

**Early Discussion:**

A number of ideas were brought up regarding the importance of observing the natural world, without being too quick to pass judgment on it. As a number of students noted, so often do we humans make an effort to rationalize and categorize our world. We are constantly seeking containers to put ideas in, explanations for phenomena and methods for synthesizing knowledge. As Jerome Bruner put it, *"To perceive is to categorize, to conceptualize is to categorize, to learn is to form categories, to make decisions is to categorize."* But to categorize prematurely, or absolutely, can often lead us astray. It is important, we found, to be willing to step back from the role of "model builder" and instead act as a noticer-of-experiences for a time. Playing this kind of role is easier said than done, and in class I expressed my concern with my ability to do so effectively. In an effort to understand how to become a more attentive observer, I asked the teachers if they had any advice. TA offered an answer that served as a wonderful metaphor and a great start to the class. To paraphrase:

*"Learning is like a geode. On its exterior, it is hard, rough, and difficult to penetrate. Just under its surface, it remains mostly the same, with a few filaments of gems scattered here or there. Further in, the filaments become more plentiful, until you reach its center, where crystals prop up in every direction, somehow managing to create great beauty in an otherwise ordinary object."*

**The Experiments:**

There were a significant number of experiments conducted over the class period, and I took notes on all of them, but for the sake of brevity, I will outline the experiments with light rays by LJ, JF and TA in detail, and note the other experiments at the end of the section.

These three experimenters used the strange little light ray machine we used on Monday, and continued experiments with the viewing of light rays in various kinds of planar lenses.

The first trial used a convex lens. LJ noted that the light entering and exiting the lens always seemed to bow inwards from the central axis. As a result, the experimenters discussed what was happening with the focal point of these light rays. "Will the focal point be in the same place if we turn the lens around?," TA asked.

Next came an effort to use a convex and a bi-concave lens in series. "This is just like Galileo's telescope, right?," TA asked. I asked the experimenters to talk about why they wanted to use a double concave lens for their mock telescope. "What does the concave lens give you that the convex alone can't?," I questioned. Here the experimenters noted that the use of the bi-concave lens seemed to take the inwardly facing lines of the convex mirror and make them seemingly parallel again -- the perfect

conditions for such light rays to enter your eye! The experimenters commented excitedly about their discovery. To paraphrase: "A concave lens by itself makes light rays go away from each other, and a convex lens makes them come together, so it makes sense that putting a concave lens next to a convex lens straightens things out again!"

Next, a different, very strange kind of lens was used. It has one convex face and an opposite concave face. From previous experiments, the experimenters were both perplexed and interested by the fact that the image through such a lens seemed to be the same no matter which way you looked through it. "How could this be?," someone questioned. Placing the lens against the light rays revealed something odd though. If the lens was put with its concave side facing the light source, the rays remained roughly parallel, but appeared to be closer together. If the convex side faced the light source, the lines appeared parallel but farther apart. Therese's clever experiments later in the day would verify that there was something very interesting going on here.

Next, as the lenses were removed from the table, LJ made a single comment. "Huh. The light spreads on its own." "What do you mean?," I inquired. "Well, the light coming from the light rays seems to spread out the farther it gets from the hole." I immediately got excited by this, but held my tongue so we could both ponder the thought for a moment.

I spent the next few minutes observing the other experimenters and their setups, and when I returned, I noticed that TA, LJ and JF had many lenses of different shapes and sizes, placed seemingly randomly in from of the light rays. They appeared to be noticing incredible amounts of detail at incredible rates, and were doing so without saying a word, so I admit it was a little hard to get caught up to speed. Instead I joined them in the exploration for a moment, noticing things myself, acknowledging features and changes in shape, only to let the idea pass, as if in some kind of meditative state. LJ broke the silence. "Look at the blue light over here." I looked at where she pointed, and sure enough, there was a blue ray of light emanating from one of the lenses. I was completely dumbfounded at this point. This was so incredibly exciting because I was witness to some miracle of nature, brought into being by this machine of these three experimenters, that was creating behavior I absolutely could not justify. There was no blue acrylic on the light ray slot, only red. And yet somehow an entirely different color of light, appearing seemingly out of nowhere, presented itself to us. This was one of the great moments of the day -- a beautiful, unusual observation, and I had absolutely not justification for what was happening. And that was okay.

