

## *Original Paper*

# Using Remotely Accessible Microscopy in the Elementary Classroom

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Received: July 19, 2018

Accepted: July 31, 2018

Online Published: August 1, 2018

doi:10.22158/fet.v1n2p137

URL: <http://dx.doi.org/10.22158/fet.v1n2p137>

### **Abstract**

*Elementary children are at an age of investigation and exploration. In today's society, this exploration often occurs using technology. Whether learning to type with Typing Club, using Google to search for information on Yellowstone National Park or designing and creating a city in Minecraft, technology has become a part of every child's existence. Early access to technology could be the impetus to a students' pursuit of a degree in STEM disciplines. Presented here is a conglomerate of University, Community College and High School sites that provide free access to advanced scientific technologies remotely for students to view and manipulate for themselves. The Remotely Accessible Instruments in Nanotechnology (RAIN) Network provides Scanning Electron (SEM), Atomic Force (AFM) and Confocal Microscopes to educators and allows an opportunity to connect with higher education scientist across the globe, with the goal of using technology to enhance the teaching of science to our children.*

### **Keywords**

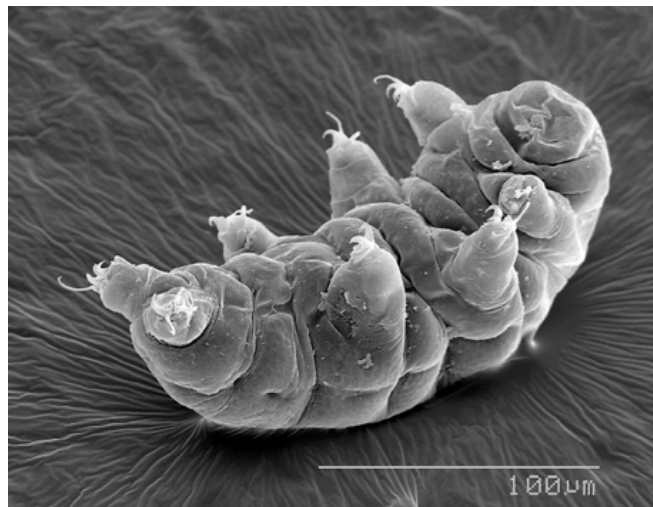
*remote instrumentation, microscopy, elementary education, scale of universe*

## **1. Introduction**

“Water Bear” Megan yelled, shocking teachers. The class generally had no idea what a water bear was, so zooming continued. Several students yelled guesses: flower petal, dogs hair and of course underpants. Fifth graders are so predictably unpredictable. Finally, upon zooming in enough where the image is recognizable and a cacophonous of sound reverberates through the room, several students scream in fear while others yell the correct answer: “Spider”. This activity was the first experience

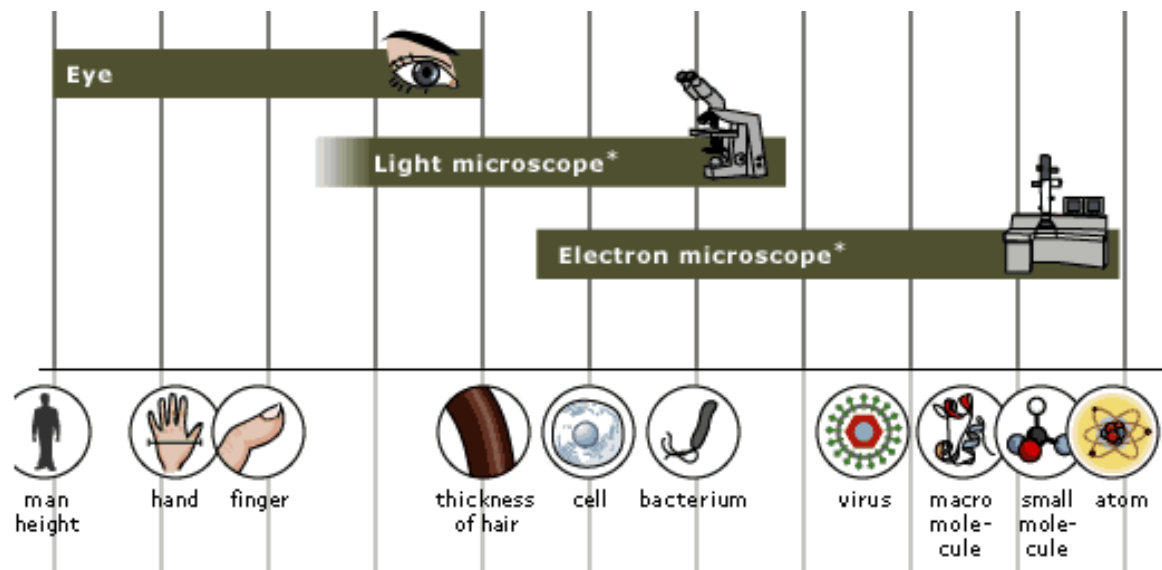
using the Remotely Accessible Instruments in Nanotechnology, known as the RAIN Network in an elementary school classroom. RAIN, despite at first glance seeming advanced for the casual elementary student, allows teachers to bring advanced technologies, specifically different types of microscopes to the elementary school classroom.

