KITCHEN CHEMISTRY

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General Description

Type of program:

Kitchen Chemistry is a live stage presentation about recognizing and exploring the science that we practice every day in our very own homes. We take a look at the chemistry behind a seemingly simple bowl of spaghetti – from boiling water, to the behavior of starches and lubricants both on the macro- and nanoscale, to the nanosensors that determine our perception of taste and smell; how cooking is a complex chemistry, and how we are complex in the ways we experience our food. The presentation consists of multiple demonstrations, many including audience participation.

Program Objectives

Big idea:

Chemistry can often be perceived as a complex science, and yet just by doing something as basic as preparing food, we are practitioners. Likewise, "nano" can often be perceived as a complex idea, and yet just by doing something as basic as consuming food, we are having a "nano" experience.

Learning goals:

As a result of participating in this program, visitors will be able to:

1. Recognize that they are practitioners of chemistry at home, often daily.
2. Understand that boiling water, the way starches behave, the effects of lubrication, and our perception of taste and smell is chemistry.
3. Learn that our noses are nano-sensors, and that our perception of food scent and flavor is the result of a nano experience.

NISE Network content map main ideas:

[X] 1. Nanometer-sized things are very small, and often behave differently than larger things do.

[X] 2. Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

[ ] 3. Nanoscience, nanotechnology, and nanoengineering lead to new knowledge and innovations that weren't possible before.

[ ] 4. Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

National Science Education Standards:

[X] 1. Science as Inquiry

- [x] K-4: Abilities necessary to do scientific inquiry
- [x] K-4: Understanding about scientific inquiry
- [x] 5-8: Abilities necessary to do scientific inquiry
- [x] 5-8: Understanding about scientific inquiry
- [x] 9-12: Abilities necessary to do scientific inquiry
- [x] 9-12: Understanding about scientific inquiry

[X] 2. Physical Science

- [x] K-4: Properties of objects and materials
- [ ] K-4: Position and motion of objects
- [ ] K-4: Light, heat, electricity, and magnetism
- [x] 5-8: Properties and changes of properties in matter
- [ ] 5-8: Motions and forces
- [ ] 5-8: Transfer of energy
- [x] 9-12: Structure of atoms
- [x] 9-12: Structure and properties of matter
- [x] 9-12: Chemical reactions
- [ ] 9-12: Motions and force
- [ ] 9-12: Conservation of energy and increase in disorder
- [x] 9-12: Interactions of energy and matter

[ ] 3. Life Science

- [ ] K-4: Characteristics of organisms
- [ ] K-4: Life cycles of organisms
- [ ] K-4: Organisms and environments
- [ ] 5-8: Structure and function in living systems
- [ ] 5-8: Reproduction and heredity
- [ ] 5-8: Regulation and behavior
- [ ] 5-8: Populations and ecosystems
- [ ] 5-8: Diversity and adaptations of organisms
- [ ] 9-12: The cell
- [ ] 9-12: Molecular basis of heredity
- [ ] 9-12: Biological evolution
- [ ] 9-12: Interdependence of organisms
- [ ] 9-12: Matter, energy, and organization in living systems
- [ ] 9-12: Behavior of organisms

[ ] 4. Earth and Space Science

- [ ] K-4: Properties of earth materials
- [ ] K-4: Objects in the sky
- [ ] K-4: Changes in earth and sky
- [ ] 5-8: Structure of the earth system
- [ ] 5-8: Earth's history
- [ ] 5-8: Earth in the solar system
- [ ] 9-12: Energy in the earth system
- [ ] 9-12: Geochemical cycles
- [ ] 9-12: Origin and evolution of the earth system
- [ ] 9-12: Origin and evolution of the universe

[ ] 5. Science and Technology

- [ ] K-4: Abilities to distinguish between natural objects and objects made by humans
- [ ] K-4: Abilities of technological design
- [ ] K-4: Understanding about science and technology
- [ ] 5-8: Abilities of technological design
- [ ] 5-8: Understanding about science and technology
- [ ] 9-12: Abilities of technological design
- [ ] 9-12: Understanding about science and technology