The final experiment I witnessed with the setup was sometime later, when LJ was working by herself. She had set up two lenses, one triangular and one trapezoidal, and was noticing rainbows of colors appearing on the fringes of the lenses. "That's interesting," she said. "What is?," I asked again. "Well, the rainbow enters one lens here, but when it bounces off, the colors are reversed. But when the light passes right through, the colors aren't reversed." "Why do you think that might

be?," I questioned, being genuinely curious and not having an answer myself. She then began drawing a diagram of light rays, labeled A, B, and C, and noted that if the light was bouncing off a surface in one order when it entered, then a consequence must be that the order is reversed when it is reflected. This was an astute observation -- one that easily could have been missed -- and I was pleased that her efforts to draw what she imagined was going on aided her development of an explanation.

The other experiments were equally interesting, but it would take many more pages to describe them all in the same detail as the light ray experiment. Yan spent a good deal of time observing images as seen through lenses, noting reflection, and changes in light around the edge of the lens. MC created a very clever experiment to observe motion: using carbon paper, she dropped a ball from a recorded height and observed the locations where the ball hit the table surface. Many experimenters explored the ramps available, doing experiments with spheres of different weights, materials and size. Strobe photography aided these efforts to some extent, and the final minutes of class were used to record a number of trails on the Edgerton Center's high speed camera.

### **The Experimenters:**

I spent some of my time observing experiments, and some time observing the experimenters. It was interesting to see how these different observers explore their worlds. TA, for example, is a very social explorer. She's gladly let you know what she's thinking, step by step, and make an effort to involve you in any way she can. Yan, in contrast, is a very private experimenter. You can see deep levels of concentration when she works, with only a few verbal hints of her internal dialogue. MC and JF are both very playful experimenters, paying close attention what they see, and conducting trials seemingly because those trials are both fun and informative. LJ is a very critical experimenter, who seems to take her work seriously, but has a kind of driven curiosity that keeps her working steadily for very long periods of time. As Edison said, "genius is one percent inspiration and 99 percent perspiration".

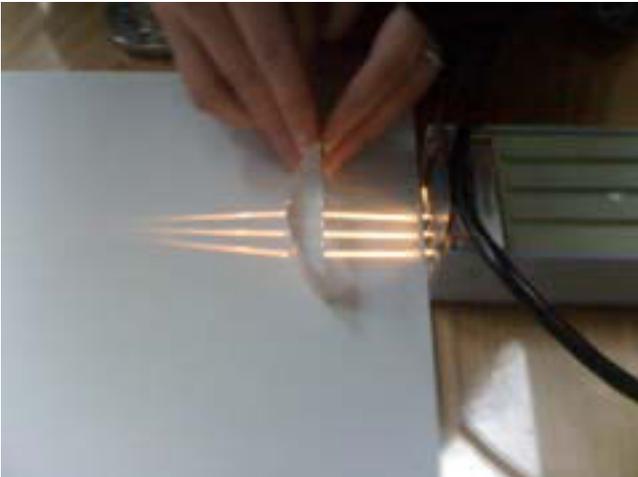
I played the role of observer again, but this time not of the world but of my classmates. I found it difficult at times to hold back from jumping into the explorations, my eagerness getting the best of me, but after Elizabeth's coaxing I worked hard to put my own curiosity and need to "be in the know" about everything aside and holistically observed the experimenter-world relationships being set up. By the end of the class I felt like I was starting to get the hang of it, until I noticed that class time was up. This was hard, as I wanted a hand in trying some of the experiments I had watched throughout the afternoon.

### **Overall:**

This class period was a very fruitful and productive one, with a lot of great thinking and great observation going on. I don't think this my understanding of the material and method of the class could be as clear had I not been put in the research-

teacher for one afternoon. I move forward promising to observe more, judge less, and experience the natural world and the things in it for what they are.

**Accompanying Images:**





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