In the first century, Romans would view objects through glass to make the images larger. Some would say this was the first microscope. Since this time, children have been amazed using microscopes to view images that cannot be seen by the eye, such as the water bear, also known as tardigrades, as found in the experience in the fifth-grade classroom (Figure 1). Being able to visualize at such a minute scale is one of the early science discoveries young scientists will remember. It is imperative that activities using a microscope are designed to have a favorable impact on our children's view of science (Holstermann, 2010).



**Figure 1. Image of Water Bear Collected by Scanning Electron Microscope (Pailly, 2015)**

There are various types of microscopes and activities demonstrating how they work (Zimov, 2004). Most common is the optical microscope, which utilize lenses and visible light to magnify images. A typical light microscope can magnify up to 500x the original image, which allows imaging of samples in the micrometer range, though the most advanced light microscopes can magnify up to 2000x and image to about 200 nm. A specialized light microscope, called a confocal microscope, is a type of optical microscope that uses a spatial pinhole to block out of focus light from imaging. This focused beam of light allows for direct, noninvasive imaging of live specimens.



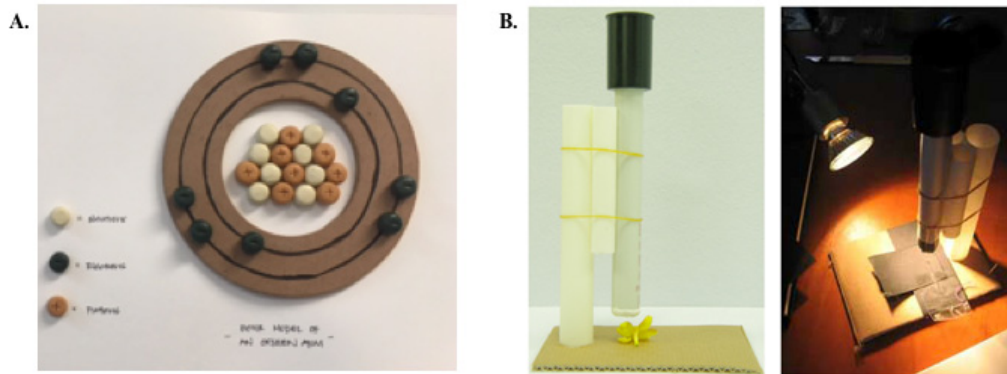
**Figure 2. Objects Imaged by Eye and Microscopes**

In 1931, Hans Busch developed the first electromagnetic lens, leading to the advent of electron microscopy (Rudenberg, 2010). The electron microscope uses a beam of accelerated electrons at the source to magnify an image (Robertson, 2013). The most advanced electron microscope, called a scanning transmission electron microscope has achieved 50 pm resolution and 10,000,000x magnification. Typical Scanning Electron Microscopes (SEM) can obtain a resolution of 50 nm and 50,000x magnification. In other words, whereas light microscopes can image cells or bacteria, an electron microscope can image small molecules and even atoms (Figure 2).

