Curriculum Units by Fellows of the National Initiative
2017 Volume IV: Chemistry of Cooking

Everyday Science of Cooking

Curriculum Unit 17.04.11, published September 2017
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Introduction

My students' are, for the most part, low income. We are about 75% African American and about 75% free and reduced lunch. At our school, K-5 students all attend science one day a week for one hour with a science teacher as part of their schedule. Science is not a focus in the main classroom. I have discovered that with so little time spent on science students are uninterested in science. This is in part due to the lack of time as well as very little, if any, hands-on time to explore the material. The lack of background content knowledge from previous grades inhibits their ability to grasp content at the 5th grade level. With such a short amount of time, the science teacher really only focuses on book work and notes. This lack of exploration time has disinterested students and frustrated the teacher. The district does not emphasize the importance of the sciences. There is no official district wide evaluation process throughout the year. The only science evaluation comes from the state. The state shows their lack of interest in students' science education by testing students in science at the conclusion of only two grades, second and fifth. 5th grade Next Generation Science Standards are also a very difficult set of standards to find explorative lessons for. The large part of the curriculum for 5th grade focuses on our earth systems and our solar system.

We are currently in the process of moving towards the Next Generation Science Standards. In making the switch I would like to incorporate more hands-on/discovery lessons in my classroom 4 days a week. I would also like to collaborate with the science teacher so that he is able to do some of the more hands-on activities in his room and I can do follow up notes and discussions in my class. This may help students to gain interest in science. Also, this unit is something that all students can relate to. We all eat. I would also like to incorporate more hands-on activities that will help students conceptualize the standards. By using a more kinetic and relatable approach, I am hoping that students will re-engage with science and pique their interest and curiosity to probe deeper.

There are not very many women that go into the field of mathematics or science. I feel that many girls in my class would be excited about science if I used cooking as a vehicle to show them how fun it could be. By developing a unit around cooking, it may help the girls bring that information home with them as well. I've learned that when students bring their learning outside of the class they are more interested, their depth of knowledge increases greatly and it helps to generate conversations with friends and family. When students "show off" what they learned in school when they get home, they have truly taken responsibility for their own learning. I have also seen that more parent involvement increases my students' chances of continuing their education. By relating science to something my students already enjoy I may be able to assist them in exploring more about science than they have in the past.

Rationale

There are two main objectives I have for this unit: The first is to renew students' interest in science and the second is to teach students about the scientific process.

To renew students' interest in science, I will be doing a few things; first, I am tying it to something all of my students love, food. In past years, I have done activities around cartography that involve cake. Students have been extremely motivated to learn the material due to the fact that they get to eat the finished projects. With about 75% of our student population on free and reduced lunch, I have found that food is something not easily accessible to them. Secondly, I will be allowing students access to hands-on discovery lessons. In previous years, their science experience has been based around reading a textbook and taking notes. More than half of my students are reading well below grade level. With a science curriculum based on reading a textbook, it is no wonder they are uninterested in the material. The majority of students who are reading below grade level do not have access to the text at all. Introducing them to a more collaborative, discussion based unit will benefit my low readers as well as the rest of the class.

My students do not understand the scientific process. The lack of practice doing hands-on experiments and discovery lessons has excluded them from the scientific process altogether. I believe that science is best learned when students are allowed to make a hypothesis, test it out, share with their peers and then make new predictions based on the experiment. I also want to allow them time to run the experiment again using the new information that they themselves, and their peers, gained from the experiment. The scientific process itself is imperative to understanding what the field of science is all about. My hope is that natural curiosity will spike and students will actively engage with the material.

Finally, I will incorporate a few more demonstrations that show a solid to a liquid, a liquid to a solid, a liquid to a gas, a gas to a liquid, solid to a gas and a gas to a solid. By allowing students the opportunity to make a hypothesis and test it, I will engage all students at every reading level in the scientific process and create a universal design for learning that will give each student access to the material. The main lesson will incorporate an engineering activity. Students will use a half cup of water and design a mold to freeze the water in order to design an ice of any shape to see which shape can last the longest before melting completely.

Content

The unit will focus on changing states of matter. I will introduce three states of matter and show students that science is around us and we use it in our everyday lives. It will include a basic lesson on three states of matter, solid, liquid and gas, which I will demonstrate with water. I will use discovery lessons where students use the scientific method to predict how water can transform from one state to another and if it can change back. The goal here is to have students realize that some matter can go from one state to another and in the case of water be reversed. “Frozen water molecules, when heated up, vibrate until they start to spin. The swiveling motion causes the Mickey-Mouse-shaped particles to break free of their ice crystal home, bump into neighboring molecules and start a chain reaction of melting.”[1]

History of Honeycomb Candy

It is important that the students know a little about the history of the food they are working with. This accomplishes two things. First, cross curricular integration helps to build interest. Secondly, it allows students the opportunity to build curiosity with further investigations.

