From Macro to Micro to Nano

Bringing the science of the small to the very small

By Troy Dassler

How does a public elementary school teacher end up doing nanoscale science with third-grade students? It all started when I was accepted to the National Science Foundation's unique program called Research Experience for Teachers (RET). RET pairs classroom teachers with researchers at universities to strengthen their understanding of science, math, and engineering. Needless to say, that first summer (five years ago) was filled with discovery and learning as I worked side by side with biochemist Doug Weibel and other researchers to come up with microscopy units of study for elementary students.


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Students were introduced to nanoscale science on a field trip to a university.

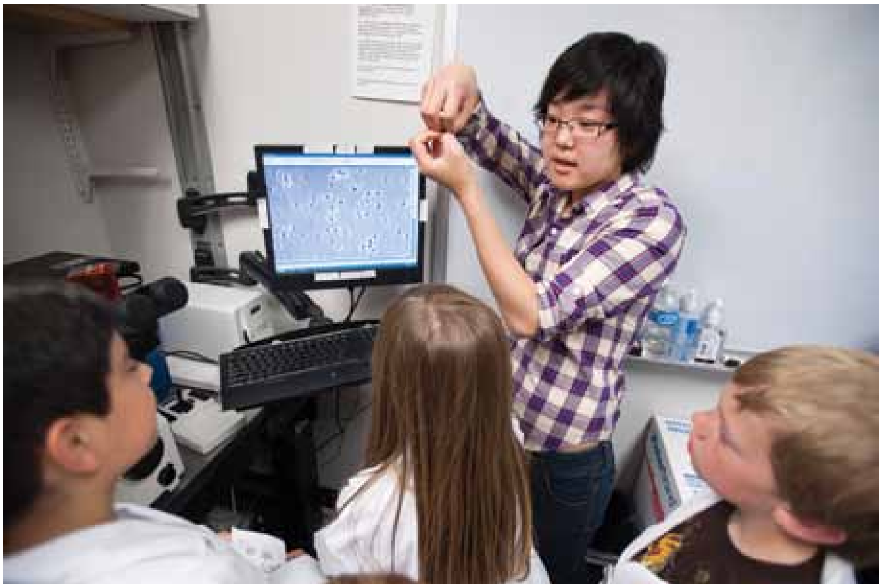
Although the units of study that we developed were engaging and interesting, the greatest effect was on my own idea of what is possible when researchers and teachers work together and have the resources needed to offer students authentic and engaging experiences. After that first summer, I remember coming back to school and making a decision that I would only offer the best for my students. I wanted microscopes that actually worked and plant or animal specimens that would inspire them and stimulate their natural curiosity. So I started working with Dr. Weibel to look for grant opportunities.

When I read about the Toyota Tapestry program, I knew that it was a perfect fit for our MicroExplorers program. Doug and I wrote the proposal together. We both were ecstatic when we received the news that others were just as passionate about bringing science to elementary students and were willing to fund our passion. We also received matching funding. With a healthy budget we placed our first order in to get some amazing science equipment. It led to an amazing discovery by one of our students.

The Lotus Effect

Throughout the school year I continued to work in the laboratory, and was able to take after-school science club students to do experiments and bring scientists to my classroom to share their research. Students were introduced to the nanoscale at the science club. With Dr. Weibel's guidance and grant support we were able to outfit my classroom lab with all of the equipment that we would need to complete hundreds of experiments. Students outfitted with lab coats and goggles used beakers, stir plates, and pipettes, and examined specimens to spark their curiosity.

However, while we were offering a variety of scientific opportunities, I still did not believe that simply using microscopes was giving students insight into the nanoscale. When asked about the smallest thing they could think of, most students responded with objects that were roughly the size of a dime. When asked about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University students shared their research.

"nano," I got quite a few surprises, "It is a nano iPod" or "I have a Hexbug Nano." Not only were these objects not nanosize; they were quite macro.

I began to look for nanoscale activities that were hands-on and could be easily modeled using macrosized items that match nanocale images. Over the course of a year of consulting with teachers, researchers, and informal science educators from the Nanoscale Informal Science Education Network (NISE Net) (see Internet Resources), I developed a series of lessons based on the lotus effect. The *lotus effect* is something that is found repeatedly in nature. The lotus leaf has waxy bumps that are covered with nanoscale "hairs" that prevent water from penetrating the surface of the leaf. This lotus effect is often referred to as *superhydrophobicity*. This property allows the water to bounce off the surface of the leaves and clean the surface.

