THE GREAT Iced-Tea Debate

by Jennifer Albert, Margaret Blanchard, Karen Keene, and Jackson Kinton

Have you ever ordered iced tea at a restaurant? Did the server ask if you wanted your tea sweetened or unsweetened? If you order sweetened iced tea in the southern United States, which is know as sweet tea, then it will be sweetened while the tea is still hot and then allowed to cool before ice is added. In other parts of the country, the iced tea is usually served unsweetened, and the server brings packets of sugar to sweeten the tea.

In the lesson described here, a teacher called “Mr. Sweets” uses these regional differences to engage students in a lab on the structure and properties of matter, asking students to help him solve the Great Iced-Tea Debate: What is the best way to sweeten tea?

This article addresses the the *Next Generation Science Standards* (NGSS Lead States 2013) disciplinary core idea PS1.A: Structures and Properties of Matter, specifically the following:

- Substances are made from different types of atoms, which combine with one another in various ways (MS-PS1.1).
- Each pure substance has characteristic physical and chemical properties that can be used to identity it (MS-PS1.2; MS-PS1.3).
- In a liquid, the molecules are constantly in contact with others (MS-PS1.4).

Prior to this activity, it would be helpful if students had already covered topics related to the structure and properties of matter and be familiar with related concepts such as density, boiling point, and pH. Alternately, this lesson could be used as an introduction to solutions.

The following description details how one class of students may enact these steps while trying to solve the Great Iced-Tea Debate.

Mr. Sweets is a middle school science teacher from the Midwest who recently moved to a southern state to teach eighth-grade science. While Mr. Sweets likes to sweeten his tea at room temperature just before he adds the ice and drinks it, he also enjoys it presweetened and has trouble understanding why his colleagues say that there is only one way to make sweetened iced tea (adding the sugar while the tea is hot). Last night at a restaurant, Mr. Sweets ordered sweetened iced tea. He and the waiter had a debate about whether it mattered if the tea was sweetened while it was hot or at room temperature.

Today Mr. Sweets poses this question to his class: "Is there only one real way to make good sweetened ice tea?" Not surprisingly, his students, all of whom grew up with tea sweetened while it was hot, unanimously agree that there is only one way to make sweetened iced tea. Amber speaks up: "Mr. Sweets, you're crazy if

FIGURE 1 **Planning template**

Hypothesis: If cup _____ is southern sweetened iced tea, then ______________________________ is different from cup _____ because ____________________________________.

What you can measure	How you will measure it	Available probes and equipment • pH probe (or pH paper) • Light sensor (or flashlight) • Digital balance • Graduated cylinders • Beakers • Stirring rods • Ice • Plastic bags • Ring stand with clamp
For example: 1. Temperature 2. Density	For example: 1. Temperature probe 2. Graduated cylinder and digital balance	
1.	1.	
2.	2.	
3.	3.	
4.	4.	
5.	5.	

Southern sweet tea	Non-southern sweet tea
• 6 regular tea bags • 8 cups boiling water • 1½ cups sugar Bring eight cups of water to a boil. Add tea bags and cover and steep for 15 minutes. Take out the tea bags. Add sugar and mix thoroughly. Cool to room temperature and serve over ice.	• 6 regular tea bags • 8 cups water • 1½ cups sugar Bring eight cups of water to a boil. Add tea bags and cover and steep for 15 minutes. Take out the tea bags. Cool to room temperature. Add sugar and mix thoroughly. Serve over ice.

Note: The recipe makes ½ gallon and can be scaled to the needs of your class. Students should not eat or drink anything prepared in the lab space.

you think tea tastes the same when you add sugar just before you drink it when it's already cooled to room temperature!" Other students laugh and nod.

Mr. Sweets, still baffled, decides to put his students' opinion to the test. "OK," he says, "then I challenge you to show me how your sweetened iced tea is different from my sweetened iced tea. If the tea tastes different, then there must be at least one thing that is different and measurable. Tomorrow you will start an investigation using what we learned about solutions to study this. Let's let the data do the talking!"

