Observing Materials

Observing a candy stick of white glass wrapped with clear glass evolve into to a bowl laced with intersecting lines with just one bubble caught in the middle was fascinating. Fire and water, heat and cooling, circular movement, gentle breaths, manipulation with tools, an artistic eye, and a keen sense of knowing the feel of material all seemed to play into the craft. First, came the joining of 30 candy sticks, carefully arranged on a ceramic stone – gently heated 10-15 seconds at time, out of the fire, gently manipulated, until all were aligned end to end and side to side and back in for a bit more heating and softening, until 30 sticks were one piece. Next, 1050 degrees F turns hard glass into thick molten lava, soft, malleable and ready to assume a shape created by the artisan. A long rod scoops up this lava and with a few turns of the rod a collar emerges and with a few rolls over the candy stick piece, the canes are attached to the long rod. P takes a tool and begins to mold the canes into a circular form. The glass cools quickly; it seems to be less malleable. Back into the fire for reheating. Out again for more shaping. He seems to work in 10-15 second intervals, his work following a rhythm of heating and softening, rolling and shaping, and cooling and hardening, until the desired effect is achieved.

I was struck by how sticky glass is when it is hot. It reminded me of a glue stick. The hotter it gets, the more gel like. Knowing this about the glass allowed P to attach objects to each other. I also noticed how glass moves when it is hot. When P was rolling the rod on the metal table, I could see the glass sway with each twist. Gentle, rhythmic rolls of the rod began to bend the white glass. This reminded me of working with clay – taking a ball and rubbing it between your hands. As the clay warms, and the rolling continues, the ball is slowly transformed into a cylinder. With more rolling and a bit of stretching, your cylinder becomes narrower and narrower. Knowing this property of glass, allowed P to manipulate and shape. Then, I noticed how quickly the glass began to harden, the movement of the white slowing down, until you could no longer manipulate. This reminded me of candle wax dripping down, until you have this creation hardened on the side. Knowing this property about glass, P had a sense of how quickly to work and when to refire. He also knew at what point the glass would no longer be malleable and he could cut off a piece that was not wanted. Last, the cooling process seemed to be just as critical to the creation of bowl. As W explained, if object you are creating cools to quickly, then the glass can shatter. It seems to me that knowing more than the melting or hardening point of glass is essential. You need to know what glass can and will do at different temperatures. To learn this must take much practice and lots of observation.

From an artisan perspective, it struck me how P had a sense of what he wanted to build and seemed to be able to create, not from a picture, but from a sense of knowing by observing and doing. This must have come from years of practice and developing the skill. He mentioned that he has made 40 of these objects and he has been happy with only 4. W also shared with us how after a while you come to know the feel of the glass. This inner knowing allows you to take risks and to do more complex and delicate work. This speaks to the iterative process that we (our class) are involved with. You do something, find out what works and doesn't work, revise, and try again. After each trial, you have gained a bit more knowledge about the material, the effects, and possibly, what you might do differently next time. I also think about the habits of mind that you would need to stick with this process. It seems to me that you would have to have a passion

for what you are doing. You need to have a sense of perseverance. You have to have confidence or trust in the process, knowing that at eventually skill, knowledge, and perhaps a bit of luck will all come together and your creation or idea takes a form that is pleasing.

Recreating history is also a theme that our class work and P's work share. He talked about the traditional Venetian style of glassblowing and how he learned from Italian masters. He is skilled in this technique. Up in 402 – we are busy immersing ourselves in explorations, trying to make sense of devices and instruments of Galileo's time. In the process of recreating, I am learning foundational ideas about optics and geometry as well as the tensions between traditional ways of thinking and the evolution of new ideas. Recreating seems to put you in a different time and place, enlarging perspective. However, we cannot totally recreate the times. We have knowledge that was not available to the people 400 years ago. P mentioned that the furnace is made of aluminum bricks. These bricks are preferred as aluminum resists the corrosion of glass. I imagined that this actually improves the quality of the final product.

Another thought, at the start of our tour, P was describing the creation of the thin globe that sat in front of us. This globe, still in the design process, is being created to solve a technical problem in industry – to house a camera. P mentioned that it wasn't quite right yet as there was too much variation in the thickness of the glass. This variation (up to $1/16^{th}$ of an inch) would cause too many distortions. This makes me think about the quality of the lenses back in the 16^{th} century. How much distortion existed then? What impact did this have on what Galileo could see through his telescope. In observing the moon, did some of the observations arise from distortion or imperfection?