Macroscale

In order for the students to get to the nanoscale, I handed out leaves of various shapes, sizes, and colors. I asked the students to make notations in their science notebooks about what the leaves felt like, looked like, and smelled like. Some plants can cause allergic reactions, so I reminded students to never taste unidentified plants and made sure they washed their hands after handling the leaves.

CAUTION

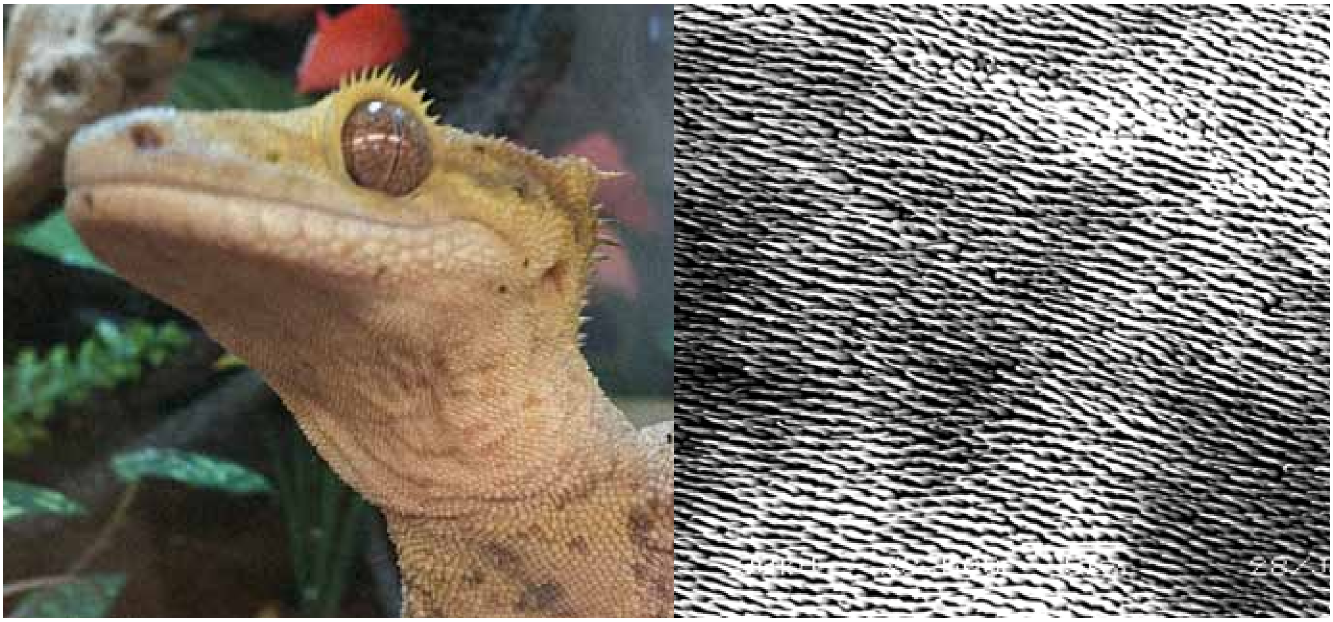
To better scaffold the writing experience for students who struggle with writing, I used sentence strips. A pocket chart is used for holding strips of paper behind plastic strips. It is an easy way to manipulate words and phrases. These strips of paper in the pocket chart helped students with the pattern of observation (e.g., the leaves are green; the leaves are the size of my hand). The students shared their observations in a group, with many commenting on the physical properties of the leaves: "The leaf feels rubbery" or "The leaf has smooth edges." Once students had the opportunity to share their observations, I announced that what we were doing was making our observations on the macroscale. This is the world around us that we can see without having to use a magnifying glass or any other tool. Students labeled their observations with the title *macro*.

Microscale

Next, we turned to the digital microscopes. I explained that microscopes are used to see things that are so small that we can't see them with our eyes. The students noted that the leaves looked different under the microscope. Plant cells could be seen, new and different colors were exposed. The students continued to make their observations and compared and contrasted their macro observations with these new discoveries.

The majority of the students started using a different sentence pattern. So, I introduced new sentence strips to the pocket chart when students began using more sophisticated sentence patterns that began to compare what they were seeing under the microscope with macro objects in on the macro scale.

