Balsamic vinegar is created by crushing grapes, including both the juice and skins, and allowing the mixture to ferment before aging it in wooden barrels for many years. This aging process produces a thick, dark-colored vinegar with a complex flavor that combines sweetness, acidity, and subtle oak notes.[26]

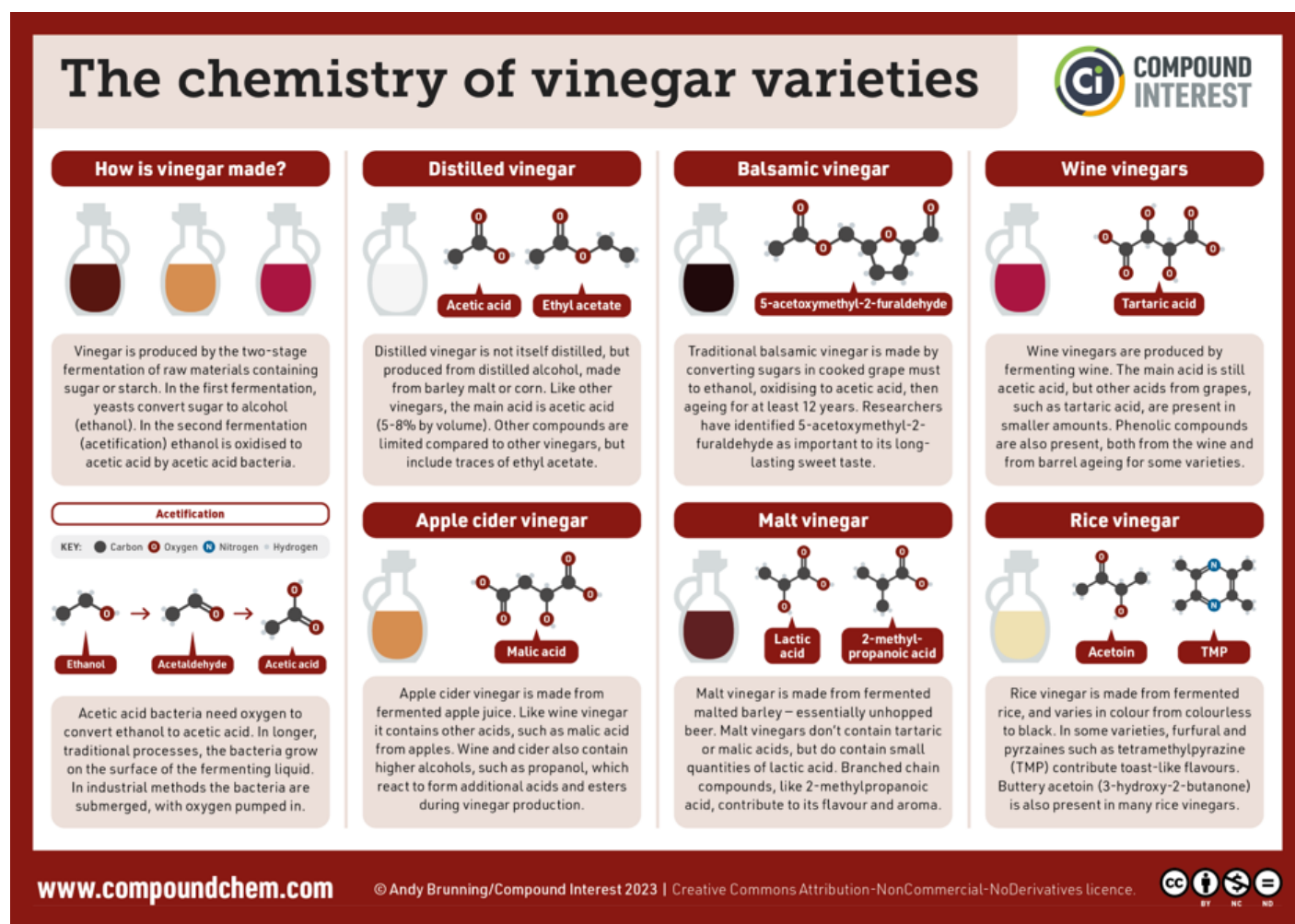


Figure 1: The Chemistry of Vinegar Varieties[27]