[ ] 6. Personal and Social Perspectives

- [ ] K-4: Personal health
- [ ] K-4: Characteristics and changes in populations
- [ ] K-4: Types of resources
- [ ] K-4: Changes in environments
- [ ] K-4: Science and technology in local challenges
- [ ] 5-8: Personal health
- [ ] 5-8: Populations, resources, and environments
- [ ] 5-8: Natural hazards

[ ] 5-8: Risks and benefits
[ ] 5-8: Science and technology in society
[ ] 9-12: Personal and community health
[ ] 9-12: Population growth
[ ] 9-12: Natural resources
[ ] 9-12: Environmental quality
[ ] 9-12: Natural and human-induced hazards
[ ] 9-12: Science and technology in local, national, and global challenges

[ ] 7. History and Nature of Science
[ ] K-4: Science as a human endeavor
[ ] 5-8: Science as a human endeavor
[ ] 5-8: Nature of science
[ ] 5-8: History of science
[ ] 9-12: Science as a human endeavor
[ ] 9-12: Nature of scientific knowledge
[ ] 9-12: Historical perspective

Table of Contents

Time Required

Set-up	Program	Clean Up
		
15 minutes	20 minutes	15 minutes

Background Information

Definition of terms

Nano is the scientific term meaning one-billionth (1/1,000,000,000). It comes from a Greek word meaning “dwarf.”

A nanometer is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second.

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eyeblink is to a year what a nanometer is to a yardstick.)

Nanoscale refers to measurements of 1-100 nanometers. A virus is about 70 nm long. A cell membrane is about 9 nm thick. Ten hydrogen atoms are about 1 nm.

At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.

Nanotechnology is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules.

Nanoscience, nanoengineering and other such terms refer to those activities applied to the nanoscale. “Nano,” by itself, is often used as short-hand to refer to any or all of these activities.

Program-specific background

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Materials

General Visual Aids

- Replica cookie dough
- Replica cookies
- "How Tall Are You?" nano poster
- Ruler with millimeter marks
- TV/Computer screen to run PowerPoint presentation
- Apron + chef's hat

Boiling Water

- Stovetop unit to boil water onstage
- Clear glass pot to boil water in
- Clear plexi shield to protect audience from boiling water splatters
- Hot pads (cloth or silicone)

Starch Structure

Pasta Toss:

- Angel hair pasta
- Timer
- Pasta spoon (this saves the need for a colander)
- Bowl to place cooked pasta in
- Olive Oil
- Butcher Paper
- Masking Tape
- Large Cookie Sheet that can be mounted to the wall (must NOT be the non-stick variety)
- Apron for volunteer
- Non-latex glove(s) for volunteer

Starch/Iodine

- Three small beakers, two pre-set with cold water
- Iodine + dropper
- Metal chemistry spatula #1 of 2
- Soup ladle
- Water from pot of boiling angel-hair pasta (after it's been cooking at least two minutes)

Oobleck

- Small beaker
- 100 ml cornstarch
- 50 ml water

- food coloring
- metal chemistry spatula #2 of 2
- plastic speaker cone set up to run a frequency that creates steady vibration
- camera + monitor for live video feed, if possible

Flavor Perception

Smell

- three clear, squeeze-style condiment bottles
- cotton balls
- three different essential oils or flavoring extracts

Flavor/Taste

- paper condiment cups
- red jellybeans
- tongs for jellybeans

Set Up

Time:

15 minutes

Prep:

- Open and set PowerPoint
- Start boiling water immediately. This needs a minimum of 10 minutes to get to a full, rolling boil.
- Make oobleck mixture (roughly two parts cornstarch to one part water – err on the thinner side), add food coloring as desired for visual interest/contrast.
- Tape down length of butcher paper to floor under "spaghetti toss" area.
- Hang cookie sheet
- Fill two small beakers with water for starch/iodine demo.
- Hang "How Tall Are You?" sign.
- Set jellybeans in cups
- Arrange remainder of demo items neatly on demo cart – sorted by experiment, working from left to right.

Program Delivery

Time:

20 minutes

Safety

- Keep several hotpads nearby for handling pot of boiling water

- Use caution when handling iodine – use non-latex gloves if you have topical allergies

Talking points and procedure

Kitchen Chemistry

DRAFT 8, 6/3/2012

Science Museum of Minnesota

Leigha Horton

Start show onstage, wearing a chef's hat and lab coat, with all experiments pre-prepped and ready on the table.