The idea of geometry – I know that geometry was involved in the making of this bowl. The rods were all the same length. The white glass needed to be bent, forming intersections that would hold just one air bubble. The tools they used measured distances. When making the second cup, this was extremely important as it had to slide in and fit just right for fusing. Perspective seemed to play a role in the shaping of the bowl, too. P spoke of having to have a larger air pocket in the outside glass so he could enlarge the inside cup into that space. What surprised me is how P and W were working from models in their heads, not from models on paper. They were visualizing and seemed to have a feel for the proportions, rather than always using a tool to measure. They also know when it is important to be precise. Geometry seems to be an integral part of their work, too.

Readings

I have yet to reread the readings for depth and subtlety. My commentary shall be brief and over the weekend, I will revisit and think more deeply. My first impressions are that Kepler's response to Galileo's work seemed a bit tongue and cheek, almost surprised that Galiloe was seeing more than Kepler had seen himself. Kepler describes his surprise at how far and wide reaching Galileo's work and ideas were and how little Galileo knew of Kepler's work.

Heilbron and Einstein present a historical perspective, giving some overview of the politics and influence of the Catholic church and why Copernicus's theory was so controversial. In this piece, I get a deepening awareness of Galileo's character and how his work was changing the

face of science from one centered around authority to one based on observation and mathematical analysis. However, Einstein suggests that we take a closer look at the idea that Galileo was the father of modern science. Were his methods empirically based? Under what circumstances did Galileo oppose the theories of his time? These are questions that I would like to reflect more on.

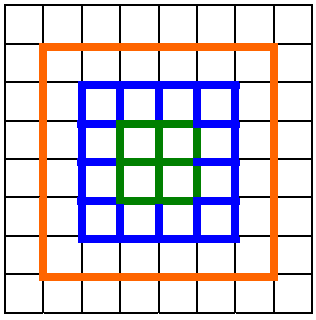
Current Explorations w/lenses

LJ and I continued our work with lenses. Exploring with concave and convex lenses, I have come to understand that a concave lens shrinks and increases the clarity of an image. A convex lens expands or magnifies the image. There seems to be two focal points to these lenses. One focal point you can see the image right side up. At the other focal point you can see the image upside down. I think this happens because the light is bent as it moves through a curve surface. The degree of the curvature determines how much and which way the light bends. I have yet to determine how you can predict where these focal points lie. [Learned today that the light ray bends as it hits the curved surface, travels through the surface in a straight line, and then exits at an angle.}

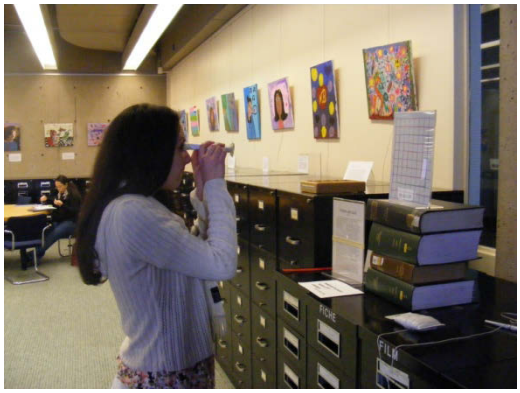
We also found a pair of lenses that work similar to what we perceive is happening w/Galileo's telescope. The following discussion describes our work.

We began with experimenting with light and how it moves through curved surfaces. I have been playing with this idea, trying to find a way for me to see where the lines travel after leaving the lens. I have had little luck. I moved away from the lens to experimenting with a glass of water. I put objects on one side of the glass and looked through. The objects appeared to bend, matching the shape of the glass. You could also see a reflection of an object in the glass. Again the object curved, matching the shape of the glass. The best representation of this was seen when I looked through my water bottled. The curvature was so clear. So I have just confirmed for myself that when light passes through a curved lens, the light bends. I am still stuck on how to represent these sight lines geometrically on the paper. I need to play with this more. Because I am stuck and the ways of representing are not making sense, I move on.

