Learning Goals, Anticipated Outcomes

Many classes on Materials start by introducing microstructures that cannot be seen by the unaided eye. In fact these images can't be seen at all: they are produced by bouncing electrons off surfaces. Example:

> introduction to Materials Science
> The student will gain a basic knowledge of metals, polymers, and ceramics along with some aspects of nanomaterials. We will cover the fundamental properties of materials along with the fundamental aspects of phase diagrams and concepts of degradation and failure.

We start with the axiom that the nature of most materials exists beyond our ability to see. Rather than map unobservable qualities into a visual medium (as is often done with electron microscopy) we will investigate observable properties including mutability, resonance/deflection, consistency, hardness, spectral emissions, absorption and fluorescence.

I have gathered 100 questions that you should be able to answer on the last day in a normal introduction to Materials Science. For the first three meetings we go over these questions and we don't try to answer them. We may discuss strategies for answering the questions and offer things to try that would narrow the possible answers. We refuse to answer them out of respect. There is no need to rush an answer, and it's certainly more fun to entertain a full range of answers.

Students usually get attached to some of the questions. The first assignment is to adopt one of the questions. The adopted question becomes the center of inquiry.

Example. Let's say that you become interested in why (most) metals feel cold to the touch. You have your experience, a few ideas, an explanation from your parents, perhaps even a chapter from your AP Chemistry textbook. We will ask you to put away the explanations and prove it to yourself using your eyes, ears, fingers, and the tools you have in your pocket to make a personal conclusion. You also have help from your colleagues and the scientific method.

You will formulate *falsifiable statements* to help design experiments. *Falsifiable statements* are lovingly explained in Karl Popper's book *The Logic of Scientific Discovery.* It's a process:

1. start with an idea about something
2. try to prove your idea wrong by describing it with falsifiable statements
3. design experiments to prove the falsifiable statements correct, disproving your theory
4. iterate until every angle has been tried
5. if the idea holds up then publish the experimental results

Back to our question: *why do most metals feel cold to the touch?* Let's say that you want to narrow your ideas before offering an theory. Here are a few falsifiable statements to help you get focused:

1. Metals are colder than other materials (measure their temperature)
2. metals conduct heat better than other materials (measure their heat conductivity)
3. metals pull the heat out of materials that are less conductive (test heat transfer between metals and skin and other materials)
4. Metals will not feel cold after they reach body temperature.
5. Other materials in contact with the body resist heat transfer.

Anyone who does these experiments will be in a good position to advance a hypothesis about why metals usually feel cool to the touch. Even more important, the student went through a process of hypothesis. experimentation, synthesis and discovery before accepting an answer.