Sponge candy is popular in some parts of the world and in a few American states, but is an unheard-of treat in other regions. The American version of this crisp, caramelized sugar is often coated with chocolate and it originates from the Buffalo area. But sponge toffee, as it is called in England, is an identical dessert, first mass produced by Britain's Cadbury company.[2]

British Sponge Candy

Sponge toffee and cinder toffee are the terms used to describe the British and Canadian equivalents of American sponge candy. The British started producing sponge candy as early as 1913 in Beamish, a village located in northwestern England's Durham county. Cooks and bakers used copper pans and an open fire when making the earliest forms of British sponge candy.[2]

Cadbury Sponge Candy

Cadbury commercialized the production of sponge candy in 1929, by launching the Crunchie candy bar brand. Cadbury marketed Crunchies in British Commonwealth countries immediately after it appeared in the United Kingdom. In fact, Cadbury first set up operations in Australia in 1922 and, during the second World War, it served as the Australian military's official supplier of candy bars, including the Crunchie.[2]

Buffalo Sponge Candy

Some foodies think of sponge candy as a specialty of Buffalo, NY much like chicken wings. Sponge candy is widely available around the Great Lakes, particularly in New York and Michigan, but it is far less common in other parts of the United States. The modern, commercial form of Buffalo sponge candy dates back to 1985, when the Whitt family opened their candy factory and began producing 30,000 pounds of the caramelized treat and related candies each year.”[2]

The Chemistry of Honeycomb Candy

The carbon dioxide is produced when baking soda (sodium bicarbonate) is added to hot syrup. It is the same process used to make some baked goods rise, except here the bubbles are trapped to form a crisp candy. The holes in the candy make it light and give it a honeycomb appearance.[3]

Adding the sodium bicarbonate ($NaHCO_3$) to the heated sugar mixture causes the bicarbonate of soda to essentially break down and release carbon dioxide. Now the syrupy solution will bubble up at a rapid rate.

Recipe for Honeycomb Candy

Caramelization

Caramelization is the oxidation of sugar, a process used extensively in cooking for the resulting nutty flavor and brown color. Caramelization is a type of non-enzymatic browning reaction. As the process occurs, volatile chemicals are released producing the characteristic caramel flavor. The reaction involves the removal of water (as steam) and the breakdown of the sugar. The caramelization reaction depends on the type of sugar. Sucrose and glucose caramelize around 160 °C (320 °F) and fructose caramelizes at 110 °C (230 °F).[4]

The highest rate of the color development is caused by fructose as caramelization of fructose starts at 110 °C. Baked goods made from honey or fructose syrup will, therefore, give a darker color.

Caramelization of sucrose starts with the melting of the sugar at high temperatures (see below) followed by foaming (boiling). Sucrose first decomposes into glucose and fructose. This is followed by a condensation step, in which the individual sugars lose water and react with each other. Hundreds of new aromatic compounds are formed having a range of complex flavors.

In the case of the caramelization of sucrose, three main product groups are formed: a dehydration product, caramelan $C_{12}H_{18}O_9$; and two polymers, carmelen $C_{36}H_{50}O_{25}$ and caramelin. The average molecular formula for caramelin $C_{125}H_{188}O_{80}$.

Caramelization Products:

$2C_{12}H_{22}O_{11}$ = $4H_2O$ $C_{24}H_{36}O_{18}$ Caramelan

$3C_{12}H_{22}O_{11}$ = $8H_2O$ $C_{36}H_{50}O_{25}$ Caramelen

Continued heating yields caramelin $C_{125}H_{188}O_{80}$

Caramelization continues to be a poorly understood process. Here is an overview:

1. equilibration of anomeric and ring forms
2. sucrose inversion to fructose and glucose

3. condensation
4. intramolecular bonding
5. isomerization of aldoses to ketoses
6. dehydration reactions
7. fragmentation reactions
8. unsaturated polymer formation[4]

Surface Area of Ice

"Solid ice has a melting temperature of 0 degrees C. When an ice cube is placed on a countertop, it will slowly melt and turn into liquid water leaving a small puddle that will eventually evaporate. How fast the ice cube melts depends on a number of factors. Some of these factors include the temperature of the room, air pressure and if there are any air currents moving past the cube."[5]