LJ and I begin to make a telescope. We have a 6 inch, 11/16 inch in diameter tube. We attach the very thin concave lens to one end of the tube. We attach the plano-convex lens to the other end (convex shape is on the outside). How does this work? We create a set up to measure how much we can see at different distances. How much does what we see increase or decrease.



First, I look at a some writing and describe how much of it I see at varying distances. This doesn't help us tell how much is magnified or not. We create a grid. It looks like this:
We then created placed this so that the center of the paper was at eye level. Standing as close to the squares as we could get, we moved back until we could see 2 x2, then 4 x4, then 6 x6, and 8 x 8 squares. Each time we recorded the distance. We repeated this twice, once with Leigh and once with me. We took the average distance between our two measurements. LJ then used a similar tube with no lens to see what she could see. The results are summarized below.



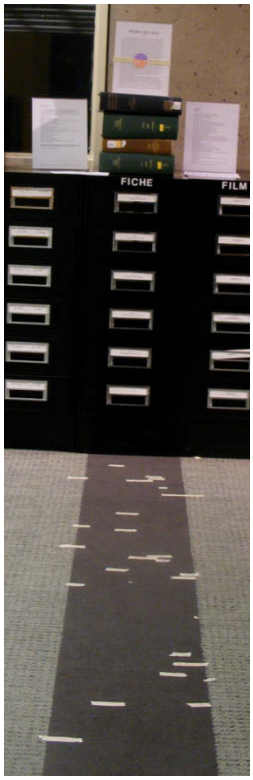
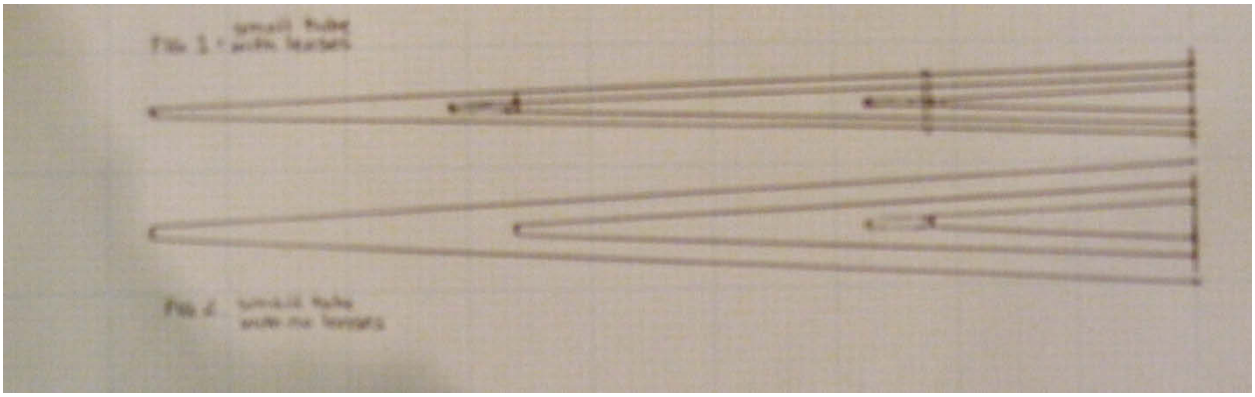


Table 1: Distance, Squares Seen,		
Distance (inches)	# of Squares Seen	
	w/lenses	No lenses
22.5	2x2	2x2
56.25	4x4	6x6
86.25	6x6	Almost entire paper
116	8x8	More than all of paper



When graphed, we notice that the greater the distance, the more we can see. We conclude that the concave lens shrinks the image and at the same time makes the details more clear. The convex lens expands the shrunken image, giving the appearance of a magnified object. We see a smaller portion of the object in much greater detail.

LJ and I notice that this drawing is very similar to the drawing we drew when we were experimenting with the frame and the relationship between the amount of an object that we can

see as we move the frame closer to the object. It also seems similar to the drawing in the Starry Messenger.

I am still puzzling over how do you calculate the focal point of the lens. What is the relationship between the focal point of the first lens and the second? What would this tell me about the magnification? Also, what happens when we change the length of the telescope? Our plans are to build another telescope with two tubes thus allowing us to change the length of the telescope and perhaps focus on objects that are further away.