Students made observations such as, "The leaf looks like tiny diamonds" and "The leaves look like mountains and hills." After they had the opportunity to explore and make observations, I told them that when we use tools to see something that is too small for us to see just using our



GEORGE LISENSKY, BELOIT COLLEGE

Coco the gecko and her skin magnified 3,5000x with a scanning electron microscope.

eyes, our observations are on the microscopic scale. The students labeled their observations with *micro.*

Nanoscale

Finally, I told the class we were going to use a special tool to help make observations on an even smaller scale. With big fanfare and enthusiasm, I pulled out a pipette (an eyedropper will work as well) and a beaker of water. I then asked them to make observations of how drops of water reacted to the surface of a variety of leaves and record their observations. Students began to notice that the water behaved differently on various leaves, making comments such as, "The water sticks to the leaves" and "The water bounces off the leaves." I made sure that I had a variety of plants for children to test (e.g., lotus, cabbage, hen and chicks, broccoli, nasturtium, columbine). As students tested the plants, they noticed that some of the leaves did not get wet, even when they were dipped in the water. With some leaves, drops of water beaded up and rolled off the surface.

After they completed their observations, I told the students that the leaves that were very water-repellent had tiny little hairs, like those on a glove for washing cars. We passed around a glove and observed the large hairs on the glove. Then, I had the students blow bubbles on the surface of the car-washing glove. (Forever bubbles work great for this because they have polymers in them, so they are long-lasting.) The bubbles stayed on the surface of the glove and did not go between the "hairs." We also used a model developed by Dr. Neil Shirtcliffe from Nottingham Trent University. He uses a bed of nails and a balloon as another model. Both models were a big hit with the students. I explained that what we had been testing for on these leaves were really small hairs that are on the nanoscale. This scale is so small that most ordinary microscopes (optical) can't get good images of the nanoscale. To show students what the structures looked like on the nanoscale, I used images of hydrophobic leaf structures that were captured by scientists and informal science educators from NISE Net. Students labeled their observations as *nano.*

Evaluation

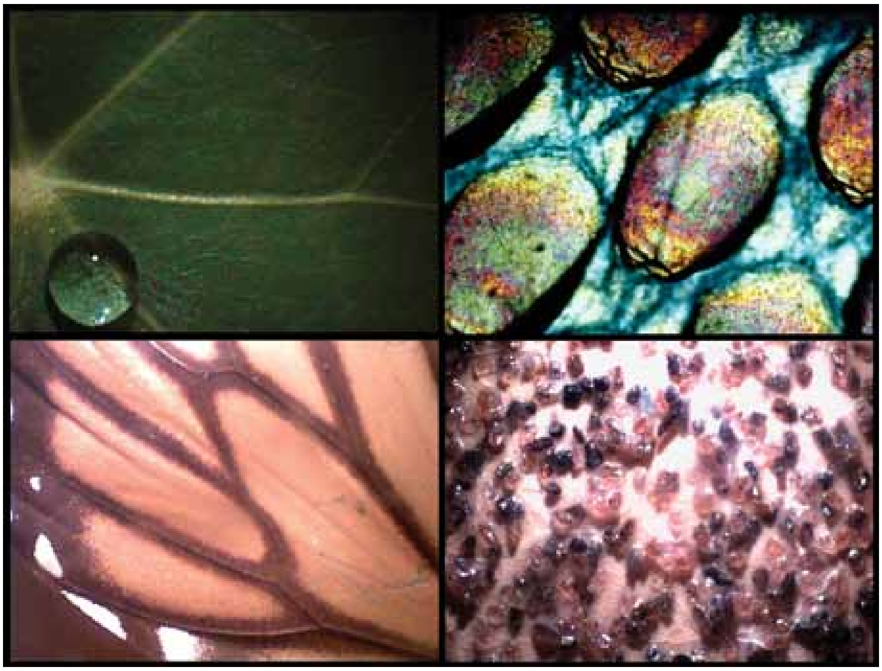
To check for understanding, I asked the students to come up with something they would like to be hydrophobic. The students came up with inventions such as hydrophobic money that would not get wet when left in a jean pocket. Another student thought that it would be great to have a hydrophobic roof because his house had a leaky roof. To further assess their understanding, I developed a rubric for my students to assess their own work (see NSTA Connection). I also examined their notebook entries and gave feedback to the students. To bring more inquiry to the lesson, I asked the students to go home and test house plants and plants around their yards to see whether any of them exhibit superhydrophobicity.