Days 1 and 2: In the lab

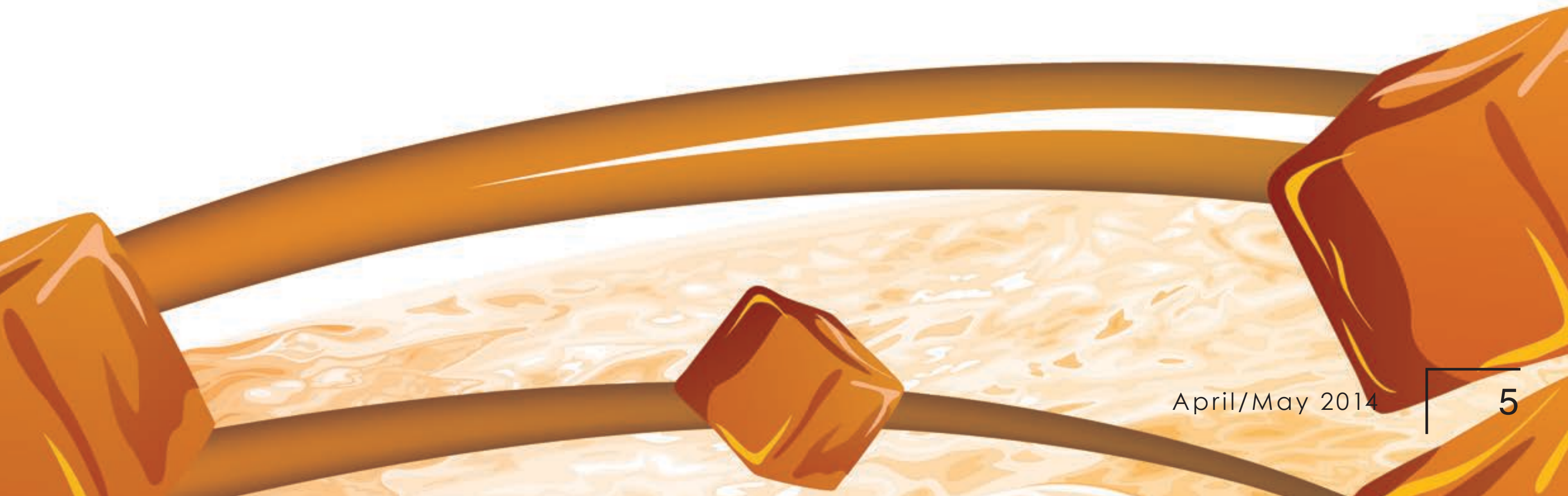
(Note: Splash-resistant goggles and aprons should be worn at all times in the lab and no tea can be drunk.)

Day 1

The next morning, Mr. Sweets greets his students with a tray of clear cups. Half of the cups are marked with the letter *A*, the other half with a *B*. Each student receives an A and a B cup. "We have two solutions," Mr. Sweets tells the class. "Both are tea, but one was sweetened while the tea was hot, and the other was made after the hot water cooled to room temperature. Take a few minutes to make observations about anything you notice that is different about these two solutions, A and B. Please write down all of your observations in your interactive lab notebook and compare your observations to those of your lab partner. Be careful not to spill the tea, and don't drink it." (For more information about using interactive lab notebooks, see Young 2003 or Waldman and Crippen 2009.)

Students excitedly start making observations and writing them in their lab notebooks. (If your students are hesitant, write a few terms, such as *color, particles*, and *light*, on the board to prompt them.) Mr. Sweets walks around the classroom, keeping students on task and asking questions and making comments such as the following to encourage students to make good observations: "So you think the teas are different colors? Do both teas let light through equally?" and "Great idea to hold the cup up to the light near the window to see if you can see particles in the teas and compare how they look!" He tells the class, "Some of you might want to see what you can notice by using natural light from the windows for your observations."