Oils and Fats

Oils and fats will float on water, but why? They float because of differences in the structure and properties of their molecules. Water molecules are polar, meaning they have a slightly positive end and a slightly negative end. These opposite charges attract neighboring water molecules, allowing them to form strong interactions and pack closely together. This close arrangement contributes to water's relatively high density. In contrast, oils and fats are made of nonpolar molecules that do not have charged ends and do not form the same strong attractions as water molecules. Their molecules are less tightly packed, making oils and fats less dense than water. Because substances that are less dense than water rise to the surface, oils and fats float when combined with water.[28]

Fats and oils are primarily made of long-chain molecules called fatty acids, which are often connected to glycerol molecules to form structures known as triglycerides. Most of the atoms within fatty acid molecules share electrons evenly, meaning the molecules do not have strong positive or negative charges and are considered nonpolar. Although small areas of these molecules may have slight polarity, the overall structure does not interact well with polar substances like water.[29]

Nonpolar molecules tend to interact with other nonpolar molecules, causing oils to group together when they are placed in water. For example, when drops of oil are added to water, the separate droplets eventually combine into a larger layer of oil on the surface. Because oils do not mix with water or other polar liquids, such as vinegar, they are described as hydrophobic, meaning “water-fearing.”[30]

Making Salad Dressing Healthier

Many commercially produced salad dressings undergo extensive processing and often include additional ingredients such as added sugars, thickeners, starches, preservatives, artificial colors, and flavor additives to improve taste, texture, appearance, and shelf life. Additionally, some dressings marketed as natural may contain common allergens, including soy, wheat, dairy, or eggs, which may make them unsuitable for individuals with certain dietary restrictions or allergies.[31]

By creating our own dressings, we can make healthier choices. Healthier salad dressings can be created by combining simple, nutrient-rich ingredients that add flavor while supporting a balanced diet. Extra virgin olive oil is a popular choice because it contains healthy fats and can enhance the absorption of certain nutrients from vegetables. Other flavorful options include lemon juice and apple cider vinegar, which add acidity and brightness without many calories. Dijon mustard can be paired with olive oil and citrus juice to create a flavorful dressing while also helping stabilize the mixture.[32]

Using a variety of oils, such as avocado oil, can add different flavors and provide sources of beneficial monounsaturated fats. For a creamy dressing alternative, Greek yogurt can replace higher-fat ingredients like mayonnaise or sour cream while still creating a smooth texture when combined with ingredients such as lemon, olive oil, and garlic. Balsamic vinegar can also add sweetness and depth of flavor; when used in moderation and paired with olive oil, it can be part of a nutritious dressing choice. By selecting whole-food ingredients and balancing flavors, students can design salad dressings that are both scientifically interesting and healthier alternatives to many processed options.[33]

Teaching Strategies

Project Based Learning (PBL)

This unit includes the key elements of Gold Standard PBL as identified by PBLWorks.[34] The unit will begin with a real-world challenge of creating appealing, scientifically sound salad dressings that aims to encourage healthier eating habits. Over several weeks, students will conduct investigations on how ingredients mix, why oil and vinegar separate, how emulsifiers work, and how ratios affect taste and texture. The work is grounded in students’ lived experiences, school gardens, and local food access issues within neighborhoods such as Church Hill in Richmond, Virginia.

Students are given voice and choice by having options to choose ingredients, flavors, emulsifiers, branding ideas, and recipe modifications while designing their final dressing products. Students will regularly reflect on both their scientific understanding and their collaboration skills throughout the project. Students will test recipes, gather peer feedback, revise formulas, and improve their products based on scientific observations and taste-testing data. The unit will culminate in a “Salad Celebration” or tasting event where students present their dressings, scientific findings, recipe cards, and marketing ideas to classmates, families, and/or community members.