Activities have been designed to bring virtual scanning electron microscopes to the elementary school classroom (Harlow, 2011). This work aims to expand on this “virtual” aspect of bringing microscopy to the classroom by utilizing the RAIN Network to bring advanced technologies, such as a scanning electron and confocal microscope by live imaging and having students at elementary schools run the instruments directly through remote access. The activities are designed to bring a sense of excitement to science for the students, as well as help students understand the scale of the universe.

## 2. Modeling an Atom and Light Microscope

To begin, students build an optical microscope (NASA, 2000; Tsagliotis, 2012) and make a model of the Bohr Atom (Schaefer, 2017). By constructing the different models (Figure 3), students will become engaged in the activity and develop a rudimentary understanding of optical microscopy and makeup of an atom that contains protons, neutrons and electrons. Though these models are oversimplifications, they are appropriate for helping elementary students begin to develop an understanding of optical microscopy and atomic theory.

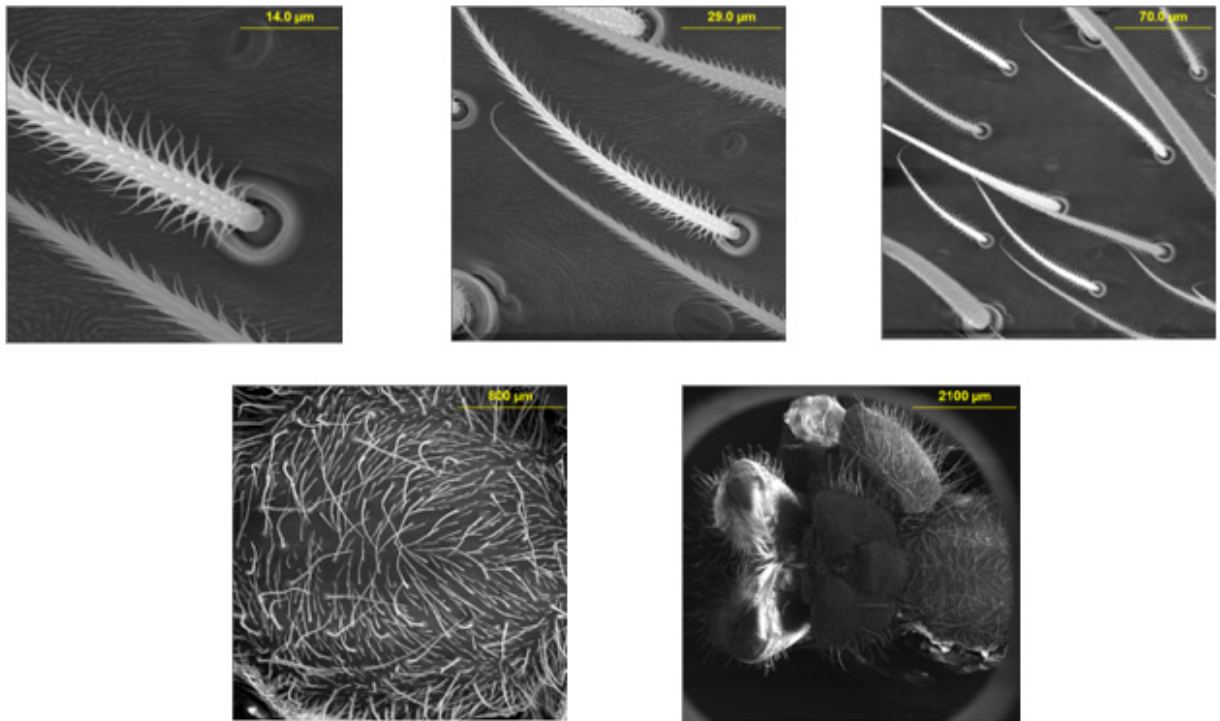


**Figure 3. A. Student Constructed Bohr Atom. B. Homemade Optical Microscope (Tsagliotis, 2012)**

### *2.1 What's That Image: A Guessing Game Using Remotely Accessible Scanning Electron and Confocal Microscopy*

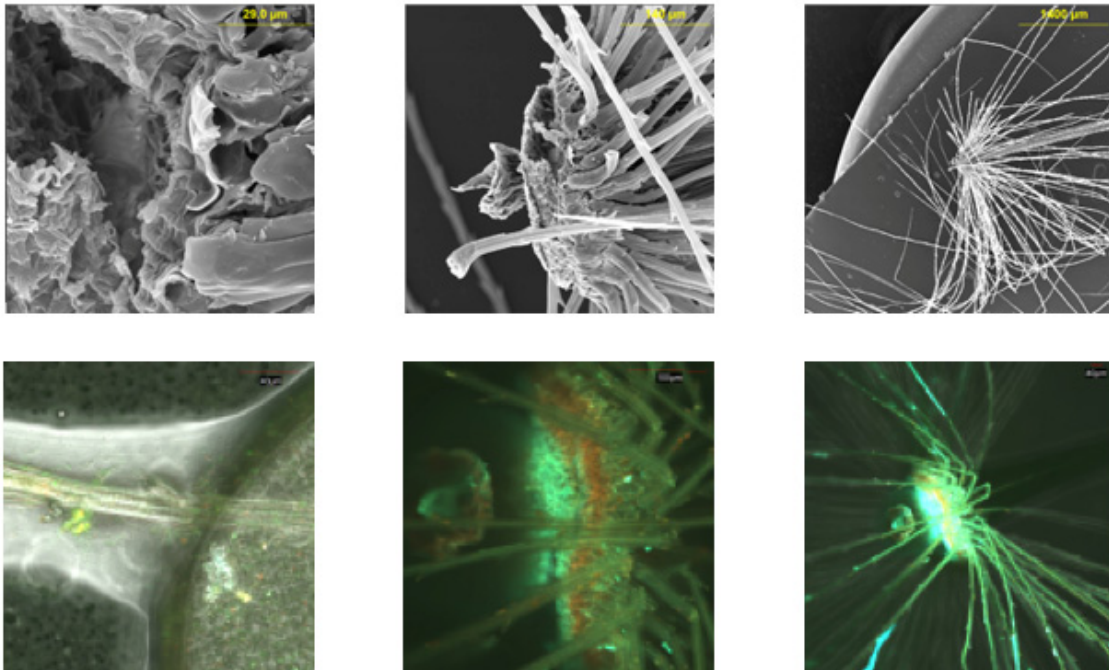
