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# Contents

# Preface

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Teaching is a question of context itself: as the Oldenburger Research Group Physics Education/History and Philosophy of Science accounts in their research for the historical context of science education, it appears to be consequential to focus on the role of the history of science in the teaching of science. Therefore, the goal of the *6th International Conference for the History of Science in Science Education* hosted in Oldenburg addressed the question of how historical context can promote the development of scientific understanding.

The richness of the 28 papers presented and the high quality of the discussions of the conference encouraged us to publish a volume, in which the majority of these stimulating papers is assembled. One reason why not all papers are to be found in this collection is due to the Editors tide timeline for the final paper submission. Some presenters had other obligations and could not submit their contributions in time. As editors, we considered it important to publish the obtained papers within a very short time as we feel that the topics presented and discussed are of major relevance to the future of our research field. This resulted in publication of nineteen conference papers in this volume.

We greatly appreciate the financial support of the German Science Foundation (Deutsche Forschungsgemeinschaft), the Ministry for Science and Culture of Lower Saxony, and the EWE Foundation (EWE-Stiftung), which made the realisation of this conference possible. We also thank the Carl-von-Ossietzky Universität Oldenburg for supporting the conference. Furthermore, our thanks go to the members of the Research Group Physics Education/ History and Philosophy of Science at the Carl von Ossietzky Universität that took the responsibility to make this conference a success. The publication of the conference proceedings was financially supported by the EWE foundation.

Peter Heering and Daniel Osewold
(The Editors)

Peter Heering, Daniel Osewold (eds.)

# Constructing Scientific Understanding through Contextual Teaching

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Struik, D.J. (editor): 1969, *A Source Book in Mathematics 1200-1800*, Harvard University Press, Cambridge.

Woodhouse, R.: 1810, *A History of the Calculus of Variations in the Eighteenth Century*, Chelsea Publishing Company, Bronx, New York (reprint of *A Treatise on Isoperimetrical Problems and the Calculus of Variations*, originally published 1810).

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# Mirrors, swinging weights, light bulbs…: Simple experiments and history help a class become a scientific community

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**Abstract:** Nine "honors" undergraduates at a public university found unexpected surprises when asked by their teacher to look in a mirror at an angle, swing weights on a fishing line, and light a bulb with a battery. Euclid, Galileo, Volta, and others long ago explored these 'simple' experiments seriously, and the students – exposed to historical accounts and apparatus, and encouraged to observe carefully – began to see why. Old queries were repeated with modern instruments: timing a pendulum with a cell phone, dissecting an "Energy Saver" bulb, beaming lasers into jello, and congealing ice cream with liquid nitrogen! Respect deepened for historical predecessors, and for each other's inventions and thoughtful conjectures. When encouraged to develop a shared understanding of both history and phenomena, the students recast themselves as thoughtful and reflective explorers of the physical world. They became a community of "scientists" and gained firsthand insight into how shared knowledge is created.

## Introduction

A class has many eyes, hearts and minds, each having potential for engaging with others and the subject. That diverse potential can emerge in unexpected ways where relationships matter and the class becomes a community. In the process they create shared knowledge, in which everyone has a part. This paper describes such a class, where so-called simple experiments and science history were the context for explorations and discussion among nine undergraduates.

The early twentieth century American philosopher John Dewey envisioned the organic interplay of life and learning as fostering a "miniature community … in close interaction with … experience beyond school walls" (Dewey 1916, 360). David Hawkins, leader in the Elementary Science Study of the 1960s, saw teacher and learners and subject as making up "a community of subject-matter and engagement which extends *beyond* the circle of their intimacy" (Hawkins 2000, p. 49). For both Dewey and Hawkins, the vitality of teaching and learning relationships enables participants to reach out to materials, each other, and to resources and people not present in the classroom.

Some recent science education literature depicts classrooms where relationships contribute to learning (Gallas 1995, Hammer 1997, Osborne 2001, Zembylas 2004;

Zion 2004). For example, by reflecting on distrust in urban schools – and realizing that trust is essential for doing science investigations -- an African-American chemistry teacher sought to develop mutual trust with those in his class (Sconiers 2000). This teacher's finding about trust correlates with philosophical and historical analyses of science, where trust is foundational to conducting science as a community (Hardwig 1991, Rolin 2002, Shapin 1994; Grasswick 2004), enabling shared evidence, critiques and dissent, to the extent that relationships among individuals and communities are inextricable from the new knowledge being generated.

These relational qualities of knowing and learning underlie 'critical exploration', the method of research and pedagogy developed by Eleanor Duckworth (2005, 2001, 1999, 1991) from the clinical interviewing of Piaget (1926/1983, 1936/1954) and Inhelder (1974). To set conditions for critical exploration, a teacher seeks to create a classroom environment where students feel safe to explore authentic materials and express tentative understandings as these evolve. Simultaneous with *students'* explorations of the subject, the *teacher* explores how they engage with it and their evolving activities and inferences. The teacher does this research so as to respond to students in ways that may keep their investigation going and widen possibilities by which they may engage the subject and apprehend its behaviors or patterns. Relationships among teacher, learner and subject, along with the history of what goes on in critical explorations, are inseparable from this work and from the new knowledge, the "wonderful ideas" (Duckworth 1973) that students generate through exploring.