The 5E Model

The 5E Instructional Model is a widely used framework for planning inquiry-based science instruction. It is grounded in principles of cognitive psychology, constructivist learning theory, and research-based best practices in science education. The model organizes learning into five interconnected phases: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase builds on students' prior knowledge and supports the development of scientific understanding through active investigation and reflection.[35]

The Engage phase captures students' interest, activates their prior knowledge, and introduces a meaningful question or phenomenon that motivates learning. The Explore phase provides opportunities for students to investigate the concept through hands-on experiences, make observations, collect evidence, and begin constructing their own understanding. During the Explain phase, students communicate what they discovered, while the teacher introduces scientific vocabulary, concepts, and explanations that connect to the evidence gathered during exploration. It is important to give the students time to explore before technical vocabulary is introduced. The Elaborate phase extends learning by challenging students to apply their new understanding to different situations, solve problems, make connections, or deepen their investigation. The Evaluate phase allows both the teacher and students to assess understanding and progress toward the learning objectives through formal and informal assessments, reflection, and opportunities to demonstrate learning.[36]

Guiding Questions

Each of my lessons starts with reviewing the overall unit Driving Question and then introducing the Daily Guiding Question to set the learning intention for the day. Beginning each lesson with a clear guiding question helps establish a focused purpose for learning and communicates what students are expected to understand by the end of the lesson. Research by John Hattie identifies teacher clarity as one of the most influential instructional practices for improving student achievement, with an effect size of 0.75.[37] Teacher clarity emphasizes clearly communicating learning goals, defining success criteria, and providing purposeful guidance throughout instruction. By using a guiding question at the start of each lesson, students are encouraged to focus their thinking, make connections between activities and learning objectives, and monitor their progress as they work toward answering the question through investigation and discussion.

Cooperative Groups

For this unit, students will work in cooperative groups of three to four students at each table, with each student assigned a specific role to support productive teamwork.[38] The roles include Materials Manager, Discussion Director, Timekeeper, and Recorder. Each student will wear a laminated clip-on nametag that identifies their assigned role and provides a brief description of their responsibilities. These collaborative roles will have been introduced, modeled, and practiced throughout the school year to help students develop effective communication, problem-solving, and teamwork skills.

The Discussion Director will support meaningful group conversations by using discussion prompts and sentence stems when needed. This student will help ensure that all group members have opportunities to share their ideas, ask questions, and contribute to the investigation. The Recorder will document important observations, ideas, and decisions from group discussions and will share the group's thinking with the class when called upon. The Materials Manager will be responsible for organizing and caring for investigation materials, while the Timekeeper will help the group manage time and stay focused on completing tasks. Together, these roles promote student ownership, accountability, and collaboration throughout the learning process.

Classroom Activities

Unit Daily Outline

Day 1: Overall PBL Driving Question Introduction and "Ingredient Investigators" Activity

Day 2: "The Salad Dressing Mystery: How Particle Properties Affect Salad Dressing"

Day 3: "What's in Your Salad Dressing"

Day 4: "Designing a Better Dressing"

Day 5: "Is it Healthy?" The Nutrition of Salad Ingredients/Reading Nutrition Facts Labels

Days 6-7: "The Food Scientist Recipe Challenge" Research and Recipe Creation

Day 8: "The Salad Celebration" Culminating Event

Unit Introduction: Food Scientists are Ingredient Investigators

To kick off this first activity, the teacher will introduce the goals of the PBL unit and the overall driving question, "How can we use the properties of matter to design and create a healthy salad dressing?" The teacher will also explain the culminating product: Students design, test, revise, and present an original healthy salad dressing recipe. By the end of the unit, they should be able to explain the physical properties of their ingredients, whether their dressing is a mixture or solution, how atoms make up the ingredients, and how matter is conserved when ingredients are combined.

Lesson 1 Ingredient Investigators: Exploring Physical Properties of Matter

To start the lesson, the teacher should introduce the Daily Guiding Question: How can scientists use properties of ingredients to design a successful product?

Engage: The Salad Dressing Challenge

Present the class with a problem: "For our next salad celebration, we need to create a new healthy salad dressing for our classmates. We need to think like food scientists to help design a dressing that tastes good, has the right texture, and uses healthy ingredients." Show students this "Discover Your STEM Career: Food

Scientists” short video describing what a career in food science looks like:

<https://www.youtube.com/watch?v=19vHHFfLB2g>

Explore

Show examples of different types of dressings (oil and vinegar, Italian, ranch, honey mustard). In small collaborative groups, students will measure and observe the ingredients’ color, texture, smell, solubility, and density. They can then discuss: What makes each dressing different? What properties can we observe?

Explain

Students should learn that matter is anything that has mass and takes up space, physical properties help scientists identify substances, and density describes how much matter is packed into a given space.