#### 2.1.1 Materials: Computer, Projector

After gaining student excitement and engagement through model design and construction students will be introduced to the RAIN Network, which provides use of Scanning Electron (SEM) and confocal microscopes for free. This free service available to educators allows classrooms to schedule live imaging with technicians at several universities where SEM and Confocal technology is available and can even be remotely controlled by students! Directions to set up a RAIN session can be found at <http://www.nano4me.org/remotearchive> under the heading "Getting Ready for Remote Access". It is important to note, that the RAIN Network also provides a scientist that will explain microscopy theory to the students if needed. In real-time, imaging of various samples was performed, starting close up in the nanometer range (Figure 4). Students guess the sample as it is zoomed out.



**Figure 4. Sequence of SEM Image from 5000X to 35X of a Spider**

In two separate groups of students (ten minutes at each microscope), the SEM and confocal microscope were used simultaneously to show the difference between optical and electron imaging (Figure 5). As students view the images and attempt to guess the sample, they are asked to take notes on the differences and similarities between the two microscopy techniques. SEM imaging can be magnified to a greater extent than the confocal microscope, and the images are all black and white, whereas the confocal microscope does not have as great magnification, but images are in color. In this sense, students can directly visualize the difference between the two microscopic techniques, which will be assessed after the activity. It is important that as imaging occurs, the scientist discuss the scale of the images being seen as a way to prepare students for the assessment performed in activity 2.