PowerPoint, Slide 1: Intro/Title on screen.

INTRODUCTION:

Hello, everyone, and welcome to the Science Museum of Minnesota! My name is ____ and this is *Kitchen Chemistry*.

I know you all know what kitchens are, but what about chemistry?

PowerPoint, Slide 2: Chemistry title card.

What *is* chemistry? *(gather answers)* Great answers!

PowerPoint, Slide 3: Chemistry Definition (formal).

The formal definition of chemistry is *(spoken in a snooty and boring tone)* "a science that deals with the composition, structure, and properties of substances and with the transformations that they undergo."

PowerPoint, Slides 4-8: Chemistry Definition (informal), clicking through as each description appears.

Another way to say that is, "chemistry is a science that deals with what stuff is made of, how it's held together, how it behaves, and how it can change."

Hold up tray of cookie dough in one hand; hold up plate of finished cookies in the other.

So when food changes form – for example, from cookie dough into cookies - that's chemistry! Cooking IS chemistry.

PowerPoint, Slide 9: image of spaghetti.

Today we're going to explore the science of spaghetti!

BOILING WATER:

Now first thing's first when you're making spaghetti - you have to boil water to cook your spaghetti noodles, whether they're dry and brittle or fresh and floppy, right?

Indicate clear glass container of boiling water, and hold up box of spaghetti noodles.

Boiling is what happens when we rapidly change water from a liquid to a vapor using heat.

Before we continue, let's quickly review the three basic states of matter. Who remembers the three basic states of matter? *(raise hand while saying this, to indicate you're looking to call on someone to answer – get their answer.)*

That's right – solids, liquids, and gasses.

PowerPoint, Slide 10: solids, liquids, gasses.

There are other kinds of matter, like plasmas, which stars are made out of; and the Bose-Einstein Condensate, which deals with matter at super-cold temperatures, but for today we're going to look at the basic three.

Now, I need a couple of volunteers to help me demonstrate these basic states of matter.

Choose three volunteers from the audience.

What are your names? Thank you for volunteering today, ___, ____, and ____!

First, I'd like you to stand in a line facing the audience *(arrange volunteers in a line parallel to the audience)*, and place your hands out in front of you like this *(demonstrate balled fists).* Your fists should be touching. Right now, together, you're a solid. All of your molecules are very close together, and if one moves, they all move. (*Gently push on one hand, and all hands will move).*

Now, the audience and I are going to add heat to you by quickly rubbing our hands together and throwing the heat on you. *(Demonstrate)* You are going to take a teeny step apart and your hands are going to get a little wiggly. But not too crazy, because you're a liquid, and molecules in a liquid still flow together and fill their container. (*Gently push on one hand, until all hands move).*

Finally, we're going to add even more heat to you, and you're going to turn into a gas – this time, I'd like you to wiggle your hands and walk back to your seats while you're doing so.

Volunteers return to their seats.

Let's give a round of applause to our solids, liquids, and gasses!

So, again, boiling is what happens when we rapidly change water from a liquid to a vapor using heat.

PowerPoint, Slide 11: image of boiling water.

Vapor is just another word for a gas that at room temperature is normally a liquid or a solid.

When enough vapor forms inside water so that the pressure of the vapor inside the water is equal to the pressure of the atmosphere above the water, the vapor can then push the air above the water away and allow vapor bubbles to be released. We call this process boiling.

The two basic factors that affect boiling are the pressure and the temperature. If the pressure changes, then the boiling temperature will also change.   It doesn't take as much heat to boil water in the mountains because the air pressure is lower in the mountains.

STARCH STRUCTURE:

So now that our water is boiling, we can toss the pasta in and let it work its way from dry and brittle to soft and supple.

Place dry pasta in original clear glass container of boiling water to cook.

Most pastas are made out of flour, salt, water, oil and eggs (which have special proteins that hold everything together). Some pastas don't use eggs, but still need that special protein, so they swap out the flour for a special kind of wheat.