When students finish recording observations, Mr. Sweets informs them that they will be conducting an investigation to detect differences between the two samples of tea. Next he projects the planning template (Figure 1) onto the whiteboard and holds up all of the probes and equipment that will be available for students to use in their investigations (e.g., probes and equipment to measure temperature, light, pH, and conductivity; see full list in Figure 1). Mr. Sweets asks students to complete the planning template, which will help them design an investigation that will answer the



question "Is there a difference between the southern tea, sweetened when the liquid was hot, and the non-southern tea, sweetened when the liquid was room temperature?" Mr. Sweets asks if students have any questions and reminds them that their procedure is due by the end of class. Students spend the rest of the class filling in their planning template and hand the form to Mr. Sweets as they leave.

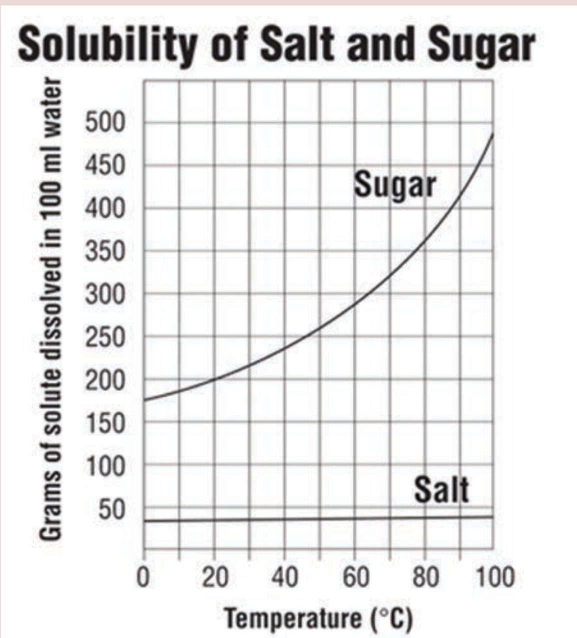
Day 2

Because Mr. Sweets collected students' ideas before they left class, he is able to gather all of the equipment and have it ready for students to conduct their investigations the next day. As students enter the next day Mr. Sweets has cards waiting on their lab desks assigning them to one of four roles in their four-person lab group: recorder, materials expert, facilitator, and data manager. (Students' roles for this investigation were changed from their last investigation, which allows students to take a turn in different roles and performing different duties.) Mr. Sweets passes out students' individual planning template from yesterday, which they glue into their notebooks with a glue stick. He asks members of the group to individually share their hypothesis from yesterday, as well as how they plan to take measurements. The groups must decide on a single hypothesis and receive approval from Mr. Sweets, then collect supplies and conduct their investigation, recording their results in a data table they create in their interactive notebook. (If possible, make sure that each group does something different to create a more lively discussion.)

During this time, Mr. Sweets walks around the classroom, probing groups to think about what they would measure and how they would do so and monitoring progress. Soon all the groups have an approved plan of action and are collecting supplies or conducting investigations. Mr. Sweets continues to walk around the class to make sure everyone is on task and answer questions.

As students finish their investigations, they clean up their tables and return their lab materials. "Before you exit class today," Mr. Sweets tells the class, "please turn in a copy of your group's data and keep another in your notebook. For homework, I would like each of you to write a half-page conclusion using your notes and supporting your conclusion with your results. Tell me what you think your data say and what that may tell you about the tea, based on what we have learned about the properties of matter. Please remember that each group member is responsible for his or her own conclusions."

FIGURE 2 Sample class data



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Day 3: In the classroom

Many students enter the classroom in playful debate. "Your data don't tell you nothin'," one student teases another. "It says a lot more than yours!" replies the second student. Mr. Sweets quiets the class and says, "Each group needs to select a speaker to tell the class what you think you learned yesterday from your investigation." He gives the groups time to select their spokesperson and confer about what the spokesperson should report. When all of the groups are ready, he calls on the first group to give its report.