**Figure 5. Electron (top) and Confocal (bottom) Microscope Image Sequences from 5000X to 35X of Dandelion**

### *2.2 Scale of the Universe*

As a means of assessing the understanding of scale demonstrated by making the Bohr Atom and using the remotely accessible microscopes, students are given a sheet of paper with sixteen cutout images (Figure 6). Students cut out each image and on a separate sheet of paper, glue the images in the correct box with the following headings: eye, light microscope, electron microscope or cannot be seen (Figure 7). In this manner, students demonstrate simple understanding of the scale of the universe. This activity combined with using remote access to the SEM and confocal microscope aims to assist elementary students in visualizing different scales, which is an appropriate precursor to teach about the metric system. For more advanced students, the cutout images could correspond to a metric unit, such as nano or kilometer and students correctly place the image in a box that is ordered from smallest metric unit to largest metric unit.

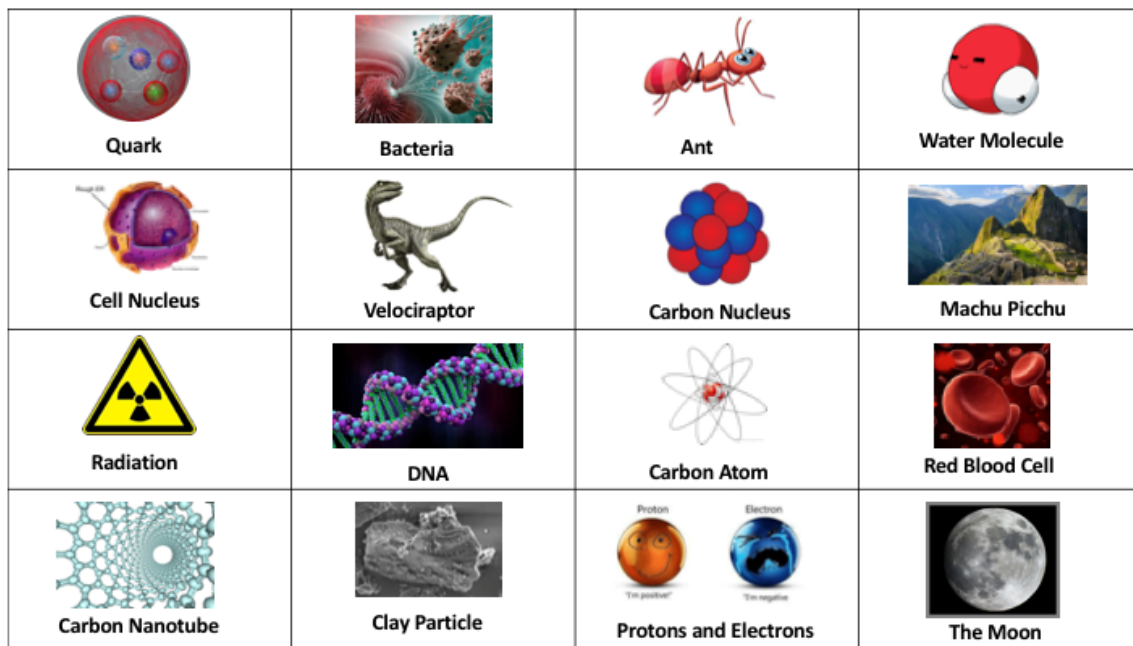


Figure 6. Cutout Images of Varying Scales

<b>Can't See With Any Microscope</b>	<b>Seen With Electron Microscope</b>
<b>Seen With Optical Microscope</b>	<b>Seen With Eyes</b>