PowerPoint, Slide 12: image of pasta starch from On Food and Cooking*, page 575.*

During cooking the starch granules absorb water and expand, and the proteins in the egg and flour form a network that binds the starch granules tightly together so they don't just dissolve in the water.

If you add cold water to a starch, the granules absorb a little bit of it, but they remain pretty much unchanged. But if you add right amount of warm water, the starch granules swell, break down and release some of their contents into the water. In other words, they gelatinize.

To help demonstrate this behavior, we're going to do a test with iodine. When iodine comes into contact with starch, it changes from red to blue.

Put on nitrile or latex gloves.

Here I have a graduated cylinder with some broken, uncooked pasta and some cold water. If I put a few drops of iodine in the cylinder, nothing happens. It remains red. That means no starch granules have gelatinized.

Add a few drops of iodine to the cold water graduated cylinder (#1). Hold up cylinder to show audience.

I have another graduated cylinder, but this time we're going to take some of our hot cooking water. If I put a few drops of iodine in the cylinder…

Add a few drops of iodine to the hot cooking water graduated cylinder (#2). Hold up cylinder to show audience.

…it turns from red to blue. I didn't even put any pasta in here! But the iodine changing from red to blue proves that the heat has made the starch break down and release some of its contents into the water. The pasta has gelatinized.

Oobleck, a mixture of cornstarch and water that you can easily make at home, helps us see what can happen to starches on the molecular level – a size so small that we would measure those starch molecules in nanometers.

PowerPoint, Slide 13: image of nanoscale.

A nanometer is a unit of measurement – much like a centimeter or meter – only it's much, much smaller – it's actually a billion times smaller than a meter!

Refer to the "How Tall Are You" poster.

How small?! Well, if we put a million lines in between two of these millimeter lines – one of those million lines would be a nanometer!

Hold up container of Oobleck and slowly sink gloved fingers into it.

As you can see, Oobleck has a thick, gluey consistency and I can sink my fingers into it.

But if I hit it – placing extreme, rapid pressure on it – this starchy mixture acts very differently – it's hard and tough.

Then hit it with a rubber mallet, to demonstrate the different properties.

And if I hit it repeatedly, very rapidly – like with the vibrations from a speaker cone – it will act very strange, indeed!

Place the mixture on the speaker cone, turn the unit on *so that the vibrations start (if possible, use a mobile unit, so that this can be walked closer to the audience, or use a camera and live video feed).*

As you can see, the vibrations are causing the cornstarch mixture to create wildly moving tendrils. This happens because Oobleck is what we call a "non-Newtonian fluid" – meaning that when it's disturbed, it becomes viscous, or thick and sticky. But just like our spaghetti noodles, when exposed to water the starch absorbs the water, expands, and gelatinizes.

This was a really good way to see chemistry in action! Remember that chemistry is a science that deals with what stuff is made of, how it's held together, how it behaves, and how it can change? We just saw some pretty cool behavior that led to a pretty cool change.

LUBRICANTS V. GELATION:

Now there's one thing that can really ruin a good bowl of spaghetti, and that's noodles that are all stuck together in a giant clump.

Noodles stick to each other during cooking when they're allowed to rest close to each other just after they're added to the cooking water. Their dry surfaces absorb the small amount of water between them so there's none left for lubrication, and the partly gelatinized surface starch glues the noodles together.

Use a slotted-spoon to remove two large spoonsful of spaghetti *onto two plates (one spoonful per plate).*

Sticking can be minimized by constantly stirring the noodles for the first few minutes of cooking, or by adding a spoonful of oil to the pot and then lifting the noodles through the water surface a few times to lubricate them. Salt in the cooking water not only flavors the noodles, but limits starch gelation and so reduces stickiness.

Stickiness after cooking is caused by surface starch that dries out and cools down after the noodles have been drained and develops a gluey consistency. It can be minimized by rinsing the drained noodles, or moistening them with some sauce, cooled cooking water, oil, or butter.

We're going to use oil.

Put a few spoonsful of oil over the spaghetti on one plate, leave the other plate as-is.

The only really good way to test if our spaghetti has avoided gelatinization in a way that everyone can see it is if we throw it. Yep, I said throw it and see if it sticks. I'm going to need a volunteer from the audience who has excellent aim.