In addition to this work, LJ and I began to explore the properties of a hand lens (two convex lenses). We directed a beam of light (originating from a flashlight) through the lens, trying to determine which way the light bent and where the focal point might be. In the process, we noticed a mysterious bright, blue dot of light on the surface of our paper. It was not aligned with the flashlight. Investigating further, we determined the light outside of the window was shining through the magnifying lens with the light rays converging in this one point. We worked on replicating this with the flashlight and hand lens and were successful.

Critical Exploration

Learner

Our walk home after class is filled with discussion and exploration of confusion, content, and teaching strategies. I am reminded of the interaction between teacher-learner-subject matter and how each influences the other. From a learner perspective, I am living with a sense of confusion. I do not know how lenses really work; I only have a growing number of observations that are suggesting that convex and concave lenses behave differently. This confusion is not particularly troubling to me (unlike other times when ambiguity and confusion put a halt to all learning). I have questions and I am still finding ways to try out ideas. I am beginning to see that the many different experiments are yielding the same results. I am looking to some of the readings to help me figure out what might be occurring. I reread the Starry Messenger. While Galileo speaks quite a bit about the moon and the moons of Jupiter, his discussion of how his telescope works is skimpy. I can't make sense of how it might work. In fact, I don't think he is quite sure. The part that is creating the most anxiety for me is the geometry. While I can draw some of what I see, I don't recall enough to figure out relationships. I am thinking that I did not work enough with the compass and never did explore scale (the day we talked for a long period of time about who's perspective were we taking when the lute was drawn). I am thinking that this experience would have been useful for me. Another issue that I seem to be struggling with is the pacing. I feel that I need more time to explore, think, and reflect. Each day I leave feeling that I have just scratched the surface. I go home, I do more exploration. I write. I read. But I am moving on too soon. I am now at the point where I feel that I am not digesting the readings. This dismays me as I find the historical perspective so enriching. I think this brings home the point that critical exploration is not to be rushed. Last, this entire experience is igniting a deeper interest in the history and nature of science. I am currently reading A. E. Chalmer's book *What is this thing called science?* It just so happens that in his discussion of the limits of falsification as a way of deriving scientific theories, he discusses at length the Copernican theory and Galileo's contributions to this theory. I now want to sit a bit more with this week's readings and compare

the ideas between Kepler, Einstein, and Chalmers. (Thanks for the recommendation for the book about the nature of science and chemistry. I will check it out.)

Teacher

Two thoughts jump out at me. First, there is much work that Elizabeth puts into setting up the class – in terms of activities, supporting materials, and sequencing of events. The activities seem to build on each other. After completing the readings and finishing the first day's activity, I found myself wanting to know how the perspectographs work. I go to class and that is the day's activity. While this might be coincidental, I think it is purposeful. If we are recreating experiments from history, then it makes sense to experience as many facets of this time period as we can. Building familiarity with the instruments of the time offers us a more complete picture of Galileo. For me, it also helps build my understanding of the science of optics. Second, the readings and glassblowing demonstration are really adding interest and offering me a different way of approaching the topic. This structure is demonstrating to me how important it is for the teacher to have some knowledge of the topic of study. Knowing the subject matter and the resources allows the teacher to provide or set up experiences that lead the learner deeper into the exploration. I also appreciate the notes. These offer another perspective on what is happening in the class. It is interesting to reread and see how different we are in interests and approaches to problem-solving. Last, as I reflect on all of this, I am thinking of how I might create a similar experience for 5th graders. What are the texts available to this age group? (Starry Messenger by Peter Sis). What diagrams would make most sense to them? Which part of this exploration would be most appropriate – lenses? Telescopes? Drawing? Given that most students this age in a traditional public school setting have had very little experience with style of learning, what could I do to scaffold the experience?

Subject Matter

We talked about the subject matter and how it seems to be so wide and encompassing. There seems to be so much to uncover. Isn't there a way to present less; to focus our attention on just one piece? YY didn't think so. She raised the issue of complexity – didn't Eleanor talk about how important it was to be immersed in the complexity of the subject. It is this complexity that offers possibilities and keeps us engaged. Yes, this is a great point. Galileo is complex. In this complexity, there is a richness. I see that I can explore the science, the person, and the history. I also see that dissecting each piece without considering the other tells only part of the story. Great subject matter has many facets. To simplify the story would reduce it to facts and bits and pieces of knowledge.

EC.050 Recreate Experiments from History: Inform the Future from the Past: Galileo
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