To my surprise, the next day one of the science club helpers made an interesting discovery that hydrophobicity exists in other areas of nature outside of the plant kingdom—in this case with geckos.

This student had a gecko as a pet at home, plus we had a classroom gecko. Because of the risk of Salmonella, reptiles and amphibians in the classroom require a strict hand washing regimen (see Resources).

CAUTION

Because Sarah made the interesting discovery, I felt that it would only be appropriate that she tell her story.



PHOTOGRAPHS COURTESY OF THE AUTHORS

Magnified images of water, gecko skin, (top) a butterfly wing, and sandpaper (bottom).

Sarah's Story

Our assignment was to go home and find something hydrophobic. At home I had three leopard geckos. While I was trying to find something hydrophobic for the assignment, I remembered that whenever we sprayed water on the geckos, it just rolled right off, and their skin never got wet. Every week or two, our geckos molt. So the next time our gecko, Zippy, molted, I took the skin to Mr. Dassler (the science club teacher). He was impressed by the skin's superhydrophobicity. Then we sprayed water on our class crested gecko, Coco, and saw that his skin was superhydrophobic, too. Mr. Dassler took Coco's skin to some scientists who had never heard about the hydrophobic properties of gecko skin.

I think something cool that could be made out of gecko skin is gecko tape. It would be made entirely from gecko parts. The setae from gecko feet (which allow them to stick to walls and ceilings) could be used to make the adhesive part, and the other side of the tape could be made of gecko skin. That's tape that's made only from gecko parts, and it's hydrophobic.

I had a great time learning about the nanoscale and experimenting in science club. It was awesome sharing my discovery about superhydrophobic gecko skin and getting to see what gecko skin looks like at the nanoscale!

Sarah's discovery and the outfitting of our elementary school science laboratory all started with one e-mail that I received asking for teachers of science to spend the summer doing research in a laboratory—what a great outcome it was for all involved! Sarah, like all children, deserve to have the best science experiences by teachers who have all the necessary technical and material resources to meet their curiosity.

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In 2010 I was awarded The Toyota Tapestry Grant for Environmental Education. The award allowed me to create a fully-equipped laboratory for elementary-age students. The laboratory and materials offered children the opportunity to explore how nature designs structures to inspire them to solve two of society's greatest challenges: energy production and efficiency. Students examined surface structures through images taken from digital optical microscopes and a Scanning Electron Microscope from the University of Wisconsin. Students investigated how nature creates color and cleans the surfaces of leaves. Students studied the design of the tiny fruit fly wing and the iridescent structures of the blue morpho butterfly. The students then used what they learned from nature to redesign eco-friendly alternative energy power generators. A windmill's design was inspired by the fluke of a whale. Surfaces of solar panels were coated with a superhydrophobic coating like that found on the surface of a lotus leaf. The ideas were only limited by the diversity of nature objects that were purchased through the award and the imagination and creativity of the children. This was only possible through the generosity of Toyota's mission to support creative endeavors. The laboratory located in Aldo Leopold Elementary Public School has been so popular that the Foundation for Madison Public Schools is raising funds to bring similar labs into all of the elementary schools in the Madison Metropolitan School District.

a new adventure with the Wisconsin Alumni Research Foundation to coordinate outreach and labs at the Wisconsin Institute for Dicovery.

Resources

Foundation for Madison Public Schools
www.fmps.org

Lotus Effect
http://mrsec.wisc.edu/Edetc/cineplex/lotus/index.html

MicroExplorers
www.microexplorers.org

Multimedia Zoom into a Nasturtium Leaf.
www.nisenet.org/catalog/media/multimedia_zoom_nasturtium_leaf

Nanoscale Informal Science Education
www.nisenet.org/

Nanoscience in Elementary Schools
www.youtube.com/watch?v=SilmuuG63Ps

Nature's Raincoats
http://Naturesraincoats.org

Reptiles, Amphibians, and Salmonella
www.cdc.gov/Features/SalmonellaFrogTurtle

Silverstein, S.C., J. Dubner, J. Miller, S. Glied, and J.D. Loike. 2009. Teachers' participation in research program improves their students' achievement in science. *Science* 326: 440–442.

UW MRSEC Interdisciplinary Education Group
https://mrsec.wisc.edu/Edetc

Wisconsin Institutes for Discovery
http://discovery.wisc.edu

Acknowledgments

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Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Grades K–4

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard B: Physical Science

- Properties of objects and materials

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.