Denaturing

Next, I will do a lesson on eggs. In this lesson, students will be asked to hypothesize from what state to what state will an egg become if fried. I will then ask students to think about ways to reverse the state of matter. I want students to investigate states of matter that are not easily reversed. This will allow students to discover that the unfolding of proteins is not as easily reversed. I will use hands-on demonstrations to illustrate the point. It will involve unraveling string, tangling it, and asking students to try to put it back together neatly. This type of hands-on, visual representation will help students conceptualize the process in a more concrete way. "Denaturation of proteins involves the disruption and possible destruction of both the secondary and tertiary structures. Since denaturation reactions are not strong enough to break the peptide bonds, the primary structure (sequence of amino acids) remains the same after a denaturation process."[6]

Heat can be used to disrupt hydrogen bonds and nonpolar hydrophobic, tending to repel or fail to mix with water, interactions. This occurs because heat increases the kinetic energy and causes the molecules to vibrate so rapidly and violently that the bonds are disrupted. The proteins in eggs denature and coagulate during cooking. Other foods are cooked to denature the proteins to make it easier for enzymes to digest them. Medical supplies and instruments are sterilized by heating to denature proteins in bacteria and thus destroy the bacteria.[6]

Heat Transfer

Heat can be transferred from one place to another by three methods: conduction in solids, convection of fluids (liquids or gases), and radiation through anything that will allow radiation to pass. The method used to transfer heat is usually the one that is the most efficient. If there is a temperature difference in a system, heat will always move from higher to lower temperatures.[7]

Conduction

Conduction occurs when two objects at different temperatures are in contact with each other. Heat flows from the warmer to the cooler object until they are both at the same temperature. Conduction is the movement of heat through a substance by the collision of molecules. At the place where the two object touch, the faster-moving molecules of the warmer object collide with the slower moving molecules of the cooler object. As they collide, the faster molecules give up some of their energy to the slower molecules. The slower molecules gain more thermal energy and collide with other molecules in the cooler object. This process continues until heat energy from the warmer object spreads throughout the cooler object. Some substances conduct heat more easily than others. Solids are better conductors than liquids, and liquids are better conductors than gases. Metals are very good conductors of heat, while air is a very poor conductor of heat. You experience heat transfer by conduction whenever you touch something that is hotter or colder than your skin e.g. when you wash your hands in warm or cold water.[7]

Convection

In liquids and gases, convection is usually the most efficient way to transfer heat. Convection occurs when warmer areas of a liquid or gas rise to cooler areas in the liquid or gas. As this happens, cooler liquid or gas takes the place of the warmer areas which have risen higher. This cycle results in a continuous circulation pattern and heat is transferred to cooler areas. You see convection when you boil water in a pan. The bubbles of water that rise are the hotter parts of the water rising to the cooler area of water at the top of the pan. You have probably heard the expression "Hot air rises and cool air falls to take its place" - this is a description of convection in our atmosphere. Heat energy is transferred by the circulation of the air.[7]

Radiation

Both conduction and convection require matter to transfer heat. Radiation is a method of heat transfer that does not rely upon any contact between the heat source and the heated object. For example, we feel heat from the sun even though we are not touching it. Heat can be transmitted through empty space by thermal radiation. Thermal radiation (often called infrared radiation) is a type of electromagnetic radiation (or light). Radiation is a form of energy transport consisting of electromagnetic waves traveling at the speed of light. No mass is exchanged and no medium is required.

Objects emit radiation when high energy electrons in a higher atomic level fall down to lower energy levels. The energy lost is emitted as light or electromagnetic radiation. Energy that is absorbed by an atom causes its electrons to "jump" up to higher energy levels. All objects absorb and emit radiation. When the absorption of energy balances the emission of energy, the temperature of an object stays constant. If the absorption of energy is greater than the emission of energy, the temperature of an object rises. If the absorption of energy is less than the emission of energy, the temperature of an object falls.[7]

Three states of Matter

Historically, the states of matter were distinguished based on qualitative differences in their bulk properties. Solid is the state in which matter maintains a fixed volume and shape; liquid is the state in which matter adapts to the shape of its container but varies only slightly in volume; and gas is the state in which matter expands to occupy the volume and shape of its container. Each of these three classical states of matter can transition directly into either of the other two classical states.

Solids

A solid's particles are packed closely together. The forces between the particles are strong enough that the particles cannot move freely; they can only vibrate. As a result, a solid has a stable, definite shape and a definite volume. Solids can only change shape under force, as when broken or cut.

In crystalline solids, particles are packed in a regularly ordered, repeating pattern. There are many different crystal structures, and the same substance can have more than one structure. For example, iron has a body-centered cubic structure at temperatures below 912 °C and a face-centered cubic structure between 912 and 1394 °C. Ice has fifteen known crystal structures, each of which exists at a different temperature and pressure.[8]

A solid can transform into a liquid through melting, and a liquid can transform into a solid through freezing. A solid can also change directly into a gas through a process called sublimation.