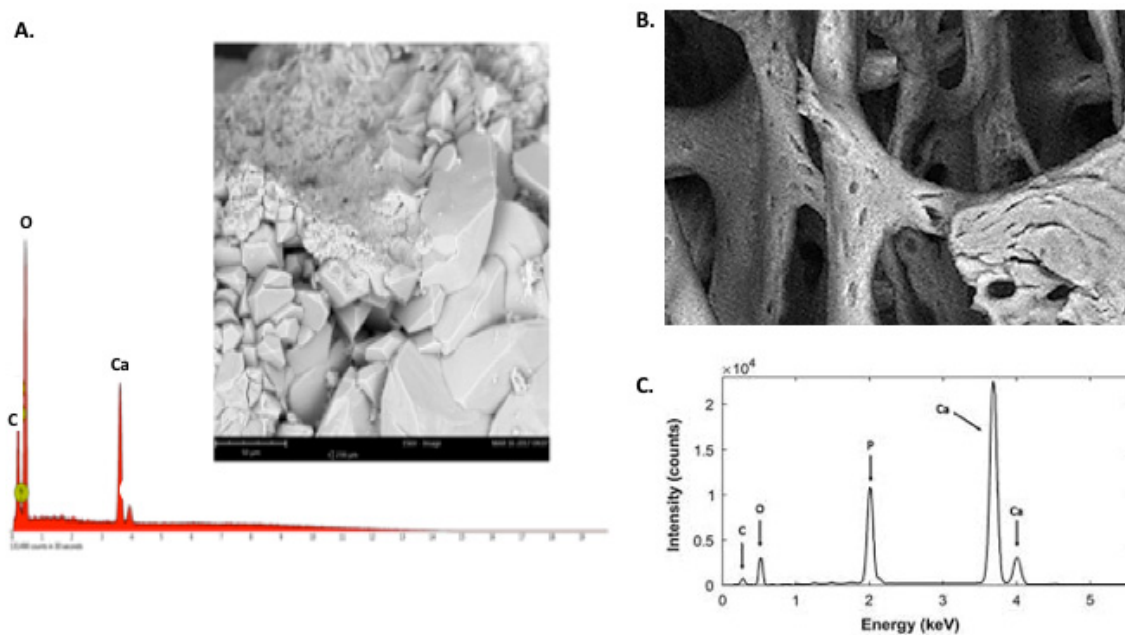
Figure 7. What Microscopes and Eyes Can See

### 3. Extensions

The power of the RAIN Network is enhanced when used to study natural science phenomenon. Educators can schedule a session to last two hours or fifteen minutes, depending on activity and need. Examples of quick activities that can utilize RAIN to enrich studying chemical composition are shown



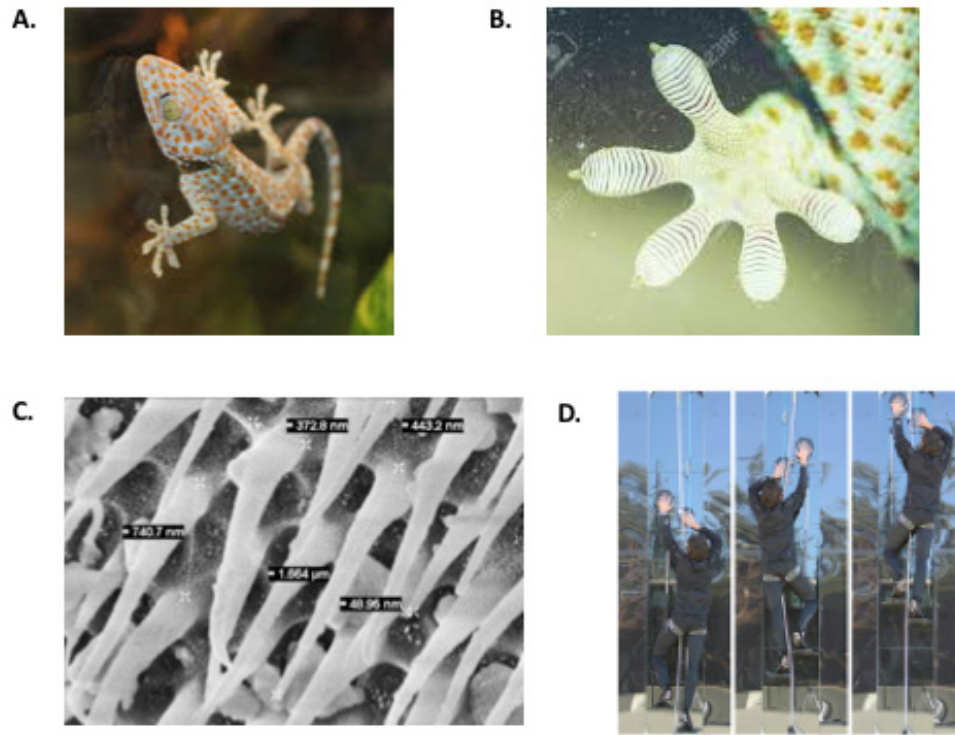
in Figure 8. If studying geology, one can image mineral samples and using a device called Electron Dispersive Spectroscopy (EDS) determine elemental analysis of samples. Imagine having a series of minerals or even everyday items from home, such as salt. The students can do physical examinations of the sample, discuss the chemical composition of each and then use RAIN to show what the chemical composition actually is. Figure 8A is a limestone ( $\text{CaCO}_3$ ), while Figure 8B is an image of rat bone that can show presence of calcium using the EDS as shown by the spectrum in 8C. This would be a great method of discussing compounds verse elements. Students can even send unknown samples to the RAIN Network and schedule a time to run the instrument themselves. They can be forensic scientists!