Choose a volunteer from the audience, give them an apron and a non-latex glove to wear.

Thank you for volunteering today, ____. Now, I'd like you to lob this handful of plain spaghetti at this giant cookie sheet.

Throw spaghetti at a large, ungreased, (and NOT non-stick) cookie sheet with a trash receptacle or butcher paper placed beneath it.

Look at that! It stuck! The starch on this spaghetti got pretty gelatinized.

Now let's try this again, only this time using the spaghetti that we added the oil to. And…. slides right off! The oil served as a lubricant, and prevented our spaghetti noodles from gelatinizing.

Get apron back from volunteer and invite them to re-take their seat.

Thank you for your help with our spaghetti tossing, _______. You can go ahead and re-take your seat.

FLAVOR PERCEPTION:

Pass around squeeze bottles containing cotton balls treated with essential oil.

Now that our pasta is done cooking, we could add some tomato sauce, grated cheese, and basil. Ever notice how that sauce gets really fragrant once it's warmed up?

PowerPoint, Slide 15: image of a person smelling food.

The aroma of foods is mainly due to the molecules interacting with air. When food is heated, more of these molecules are released and make the food smell stronger.

I've got three squeeze bottles with cotton-balls inside, and these cotton balls have some essential oils on them. I'd like three volunteers who have good senses of smell and like jellybeans to join me up here, too.

Choose three volunteers from the audience.

What are your names? Thank you for volunteering today, ___, ____, and ____! Hold the bottle about waist-high, and give them a squeeze. Can you tell me what you smell?

Hand them bottle #1 (orange), and make sure they hold each bottle at about waist-high (too much closer to the face reduces the effectiveness). Also, use whatever scents you'd like, but make sure mint is always last – it's too strong otherwise and makes anything following difficult to identify.

Let them smell the first bottle and identify the smell.

And how about this one?

Let them smell the second bottle (bottle #2, vanilla) and identify the smell.

And this one?

Let them smell the third bottle (bottle #3, mint) and identify the smell.

Good! You all got those scents right! And as you can plainly see, what you were smelling was not actually an orange, vanilla, or mint – it was just essential oil - tiny particles, too small to see, of orange, vanilla, and mint.

PowerPoint, Slide 16: image of scent molecules.

It turns out that our noses are highly developed nano-sensors. Your sense of smell works by identifying the shape of scent molecules. These molecules are so small that they're measured in nanometers.

Hold up model of a scent molecule (or show all three and their different shapes via PowerPoint).

Remember from our Oobleck experiment that nanometers are itty-bitty units of measurement. We can use our sense of smell to explore the world on the nanoscale, because we can smell some things that are too small to see.

It turns out that a great deal of what you taste is actually a matter of smell, and to demonstrate that, I'd like our volunteers to help me out.

I am going to give each of you a red jellybean, which could be either watermelon, cherry, or cinnamon – but before you put it in your mouth, I want you to pinch your nose and keep it pinched. Then I'd like you to pop in the jellybean, chew *very slowly*, and don't swallow until I tell you to. Keep those noses pinched!

Ensure that the recipients aren't allergic to jellybeans, and then hand out one jelly bean per person in a hygienic method (disposable hospital pill cups or small condiment cups recommended).

Can you identify the flavor? No? Okay, now go ahead and unpinch your nose. How about now?

Give focus to the volunteer's reaction, which will probably be pretty strong/surprised.

What could you taste?

Have each volunteer identify the flavor of their jellybean for the audience.

If you haven't already, you can go ahead and swallow your jellybeans now.

Give our volunteers a big round of applause! Thank you, you may go ahead and have a seat.

On the way into your mouth, foods are giving off vapors that waft up into your nose. Once you start chewing, more vapors travel the retronasal route, up the pharynx and into the nasal cavities.

PowerPoint, Slide 17: image of human olfactory system.

At the back of each nasal cavity, the scent molecules hit the olfactory membrane, a postage stamp-sized patch of yellowish gray tissue responsible for determining odors.

SUMMARY:

PowerPoint, Slide 18: outro/title

And there you have it! We've just explored a whole lot of science in just one simple bowl of spaghetti!