Liquids

A liquid is a fluid that conforms to the shape of its container but that retains a nearly constant volume independent of pressure. The volume is definite (does not change) if the temperature and pressure are constant. When a solid is heated above its melting point, it becomes liquid because the pressure is higher than the triple point of the substance. Intermolecular (interatomic or interionic) forces are still important, but the molecules have enough energy to move around, which makes the structure mobile. This means that a liquid is not definite in shape but rather conforms to the shape of its container. Its volume is usually greater than that of its corresponding solid (water is a well-known exception to this rule). The highest temperature at which a particular liquid can exist is called its critical temperature.

A liquid can be converted to a gas through heating at constant pressure to the substance's boiling point or through reduction of pressure at constant temperature. This process of a liquid changing to a gas is called evaporation.

Gases

Gas molecules have either very weak bonds or no bonds at all, so they can move freely and quickly. Because of this, not only will a gas conform to the shape of its container, it will also expand to completely fill the container. Gas molecules have enough kinetic energy that the effect of intermolecular forces is small (or zero, for an ideal gas), and they are spaced very far apart from each other; the typical distance between neighboring molecules is much greater than the size of the molecules themselves.

A gas at a temperature below its critical temperature can also be called a vapor. A vapor can be liquefied through compression without cooling. It can also exist in equilibrium with a liquid (or solid), in which case the gas pressure equals the vapor pressure of the liquid (or solid).

A supercritical fluid (SCF) is a gas whose temperature and pressure are greater than the critical temperature and critical pressure. In this state, the distinction between liquid and gas disappears. A supercritical fluid has the physical properties of a gas, but its high density lends it the properties of a solvent in some cases. This can be useful in several applications. For example, supercritical carbon dioxide is used to extract caffeine in the manufacturing of decaffeinated coffee.[8]

Ice to Water

A solid, ice cube, is in a solid state at -5 degrees C. When the ice is heated the ice particles begin to vibrate. Soon they vibrate so fast that they break free from the crystal lattice that holds them in place, and creates the solid shape, and eventually the lattice breaks completely. It is at this point that the solid structure is broken and you have a liquid.

What is an Engineer?

Engineering is the application of scientific knowledge to solving problems in the real world. While science (physics, chemistry, biology, etc.) allows us to gain an understanding of the World and the Universe, Engineering enables this understanding to come to life through problem solving, designing and building things.[9]

Teaching Strategies

Collaboration in Groups

Students are in groups of four per table. They will each be given a task for each experiment (i.e. Materials monitor, artist, timekeeper, etc.) so that they will all be involved in the process. During each step of the process, they will draw their own conclusions and then discuss them with the group. They will then, using data, come to a conclusion. This information will then be shared out to the class in a whole group discussion. One student from each group will explain the process and conclusions derived from the data.

Inquiry Based

Students will pose claims or hypotheses before the experiment. Then each student will be responsible for using their science notebook to follow the scientific method. This guideline and template (see notebook setup) helps to scaffold the scientific method for students and ensures they are using it. The scientific method is essential so that students can report their findings and then draw conclusions. This made lead students to pose more questions and adjust their experiment accordingly.

Discovery Based

Discovery-based learning is a largely unstructured, situational method or philosophy of teaching whereby students are permitted to find solutions to problems on their own or at their own pace, often jointly in group activities, either independent of or under the guidance of a teacher.[10]

How to Set Up a Science Notebook

Keeping a good science notebook ensures students are following the scientific method. This is a great way to scaffold for students who are unfamiliar with the process completely as well as serving as a great organizational tool for students who are more familiar with the process. Good notes in an organized fashion with pictures is a great reference tool as you move from one day to the next. This works well with experiments or investigations that last days or weeks. It can also be applied to shorter term investigations as well. A good example of this is the engineering of an ice cube and documenting in intervals, such as minutes, the phase change from a solid to a liquid.

The following checklist can be used to assess how well a student is keeping records during science activities. You may consider giving students a copy of the checklist to enable them to monitor themselves through the process.

General information

Question or problem being investigated is stated.

All entries are dated.

Writing conventions (e.g., punctuation, capitalization) are correct.

Presentation is clear.

Observations

Description is very detailed

Description is complete

Illustrations

Drawings are accurate

Drawings are in color

Drawings are labeled

Procedure

List materials used

Sequence steps followed

Communication of data

Graphic/table is complete

Graphic/table is labeled.