"Our group wanted to see if there was any difference in the color of the teas," reports Group 1's spokesperson, Tameka. "When we looked at each cup, it looked like the color was a little different. So we took each tea and poured 50 mL into a plastic bag. Then we held the bag up to the light. We made sure that the light sensor was pointing at the light with the bag in between the sensor and the light. We found that when we measured cup A, the result was 5,500 lux, and the cup B result was 5,496 lux. We think that means that cups A and B are absorbing the same amount of light."

"That's great Tameka and Group 1," says Mr. Sweets as he writes their results on the board, "but tell me why you put the tea into plastic bags and what you think your data mean."

Cicelia, also in Group 1, says, "We wanted to make sure that it was clear. The cups were not completely clear. We thought that the teas seemed to be different colors and maybe had different amounts of stuff in them."

Mr. Sweets nods his head and asks, "Does anyone have any questions for Group 1?"

Everyone shakes their heads no.

"Why do you think that the teas were similar with regard to light absorption?" asks Mr. Sweets.

Group members look at each other. "Maybe 'cause there is the same stuff in cup A and cup B," says Cicelia. "Like, no sugar or whatever was floating around in the tea blocking the light because it was all disappeared or dissolved in both samples."

"So maybe this relates to solubility," Mr. Sweets says, and calls on the spokesperson for Group 2.

"Group 2 decided that we would test conductivity like we did when we were learning about solutions," says Carlo. "We found that the conductivity of cup A was 914 µS/cm, and cup B was 855 µS/cm. We are thinking that means that cup A has some sort of salt in it, since we learned that sugar does not conduct a solution but salt does."

As he writes the results on the board, Mr. Sweets thanks Carlo and asks, "Thinking back to our lesson on solutions, does sugar just disappear in water?" Many students shake their heads no. "OK, what happens then?" Mr. Sweets asks.

Rachelle raises her hand. "It dissolves because it is highly soluble in water."

"Right!" says Mr. Sweets and asks if there are any other questions for Group 2 before calling on Group 3.

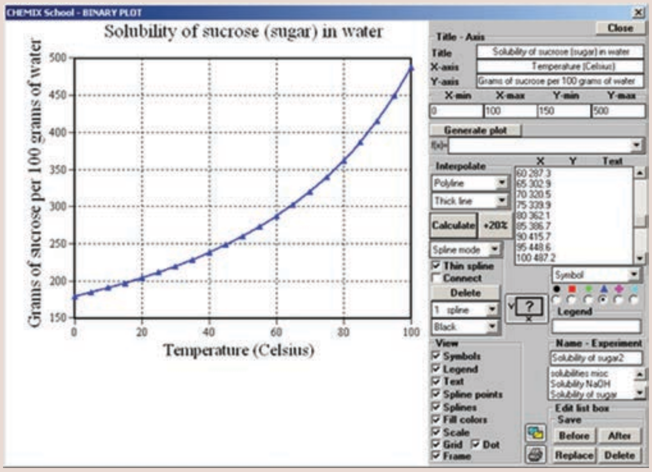
Michael stands up looking a little defeated and says, "Group 3 used the pH sensor, but we got a pH of close to 5 for both teas, and we took a whole bunch of measurements."

"That's OK," says Mr. Sweets. "Finding similarities is just as important as finding differences. Why do you think that they have the same pH?"

Kelly raises her hand and says, "Because they are made of the same stuff?"

"Right!" confirms Mr. Sweets. "So the difference in when the sugar was added makes no difference in pH?" When students nod yes, Mr. Sweets goes on: "So right now, we have similar light absorbance readings, very close conductivity readings, and similar pH. Raise your hand if you think that cup A and cup B are different." When no one raises a hand, Mr. Sweets asks someone to explain, using the data on the board, how and why the teas are the same.

FIGURE 3 Solubility of sucrose (sugar) in water



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Kaloni raises her hand and says, "I think that the teas are similar because they do not look different and have similar numbers for light, pH, and conductivity."

"Great," say Mr. Sweets. "I think you have shown me that cup A really is not different from cup B based on our measurements."