**Figure 8. A. SEM Image of Limestone with Elemental Analysis B. SEM Image of Bone C. Elemental Analysis of Bone**

The RAIN network does not have to be limited to chemistry. Biological structure and function can also be observed using the network. For example, geckos are able to walk up glass without falling (Figure 9A and 9B). This is due to the setae on gecko's feet (Figure 9C). A teacher could ask students "How can gecko's walk on glass?" After allowing time for answers, the RAIN Network can be used to zoom in on a gecko's foot. As the image is zoomed in to the nano scale, the setae on the gecko's foot can be observed and the fact that the attraction of these setae to the glass is what allows the gecko to walk on glass. Asking the students how this can be utilized in everyday life could lead to an interesting discussion. Maybe they will come up with tape or gloves, which would be appropriate since like in the movie Mission Impossible, adhesive tape inspired by Geckos feet has allowed people to climb up walls (You, 2014). In fact, a group at Stanford has been using the gecko feet properties to develop gecko gloves that can be used to scale glass walls (Figure 9D, Hawkes, 2014).





**Figure 9. A. Gecko on Glass B. Gecko's Foot C. Setae Nanostructures on Gecko's Foot D. Stanford University Gloves Inspired by Geckos (Hawkes, 2014)**

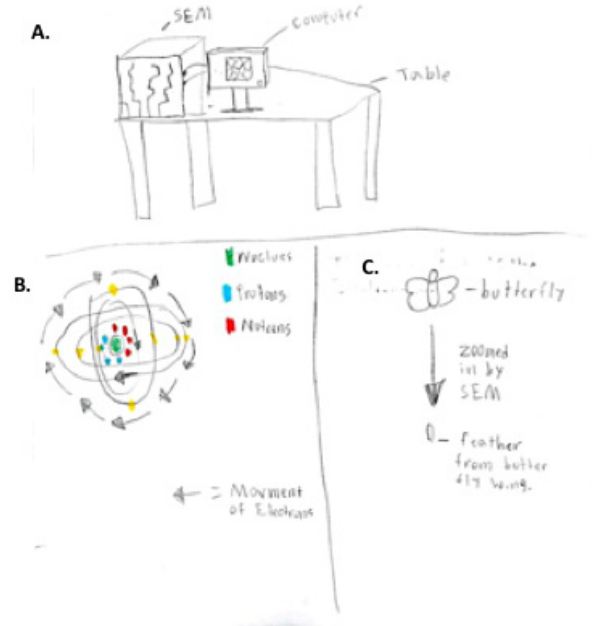
#### 4. Assessment

Students are assessed on how well they place the images in the correct section on the worksheet, as well as doing a summative assessment on microscopy. From these assessments, the teacher expressed a desire for the RAIN Network to increase the amount of discussion on microscopy theory before the two activities. An informative video, "Types of Microscopes: Electron, Light and Fluorescence" can be shown to introduce microscopy theory. The fifth-grade students performed well on activity 2, correctly placing on average 13/16 image, carbon nanotube and radiation being the choices missed most often.