Elaborate

Students will create an “Ingredient Scientist Profile.” An example of this would be olive oil. The students should describe its physical properties (liquid, low density compared to water, does not dissolve in water). They should also be able to describe its possible role as an ingredient (adds healthy fats and smooth texture).

Evaluate

Ask the students: “Which physical properties would be most important when designing a salad dressing? Explain why.”

Lesson 2 Tiny Ingredients, Big Ideas: How Particle Properties Affect Salad Dressing

The teacher should begin the lesson by introducing the daily guiding question: “How do the tiny particles that make up ingredients influence how they interact when we create a salad dressing?” The standards for this lesson are that matter is composed of atoms and substances have properties that can be used to describe and identify them. Students will be acting as food scientists who need to understand why certain ingredients combine well while others separate when designing a healthy salad dressing.

Engage: The Salad Dressing Mystery

The teacher will display two salad dressings (a homemade oil-and-vinegar dressing that separates into layers and a creamy dressing that stays mixed longer). Students should observe that oil floats on top of vinegar, some ingredients mix easily, and that some ingredients separate. Ask the students: “Why does one dressing separate while another stays together?”

Explore: Investigating Ingredient Interactions

The materials you will need are small cups or jars, measuring spoons and cups, water, vegetable oil/olive oil, vinegar, honey, mustard, and yogurt. The quantities would depend on your class size, but each small group should have enough of each material to combine ingredients and make basic observations. The students should work in small groups to make observations. (Which ingredients combine? Which ingredients separate? Which ingredients help mixtures stay together?)

Explain: Connecting Properties to Particles

Students should learn that the way substances interact depends on the properties of their particles. Explain to students the difference between hydrophilic properties (“water-loving”) and hydrophobic Properties (“water-fearing”). They do not need to memorize these terms, but it is helpful in explaining why some materials mix with water and others do not mix. Students should understand that some substances are attracted to and mix well with water (salt, vinegar, and sugar) and some substances do not mix well with water and tend to separate, like oils and fats.

The teacher should also explain how this connects to atoms. Students should understand that all substances are made of atoms, different substances have different types of atoms and arrangements, and these differences influence observable properties, such as whether ingredients mix or separate.

To help explain the concept, the teacher will have the students complete a particle modeling investigation: “Create a model that explains why oil and vinegar behave differently in a salad dressing.” Students will create particle models using one of the following materials (colored beads, clay, digital drawings, round counters, or paper circles). One possible model example could be water/vinegar (hydrophilic). Students’ models should show evenly distributed particles that can interact with water particles. If students are creating a hydrophobic model like oil, their models should show particles grouping separately from water.

Water & Vinegar (Hydrophilic)



Water & Oil (Hydrophobic)



Figure 2: A visual model representation of hydrophilic and hydrophobic particles.

Evaluate

Students should complete a Claim, Evidence, Reasoning (CER) response. For example: Claim- Oil and vinegar do/do not form a stable solution. Evidence “When I mixed oil and vinegar, I observed...” Reasoning: “The particles in oil and vinegar have different properties. Oil is hydrophobic, while vinegar is hydrophilic, which causes...”

Lesson 3: What's in Your Salad Dressing?

Introduce the guiding question: “How can we tell if a salad dressing is a mixture or a solution?” In this lesson, students will investigate different salad dressings to determine whether they are mixtures or solutions by observing the distribution of materials and explaining how the ingredients are combined.

Engage: Phenomena

Display two clear bottles, one with Italian dressing (oil, vinegar, herbs) and one with vinegar with dissolved salt or sugar (clear). Ask the students, “Both of these are made by mixing ingredients. Why does one look different from the other?” Shake the Italian dressing. Have students make predictions. Will the dressing stay

mixed? Can you see all the ingredients? Which bottle is a mixture? Which might be a solution? Record their predictions.

Explore: Salad Dressing Investigation Stations

For this investigation, you will need to set up four stations (Italian dressing, salt and water, sugar and vinegar, oil and vinegar). The students will visit each station in small groups. The materials you will need are clear cups, Italian dressing, Ranch dressing, oil, vinegar, salt, sugar, water, stir sticks, timers, and magnifying glasses for each station.