From boiling water, to the behavior of starches and lubricants, to the nanosensors that determine your perception of taste and smell, cooking is a complex chemistry, and *we* are complex in how we experience our food.

Give yourselves a big round of applause - thank you for joining us for *Kitchen Chemistry!*

Tips and troubleshooting

General Visual Aids

- Kids love – LOVE – the replica cookie dough and cookies and always want to touch it.

Boiling Water

- We have a tight stage schedule, and so cannot start water boiling from cold onstage in time for the demo. That said, I start the water boiling downstairs 30 minutes before showtime, and then transport it up to the stage. It then takes only about 3-5 minutes to get it back to boiling.
- Keep plenty of hot pads around and readily available.

Starch Structure

Pasta Toss:

- Angel hair pasta seems to cook the fastest, at about 6 minutes.
- Butcher Paper is great for underneath the pasta toss area, in that it makes cleanup a cinch. Any dropped pasta and/or oil falls right onto the butcher paper and then the entire mess can be folded up neatly and composted.
- The fewer strands of un-oiled pasta thrown, the better it sticks to the cookie sheet…too much and gravity takes over.
- Be sure to give the volunteer a non-latex glove to wear to throw the pasta (both pre- and post-oiling) so they don't return to their seat with gross hands.

Starch/Iodine

- Make sure your chemistry spatula #1 of 2 is clean, so that it doesn't transfer unintended starch into your water/iodine solution.
- Use water from pot of boiling angel-hair pasta after it's been cooking at least two minutes – the longer the pasta has been boiling, the better the inky-blue reaction will be.

Oobleck

- When mixing oobleck, it's safer to err on the side of thinner rather than thicker – too thick and the speaker won't have the power to move the mixture.
- Oobleck needs to be re-stirred right before going onto the speaker because it separates rather quickly.

Flavor Perception

Smell

- The older the participants, the better. Teenagers and adults are best for this experiment because younger children have a difficult time identifying scents. Instead of "vanilla," younger children will say things like, "cookies." Or instead of "oranges," they might say "candy."

- Make sure participants hold the squeeze bottles no closer than waist-height (demonstrate before handing them the bottle). Any closer than that and the scents are too concentrated and become difficult to determine.
- If using mint as one of your scents, make sure it is always presented last because it distorts and overpowers the scents of everything that follows.

Flavor/Taste

- Ensure that before coming to the stage, the participants have no sensitivities or dietary restrictions to eating jellybeans. Many brands of jellybeans are not pareve or kosher.

Clean Up

- The butcher paper, cooked angel hair pasta, oobleck, and paper condiment cups can be composted.
- Oobleck is often easiest to clean up after it dries up, which doesn't take terribly long to do…at that point you can just brush it right off and it turns to dust.
- If needing to clean up oobleck when it is still wet, use its non-Newtonian properties to your advantage…if you go at it quickly and forcefully, it will stay together in a hardened mass, rather than oozing everywhere.
- Dishes soiled with oobleck can be quickly and easily rinsed with water.

Common visitor questions

- What is Oobleck made of again?

Going further…

Here are some resources you can share with your visitors:

Non-Newtonian Fluid on a speaker cone:
http://www.youtube.com/watch?v=3zoTKXXNQIU

Clean Up

Time:
15 minutes

Universal Design

This program has been designed to be inclusive of visitors, including visitors of different ages, backgrounds, and different physical and cognitive abilities.

The following features of the program's design make it accessible:

[x] 1. Repeat and reinforce main ideas and concepts
Through discussion, live demonstrations, volunteer-assisted demonstrations, and power-point slides the main ideas and concepts will be verbally and visually reinforced.

[x] 2. Provide multiple entry points and multiple ways of engagement
Again, through discussion, live demonstrations, volunteer-assisted demonstrations, and power-point slides, audiences will be engaged with hands-on/tactile activities, visually through the demonstrations and slides, and aurally through the live, spoken presentation.

[x] 3. Provide physical and sensory access to all aspects of the program
See above.

This project was supported by the National Science Foundation under Award No. 0940143. Any opinions, findings, and conclusions or recommendations expressed in this program are those of the author and do not necessarily reflect the views of the Foundation.