Lesson Title	Zooming in on Microscopes
Length of Lesson	1 hour 15 min
Created By	Chris Ruhs
Subject	Biology, Physics
Grade Level	10-12th Grade
State Standards	Biology I 2(a); Physical 3(a), 8(b);
DOK Level	DOK 1
DOK Application	Straight-forward recognition tasks related to identifying features, objects and/or steps that don't vary greatly in form.
National Standards	9-12: A (Inquiry); B (Physical Science); C (Life Science)
Graduate Research Element	Scanning electron microscopy is an invaluable tool, enabling biogeochemists to see the surface features of sediments, microorganisms, and the micro-environments.

Student Learning Goal:
MS 9-12th Grade:

Biology I 2 (a) Identify the characteristics of living things. *Students will observe the characteristics of biological samples at the microscopic level, tying structure to function.*

Physical 3(a) Define and specify the location of the basic components of the atom. *Students will be reminded that electrons are negatively charged particles that surround the nucleus of an atom, but are here being shot at a sample and detected to form an image.* 8(b) Describe the emission of light by electrons when moving from higher to lower energy (photons as quanta of light). *Building on the idea that photons are quanta of light, students will be taught that light carries information about materials it interacts with, bringing that information to our detectors (eyes) so that we can understand concepts like color, opacity, reflectivity, and brightness. This understanding is in turn used as an analogy for shooting electrons at a sample, which interact with the sample (often knocking other electrons out of the sample) which are then detected allowing an image of a surface to be rendered.*

National Science Education Standards of Content 9-12:
A: Inquiry: Identify questions and concepts that guide scientific investigation. Design and conduct scientific investigations. *Students will be asked what photons are, how light works, what photons are, what microscopes do, etc. Students will be allowed to choose their own samples for viewing under the ProScope.*
Use technology and mathematics to improve investigations and communications. *Students will use the microscopes to image samples of their own choosing as a tie-in to other lessons.*

B: Physical Science: Structure of atoms. *Students will use their knowledge of electrons to understand how the SEM works.*
Interactions of Energy and matter. *Students will use their knowledge of photons to understand how sight and optical microscopes work, which will be used as an analogy for how the SEM works.*

C. Life Science: The Cell. *Students will be observing biological samples on a scale that reveals tissue structures and individual cells, and while the SEM cannot image* into *a cell, it can show the surface of cellular structures such as a hair follicle or insect eye.*

Materials Needed (supplies, hand-outs, resources):
Mobile Scanning Electron Microscope (provided by the Electron Microscopy Center at Mississippi State University through Ms. Amanda Lawrence and others), Microscope tech, ProScope, laptop, projector.

Lesson Performance Task/Assessment:
Formative:
To begin, the teacher/tech leads an inquiry-based, open discussion on

1. What microscopes do.
2. How ordinary (optical) microscopes work.
3. What light is made of (photons).
4. How photons are emitted from a source, interact with materials, and then carry information about those materials to your eye.
5. How photons are the only things students have ever seen (proven by turning the lights off and making it pitch dark—photons are what makes sight possible.
6. What electrons are.
7. How electrons are emitted from a cathode and are incident on a sample, interacting with that sample (knocking other electrons out of it), which are captured by detectors and converted into an image.
8. How electrons are able to give surface information only (shape and texture), and cannot give optical information the way photons can (color, opacity, brightness).
9. What is meant by magnification (up to 10,000 times for our SEM), scale (down to 10 um), scanning (rastering), and zooming.
10. What sample is being observed, including any information related to function or form, for example, an ant has a compound eye which can be seen as individual hexagonal shapes using this microscope, or hair grows in “sheaths” which can be seen as layers along the strand of hair similar to what is shown on the Pantene® commercials.

At this point, the teacher/tech can discuss other images captured previously using the microscope and/or change samples for further observation depending on classroom needs.

After observing and discussing other samples with the SEM, the teacher/tech can then change over to using the ProScope, which has the ability to image almost anything in the room at 50 X—200 X very rapidly, display it on the laptop and projector, and capture pictures for later use. Once instructions have been given on how to operate the ProScope, students are allowed to come up to "play" with the ProScope, taking whatever pictures they please. This activity holds students' attention extremely well, lends itself naturally to inquiry, gets the students thinking on the microscopic scale, and leads to some very entertaining moments as students image their hair, skin, ears, etc. American money, especially the penny, the one dollar bill, and the five dollar bill have very interesting details to find using the ProScope.

Summative:
Student-lead, teacher-guided end-of-class summary of the lesson.
Exam questions.

Lesson Relevance to Performance Task and Students:
This lesson plan works nicely for biology and anatomy classes that are interested in looking at living tissues, tying structure to function, and understanding the world around them on the microscopic scale. The lesson plan lends itself to inquiry and inspires students to ask questions of nature, i.e. think like a scientist.
This lesson plan also works well for physics classes that are discussing matter and particles, and how they interact. It is important for students to be able to think of photons as information carriers and to transfer that understanding to electrons. A deeper understanding and discussion on the instrumental components would be useful for advanced physics classes.

Anticipatory Set/Capture Interest:
The tools used in this lesson plan sell themselves, however, a few questions I have been asking in this lecture have proven extremely useful in capturing interest:

1. "What is the only thing required for you to be a scientist? (allow for guesses) You do not have to be smart, hold a degree, or know everything; the only thing required for you to be a scientist is curiosity…if you are curious, you will pursue knowledge."
2. "How many of you are going to college" (allow a show of hands), "how many want to be a scientist of some kind?" (allow a show of hands). Have each student tell you what they want to study or be, and then point out the relevant science behind that field.
3. "Think about this: the only things you have ever seen in your entire life are photons (pause) you have never seen anything but photons."
4. "If light is made of photons, then electricity is made of electrons."

Guided Practice:
Instructions on how to use the ProScope.

Independent Practice:
Students are allowed to play with the ProScope and take pictures.

Remediation and/or Enrichment:
Remediation:
Individual IEP

Enrichment:
Biology: have students bring in biological samples to observe and discuss.
Physics: open and discuss the different instrumental components of the two microscopes, talk about the five different types of physical interactions between electrons and samples, and how those interactions require different energy levels and detectors.

Check(s) for Understanding:
What is the only thing you've ever seen?
What is a photon?
What is an electron?
What do mm and um stand for?
Explain the scale bar and the magnification level.

Closure:
A student-lead, teacher-guided summary discussion will bring closure to the lesson plan.

Possible Alternate Subject Integrations:
This lesson plan can produces images that could be (and have been) used in math classes, chemistry classes, and even art classes.

Math: looking at angles and shapes of biological or crystalline structures and looking for patterns (such as the Fibonacci series or the golden ratio).

Chemistry: looking at different crystalline structures, thinking about the size of atoms, thinking about subatomic particles and how they operate.

Art: looking at samples with an eye for abstract or unusual artistic value.

Teacher Notes:
Having students bring samples to be viewed under either microscope can be very entertaining for the students.

Students will not want to use the ProScope until you have shown them clearly how to use it. Give them a demonstration on your own hair, clothing, etc, and show them how to take a picture (clicking the button). Once they know how to use it, they will want to look at everything—many students wanted to continue to look at materials/samples even after class was over.

Overall, this is an experience-based, inspirational lesson plan, designed only to expose students to high-tech tools used in science and to get them thinking about subatomic particles and about materials/samples at the microscopic level. This lesson plan is easily adaptable to almost any subject and acts a supplement.