Students will travel to each station in their small groups for about 10 minutes each. Directions should be clearly posted at each station. For station 1, the students will observe store-bought Italian dressing. They should observe it before shaking, after shaking for 10 seconds, and five minutes later. They should record answers to the following questions: Can you see different parts? Do ingredients separate? For station 2, the students will start with salt and water in separate cups. Then, they should combine the ingredients and stir until dissolved. Once the students have observed the salt dissolved in water, they should answer the following questions: Can you see the salt? Does it separate after sitting for 5 minutes? In station 3, students are provided with separate cups of sugar and vinegar. Once they combine and stir the ingredients, they should make observations and answer the following questions: Does the sugar disappear? Is the mixture clear? In station 4, students will mix together oil and vinegar and then answer the following questions: Does it stay mixed? What happens after it sits for 5 minutes? A data table (see Figure 3) can be used to help students record and organize their observations. Then they can determine whether they think each substance is a mixture or solution while providing their evidence in the last column.

Salad Dressing Investigation Stations	Can you see different parts?	Does it stay mixed or separate after 5 minutes?	Is it a mixture or solution?	What's your evidence?
1 Italian Dressing				
2 Salt + Water				
3 Sugar + Vinegar				
4 Oil + Vinegar				

Figure 3: Table for the students to record their observations and conclusions during the Salad Dressing Investigation.

Explain: Class Definitions of Mixtures and Solutions

Develop class definitions with the students and record them on chart paper. Characteristics of a mixture could include that materials are combined physically, different parts can often be seen, or that they can often be separated. Have students brainstorm examples of mixtures. Examples could include salad, Italian dressing, or Ranch dressing.

Students should then describe the attributes of solutions. Possible answers might include that one substance dissolves completely and that separate parts cannot be seen. Some examples could include salt water and sugar/vinegar. (The salt can be recovered in its original form by evaporating the water.)

Elaborate: Design a Salad Dressing Challenge

The students will work in small groups to create a salad dressing that contains both a mixture and a solution. Possible ingredients include oil, vinegar, salt, sugar, Italian seasoning, pepper, and mustard. They must explain what parts of their dressing are solutions and what parts are mixtures. (Example: salt dissolves in vinegar = solution, herbs remain visible = mixture) The students will then draw a particle model showing dissolved particles, visible herbs, and an oil layer if applicable.

Evaluate: Exit Ticket

Students will label pictures as mixtures or solutions. Items pictured include Italian dressing, salt water, chocolate chip cookie dough, Kool-Aid, and trail mix.

Extension: Compare Ingredient Labels

Have students compare ingredient labels from different salad dressings. Possible dressings include ranch, Caesar, Italian, or balsamic vinaigrette. Ask the students which ingredients have dissolved, which stay separate, and why do some bottles say "Shake well." Connect this to the idea that shaking creates a temporary emulsion, where tiny droplets of oil are dispersed in vinegar, but they eventually separate because oil and water-based liquids do not naturally mix.

Lesson 4: Designing a Better Dressing**Engage**

Have students observe a small jar of oil and vinegar that have separated. (This will become the control during the upcoming investigation.) Ask students: "Why do you think the ingredients are not mixing?" Review the visuals of hydrophobic and hydrophilic from the first lesson. Then ask, "If you were creating your own salad dressing, how could you keep the oil and vinegar from separating?" Introduce the guiding question: "How could you design a dressing that combines hydrophilic and hydrophobic ingredients?"



Figure 4: Photo of oil and vinegar separated in a jar. *Photo by author.*

Explore

Explain that food scientists often use emulsifiers to help ingredients that normally separate stay mixed. Tell students that today they will investigate whether mustard, tomato paste, or garlic is the more effective emulsifier and use evidence from their investigation to determine which ingredient would make a better salad dressing.

Have students work in small groups. Each group will test one emulsifier and then groups can compare results. Each group will need a small glass jar or other container for mixing ingredients. In each container, the students should add $\frac{1}{2}$ teaspoon of their designated emulsifier. Then, the students should add 1 tablespoon of vinegar, and swirl to fully mix in the emulsifier. Next, have the students add 3 tablespoons of oil. Have them observe the layers of oil and vinegar as they avoid mixing with one another. This is what separation looks like, a process they'll need to be familiar with in order to collect data in the next step.

Instruct students to shake the oil and vinegar in the control glass for 30 seconds. At the end of 30 seconds, have students immediately start a stopwatch and observe the sides of the glass for 1-5 minutes, watching for signs that the oil is separating from the vinegar. Remind students to stop the stopwatch when most of the oil has separated and record the separation time on their data sheet.