A formative assessment, asking students to draw the microscopes, as well as pictures showing the sizes of images observed by the light and electron microscope, allows for students to demonstrate their sense of the scale of the universe. The three assessment questions can be asked as the experiment is performed or as a cumulative assessment at the conclusion of the activities. An example of a student's model is shown in Figure 10.

**Formative Assessment Scale of the Universe**

1. Draw a picture of a light and electron microscope.
2. Draw a picture of the particles that are not seen by the eye that create images in the light and electron microscope.
3. Draw a picture of the images seen by your eye, by a light microscope and the electron microscope. Images should be drawn demonstrating the relative scale going from eye to the light microscope to the electron microscope.



**Figure 10. Formative Assessment Questions about Scale of the Universe. A. Student Drawing of a Microscope B. Student Drawing of Particles Used in Electron Microscopy C. Student Drawing of Images Seen by Eye as well as Zoomed in with an Electron Microscope**

The following rubric can be used to assess the formative assessment in Figure 10:

**Table 1. Scale of the Universe Formative Assessment Rubric**

	1	2	3	4	
Addressing Images	Unseen	Student does not draw any pictures of matter not seen by the eye	Student illustrates the atom or light, but does not show protons or electrons.	Student illustrates the atom for the electron microscope and light for the light microscope.	Student illustrates the atom, as well as shows the presence of electrons and protons.
Addressing Images.	Seen	Student does not draw any zoomed in or zoomed out images.	Student draws an example of an image that can be seen by the eye, but does not demonstrate zoomed in images from microscopes.	Student draws an example of an image seen by the eye and one zoomed in image demonstrating scale seen by a light or electron microscope.	Student draws an example of an image seen by the eye and a zoomed in image demonstrating scale seen by a light and an electron microscope.

## 5. Teacher Feedback

The RAIN activity was performed in five elementary school classrooms. The teachers especially liked the expense of the program and the ease of set up. They also were enthusiastic having experts in labs across the country that could interact with their students. One teachers said “this was an incredible educational experience”. As a note, it is imperative that the teacher did a test session for using RAIN. At one school, the test session was done the same day and due to connection issues, the RAIN experience almost had to be cancelled. Therefore, the test session should be done at least one day before the RAIN session is performed in the classroom.

## 6. Conclusion

Understanding a sense of scale and size is vital for success in science and is an important concept within the Next Generation Science Standards. Two activities were designed and performed in an elementary school class that aim to bring an understanding of the scale of the universe to children at a young age. The use of a scanning electron and confocal microscope remotely and in real time brings a sense of how we can visualize small things. Used in tandem with the scale of the universe cut-outs assist students to visualize the very big to the very small. Using these tools helps to bring a sense of wonder and excitement to the class, providing students engagement in their science learning, promoting a critical spark towards pursuing a science degree in the future.

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### Standards Alignment

<b>Standard</b>	
4-PS4-2 Wave and their applications in technologies for information transfer	
<b>Performance Expectation</b>	
4-PS4-2 Develop a model to describe that light reflecting from objects entering the eye allows objects to be seen.	
<b>Dimensions</b>	
<b>Science and Engineering Practice</b>	
Developing and using models: develop a model to describe a phenomenon.	Students will be given opportunities to construct representative models based off the images collected from two types of microscopes in order to explain which tool is needed when.
<b>Disciplinary Core Idea</b>	
<u>PS4.B</u> Electromagnetic radiation: An object can be seen when light reflected from its surface enters the eyes.	The movement of electrons and photons can be used to create images of microscopic objects. Via the movement of these particles, students will be able to visualize an array of microscopic objects.
<b>Crosscutting Concept</b>	
Cause and effect Influence of Engineering, Technology, and Science, on Society and the Natural World.	Students will produce blueprints of their models via analysis of microscopic images with scientific instruments, demonstrating to students how their classwork is tied to technology.  Just as their blueprints determine how microscopes are used and in what circumstances, so too are the technologies used in advanced scientific research today.