Mr. Sweets tells students that they will conclude the investigation with a taste test. "I didn't want you to be able to taste the tea earlier," he says, "because it might have prejudiced the data you collected. Does anyone know what our investigation is called?"

"A blind investigation?" Martin offers.

"Yes, that's right. And if I also had not known which tea was A and which was B, that would have been called a _____." Mr. Sweets pauses to see if anyone knows the term.

"A double-blind investigation?" Anna asks.

"Yes! I knew which tea was sweetened while it was hot, but you did not. If I had wanted to double-blind it I could have asked another teacher to sweeten the teas but not tell me. I was afraid that some of you who have been drinking southern-style iced tea all your life might be able to tell what kind of tea A and B were if you tasted first. If you knew ahead of time, it may have affected your observations and your results."

Mr. Sweets has students move into the nearby hallway and be seated on the floor. He gives each student a set of fresh cups marked A and B and instructs students to take a sip from each cup and record in their notebook which they believe contains the iced tea sweetened when it was hot (southern iced tea) and which is the iced tea that had sugar added after it had cooled to room temperature (non-southern iced tea). Both teas were prepared at home by Mr. Sweets to avoid lab contamination. “Remember,” Mr. Sweets says, “both teas were made with the exact same amount of sugar, tea, and water. Can you tell a difference?” (Students with diabetes or other health concerns should not taste the tea.) As students taste the tea, they make comments such as “I told you the southern tea was A!”

After all students have tasted the teas and recorded their observations, Mr. Sweets takes a sip of each tea and notes that they taste about the same to him. “How many of you are like me and can’t tell a difference in taste?” Four students out of 25 raise their hands. “OK,” Mr. Sweets goes on, “obviously about three-quarters of students can taste a difference.” He then asks the class to compare the results of the taste test to the results they got when they made measurements of the two cups of tea and figure out what the comparison tells them. Several students point out that the measurements show tea A and tea B to be very similar, which is different from the taste-test results. “So maybe our taste buds and our ability to taste degrees of sweetness are different, making taste an unreliable test,” Mr. Sweets says.

Now students are asked to explain what difference it makes if the tea is hot, room temperature, or cold when the sugar is added. Here the teacher could ask students to think of reasons why the temperature might matter, trying to get them to bring in the part of the standard that says in a liquid the molecules/particles are constantly in contact with others and suggesting that the added heat makes them move quicker and come in contact with the sugar particles more often—which would make the same amount of sugar dissolve faster. The teacher could ask for ways to verify this. Students should be able to suggest that they could add the same amount of sugar to the same amount of water in the same kind of container at several different temperatures, from very hot to very cold, and compare how much sugar dissolves at each temperature if the mixtures are stirred equally. Students could also do this as an extension where they will see that much of the added sugar will fall to the bottom of a very cold glass of tea and not dissolve and that more sugar will dissolve as the temperature of the tea gets hotter and hotter. The teacher could also have students verify this using a solubility curve of sugar (Figures 2 and 3). Students could then be asked to use the graph to determine the maximum amounts of sugar that will dissolve at various temperatures of tea. From the graph they should be able to see that much less sugar will dissolve in a very cold glass of tea compared to a warm glass of tea. They should be able to infer that if a lot of sugar is added to ice cold tea, much of the sugar will end up on the bottom of the glass and that the tea would not taste as sweet as tea at warmer temperatures.

Mr. Sweets then asks the class how this could help them explain their investigation results where cups A and B were the same in measurements. Students are able to infer that the temperature of the tea when it was hot and when it was room temperature were both high enough to dissolve the 1½ cups sugar that was added, making them both taste the same.

To work in the characteristic properties of salt, students could use the solubility graph to compare how well salt dissolves as the temperature increases (as seen in Figure 3). Then ask students if this would be a characteristic property that could help them identify salt from sugar.

Conclusion

This article connects what students are already learning about the properties of matter to a real-world question. It also brings a little fun to the classroom. If this is not your cup of tea, try comparing diet and regular sodas, fresh lemonade and canned lemonade, or name-brand and generic sodas to determine differences in their properties. ■

References

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