Graphic/table is mathematically correct.

Written portions are clear and complete.

Analysis, Argumentation, and Conclusion

Analysis is clear and logical.

Explanations and claims are made using evidence from the data.

New questions, models, or investigations proposed.

Line of Learning

New learning is shared.

New curiosities are shared

Classroom Activities

Honeycomb Candy

PREP TIME:

5 Minutes

DIFFICULTY:

Easy

COOK TIME:

10 Minutes

SERVINGS:

16 Servings

INGREDIENTS

- 1 cup Granulated Sugar
- 1/4 cup Corn Syrup
- 2 Tablespoons Honey
- 1/2 cup Water

- 2 teaspoons Baking Soda

INSTRUCTIONS

Line an 8x8 pan with parchment paper. It doesn’t need to sit neatly in the pan, since the honeycomb candy will weigh it down later.

In a heavy-bottomed saucepan, add sugar and give it a shake so it lays flat in the pan. Add corn syrup, honey, and water, so all of the sugar has been moistened, but do not stir. Turn the heat to medium high, and watch closely as the sugar starts to dissolve and the ingredients start to meld together.

Cook the mixture to 300 ºF, which should take about 5–10 minutes depending on the strength of your stove, then remove the pan from the heat. Whisk in the baking soda for about 5 seconds, and once it has stopped foaming up, immediately pour the mixture onto the parchment paper. Let cool for 1 hour until hardened, then whack the honeycomb with a knife to break into pieces.

Immediately store any uneaten honeycomb in an airtight container, otherwise it will absorb moisture from the air and soften. Enjoy!

Note: Honeycomb will keep for 3–4 days at room temperature in an airtight container.

Three States of Matter Using Water

First, you will explain what the three states of matter are (please see content section). Then you will show the students that water will start out as an ice cube, then melt into water and finally evaporate into a gas. For this activity, you will need some kind a heat source (i.e. burner, induction burner, Bunsen burner), one pan and each student with a science notebook. They will use the science notebook (see content) to practice the scientific process while also learning about the three states of matter.

Designing an Ice Cube and Heat Transference

Teach students first about heat transference (see content); next you will have students design an ice cube in groups where each group gets one cup of liquid water to start. After the groups have designed their ice cube, all groups will compete to see whose ice cube lasts the longest before becoming a liquid. You will have each group make 3 ice cubes and then each group places one of their cubes in the exact same conditions as the other groups. One cube will be subject to each form of heat transference.

After each cube faces all three forms of heat transference, groups will be allowed to meet and redesign another cube based on what they have observed in order to engineer another cube that may hold up better to the heat.

Appendix

This unit touches on a few different standards that our school observes. We are currently using the Next Generation Science Standards at our K-8 school.

PS1.A: Structure and Properties of Matter

Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)

The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)

Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3)

PS1.B: Chemical Reactions

When two or more different substances are mixed, a new substance with different properties may be formed. (5-PS1-4)

No matter what reaction or change in properties occurs, the total weight of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) (5-PS1-2)

Notes

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1. Mosher, Dave. "Inside Look at How Ice Melts." LiveScience. January 07, 2008. Accessed July 14, 2017. https://www.livescience.com/2171-ice-melts.html.
2. "The History of Sponge Candy." EHow. September 18, 2010. Accessed July 15, 2017. http://www.ehow.com/facts_7188208_history-sponge-candy.html.
3. Helmenstine, Ph.D. Anne Marie. "Use Chemistry to Make Honeycomb Candy." ThoughtCo. Accessed July 13, 2017. https://www.thoughtco.com/honeycomb-chemistry-candy-recipe-60
4. What is Caramelization? Accessed July 14, 2017. http://www.scienceofcooking.com/caramelization.htm.
5. The Effect of Surface Area on the Rate of Melting in Ice Cubes. Accessed July 10th , 2017. http://grade9sciencepedagogics.pbworks.com/w/file/fetch/47844626/elodea
6. Denaturation Protein. Accessed July 15, 2017. http://chemistry.elmhurst.edu/vchembook/568denaturation.html.
7. How Does Heat Travel? Accessed July 12, 2017. http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/transfer.html.
8. Boundless. "Three States of Matter - Boundless Open Textbook." Boundless. May 26, 2016. Accessed July 14, 2017. https://www.boundless.com/chemistry/textbooks/boundless-chemistry-textbook/introduction-to-chemistry-1/classification-of-matter-27/three-states-of-matter-178-10543/.
9. "What is Engineering?" What is Engineering. Accessed July 16, 2017. http://whatisengineering.com/.
10. http://www.dictionary.com/browse/discovery-method Accessed July 10, 2017