Next, direct students to repeat the same procedure for each glass containing an emulsifier. If a mixture has not separated after 5 minutes, instruct students to record "over five minutes" and note the current time on their data sheet. After all emulsifier combinations have been tested, have students revisit any mixtures that had not yet separated. Instruct them to observe each mixture again and record any additional separation that has occurred, including the final separation time, in the appropriate column on their data sheet.

Explain

Bring the class back together and facilitate a whole-class discussion. Ask student groups to share their data and compare the separation times for each emulsifier. Create a class data table on the board or project one so students can identify patterns across the class. Guide students in discussing questions such as: “Which emulsifier produced the most stable emulsion? Did every group get the same results? If not, what variables might have caused differences? Why did the control separate more quickly? and “What does an emulsifier do that oil and vinegar cannot do on their own?”

After students have shared their ideas, review that oil is hydrophobic (repelled by water) while vinegar is hydrophilic (mixes with water). Because these two substances have different properties, they naturally separate. Introduce the idea that an emulsifier contains molecules with both hydrophilic and hydrophobic regions, allowing it to interact with both oil and vinegar. These molecules surround tiny droplets of oil, helping keep them suspended in the vinegar and slowing the separation process.

Evaluate

Conclude by asking students to revisit the guiding question: “How could you design a dressing that combines hydrophilic and hydrophobic ingredients?” Have students use evidence from their investigation to answer in writing using a CER (Claim-Evidence-Reasoning) format:

Claim: Which emulsifier would you recommend for making salad dressing?

Evidence: Use data from your investigation, including separation times.

Reasoning: Explain how emulsifiers help hydrophilic and hydrophobic ingredients remain mixed by interacting with both substances.

Lesson 5: “Is it Healthy?” The Nutrition of Salad Ingredients/Reading Nutrition Facts Labels

Engage

Display two bottles of salad dressing: one creamy ranch dressing and one vinaigrette.

Ask students: “Which dressing do you think is healthier?” “What makes you think that?” “Can you tell if a food is healthy just by looking at it?” Allow students to vote and briefly justify their thinking. Explain that today they will continue their roles as food scientists by using Nutrition Facts labels instead of advertisements or packaging to determine whether a food is a healthy choice.

Explore

Divide students into small groups. Provide each group with Nutrition Facts labels (or actual bottles) for several salad ingredients or dressings. Students analyze each label, recording: serving size, calories, total fat, saturated fat, sodium, sugar, and ingredients.

Explain

Bring the class together to compare rankings. Guide students in discussing: Why is serving size important? Does more fat always mean a food is unhealthy? Why is olive oil considered a healthy fat? Why should we pay attention to sodium and added sugars? Why is the ingredient list important in addition to the Nutrition Facts

label?

Explain that food scientists and consumers use Nutrition Facts labels to make informed decisions. Emphasize that healthy choices involve looking at the whole label and considering nutrients, ingredients, and portion size. Introduce or review terms such as serving size, unsaturated fat, saturated fat, sodium, added sugars, and nutrients.

Elaborate

Tell students they are creating a healthy salad dressing for their upcoming Salad Celebration. Working with a partner, students select ingredients they believe will create a nutritious dressing while also providing good flavor. They must justify each ingredient using information from its Nutrition Facts label. Students will complete a planning sheet that includes ingredients selected, why each ingredient is healthy, evidence from the Nutrition Facts label, and predicted taste.

Evaluate: Exit Ticket

Imagine a friend says, *"This dressing is healthy because the bottle says 'Natural!'"* Using evidence from today's lesson, explain how you would determine whether the dressing is actually a healthy choice. Students should include at least two pieces of evidence from the Nutrition Facts label or ingredient list to support their response.

Lessons 6-7: "The Food Scientist Recipe Challenge" Research and Recipe Creation (2 Days)

Engage

Present the students with the design challenge: "We want to have a healthier salad dressing option for our upcoming Salad Celebration. We need teams of food scientists to design salad dressings that taste good, use nutritious ingredients, and have the right texture. Your team must research ingredients and create a recipe supported by science."

Explore: Ingredient Research Investigation

Students work in design teams to research possible ingredients. Each team investigates ingredients in several categories:

1. Base Ingredients: Provide liquid, flavor, and texture. Examples could include olive oil, avocado oil, vinegar, lemon juice, and yogurt. The students will research the following questions: Is it hydrophobic or hydrophilic? What physical properties does it have? What role does it play in the dressing?
2. Emulsifiers: Help hydrophilic and hydrophobic ingredients stay mixed. Some examples are mustard, egg yolk, honey, Greek yogurt, and mayonnaise.
3. Flavor and Nutrition Ingredients like herbs, garlic, spices, and seeds. Students will investigate: What flavor does it add? Does it change texture? What nutritional benefits does it provide?

The teams will record their research in a Salad Dressing Research Organizer (Figure 5).

Ingredient	Physical Properties	Hydrophilic or Hydrophobic	Purpose in Dressing	Why Did We Choose It?

Figure 5: Salad Dressing Research Organizer

Elaborate

The teams of students will use their research to create a salad dressing recipe with ingredients and quantities. Their recipes must meet certain requirements. Each recipe must include at least one hydrophobic ingredient, at least one hydrophilic ingredient, at least one emulsifier, and at least one ingredient chosen for nutrition.

Evaluate

Students will complete the following statements about their salad dressing recipe: “Our dressing is a mixture because _____. Our emulsifier helps because _____. Our dressing is healthy because _____.”

Lesson 8: “The Salad Celebration” Culminating Event

The students will participate in a Salad Celebration that showcases their learning and authentic application of science concepts. Prior to the event, students will harvest lettuce they have grown in the school's hydroponic gardens and prepare it for serving. During the celebration, students will present the healthy salad dressings they designed, explaining how they applied their understanding of mixtures, solutions, emulsifiers, nutrition, and the engineering design process to create their recipes. Family members, school staff, and community representatives will be invited to sample the salads and dressings while students share the scientific reasoning behind their ingredient choices and reflect on their investigations. Students will also display their laboratory data, design journals, and nutrition analyses to demonstrate how evidence informed their final products. Each student and guest will receive a copy of the class recipe book featuring the student-created salad dressing recipes. This culminating event provides students with an authentic audience for their work while celebrating the integration of science, engineering, health, literacy, and collaboration.

Appendix on Implementing District Standards

The following Virginia 5th grade science standards are aligned with this unit.

5.1 The student will demonstrate an understanding of scientific and engineering practices by

b) planning and carrying out investigations

- plan and conduct investigations to produce data
- identify independent variable, dependent variables, and constants
- determine data that should be collected to answer a testable question

c) interpreting, analyzing, and evaluating data

- organize and represent data in tables and graphs
- read, interpret, and analyze data represented in table and graphs
- use data to evaluate and refine design solutions

d) constructing and critiquing conclusions and explanations

- use evidence (measurements, observations, patterns) to construct or support explanations and to make decisions
- make, support, and evaluate a claim or argument with evidence, data, and/or a model
- describe how scientific ideas apply to design solutions
- generate and compare multiple solutions to problems based on how well they meet the criteria and constraints

f) obtaining, evaluating, and communicating information

- read and comprehend reading-level-appropriate texts and/or other reliable media
- communicate scientific information, design ideas, and/or solutions with others

Matter 5.7 The student will investigate and understand that matter has properties and interactions. Key ideas include

a) matter is composed of atoms;

b) substances can be mixed together without changes in their physical properties; and

From the Virginia Department of Education 5th grade Instructional Guide:

“Matter can be combined in different ways. Sometimes when two or more substances are combined, they do not lose their identifying characteristics. These substances are called mixtures. Mixtures (e.g., soil, sidewalk chalk, sugar water, saltwater, air, trail mix, a mud puddle) can be solids, liquids, or gases (5.7 b). Solutions are a special type of mixture in which one substance is uniformly dissolved in another. Many common solutions (e.g., lemonade, soda) are made by dissolving a substance in water. Air is an example of a gaseous solution and steel is an example of a solid solution (5.7 b). Students are not responsible for the terms solubility, solute, and solvent. Matter is conserved when it is combined (5.7 b).”[39]

Vertical Progression: Students are introduced to solutions in Grade 3 as materials interact with water (3.3). In Grade 6, students further develop their understanding of atoms, as they learn about subatomic particles, compounds, and chemical change (6.5)[40]

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