In communicating critical exploration as research, narratives are derived from the experience with supporting documents (such as photos, journals, and assignments) and accompanied by the reflective writing of teacher and participants. Such narratives of learning together with the accompanying confusions, uncertain understandings and relationships become, in turn, a resource for further exploration. In these narratives, community becomes conspicuous, as Duckworth wrote in opening her account of the floating and sinking investigations of a class of adults: "This is a story about the collective creation of knowledge: its multiple beginnings; its movement forward, backward, sideward; its intertwining pathways" (Duckworth 1986).

## Setting

A new science course offered through in the honors program at the public university was the setting for the critical explorations presented here. The students in the course were beyond their first year of college and all but one had chosen non-science majors.

Many expected that taking a science course meant formulas and cookbook labs. But instead, together we explored pendulums, mirrors, batteries and bulbs, magnets, prisms and tuning forks.

The design of this course was an extension of my earlier teaching research with students' science experimenting in relation to history (Cavicchi 2007, 2006, 2005, 1999). Beginning with in-class explorations of physical science materials and outside-class assigned activities using materials and readings, by mid-term I asked the students to pursue an exploratory project of their own (or with a partner) outside of class. Class sessions for the first half of the semester included exploratory activities and discussions. We read scientific and reflective writing by scientists such as Euclid (translated in Kheirandish 1999, Smith 1999), Gilbert (1600), Galileo (1632, 1638), Payne-Gaposchkin (1984), Sacks (2001), Vermeij (1997) and essays about historical experimenting (Abbott 1987, Bonnet 1994, Corn 1996, Dibner 1947, 1964, Klein 1971, Needham & Ling 1962, Settle 1996, Simms 1977, Smith 1982). In the middle of the term, I arranged field trips to: the Burndy rare book library and Westinghouse-Hibben Historical Lamp Collection; the MIT Museum for its nineteenth century surveying tools; and a 1911 power substation remaining from Boston's early electric railway. During the final meetings, each student or pair involved their classmates in exploratory experiences with the science materials of their project. Projects included: papermaking, the sounds of guitar strings, optical illusions, dissecting electrical appliances, making visible the paths of light in materials.

The three following sections of this paper excerpt from the class' critical explorations with: swinging weights; mirrors; and light bulbs. In each of these three cases, exploratory work that originated with assigned exercises involving the whole class, was continued in the journal assignments, projects, and shared activities that were initiated by individual students. Across these stories, the class moves from doing groupwork to becoming a fluid evolving experimental community. Historical science readings and experiments are an inspiration for this development. As the students become explorers of their own, the questions they explore have to be their own. They become more like Galileo and other historical experimenters, the more they are working from their own curiosity and observations.

## Swinging Weights

After two weeks of class experimenting with pendulums, and reading excerpts from Galileo, we began one session by reading a children's story about an African boy, Chima, and his time-keeping rock-on-a-string (Savage 1967). One student, Annamarie compared swinging Chima's boulder with swinging a pebble. She said Galileo found weight did not "affect the length of time it took to go back to rest." Then another student, Samantha, described a check up on Galileo she had done on her own at home. She had timed the successive swings of a pendulum, and found these times all about the same. Her careful findings attracted no interest, since the class was becoming focused on the weight coming to rest. Samantha next invited us to do an experiment: "Is there … a certain length of something that ensures that it will have an arc that you could time?" (Transcript, 2005)[1]

Out of the class' evolving discussion came a specific challenge: to make a pendulum that would go for one second. The first of many such whole-class experiments, what surprised me most was the class' desire to work together, not in pairs. Experimenting together, their community gelled.

Soon Samantha and her partner Andrew took the stage, tying a weighted string to a coat-rack. Annamarie said, "ready, set, go" (Figure 1 left). The half-swing was over so quickly that Annamarie missed reading my watch, which had no stop. Everyone laughed. Annamarie asked Andrew: "could you be the eyes ….say stop?" A classmate, Devin, interrupted; her cellphone had a stopwatch. Timing 9/10 second with it, Devin exclaimed "Galileo didn't have a cellphone!"

They lengthened the string (Figure 1, right). Devin's next reading went the wrong way, at 8/10 second. This was perplexing. Lucienne, who had often restated Galileo's finding that shorter strings gave shorter times, now questioned whether our string should shorten. Devin disagreed saying "Maybe we are just better at timing". When the next reading came in low, Samantha *lengthened* the string again. No one dissented. The first swing time at this new length, .97 second, gave the appearance of closing in on the second. Devin's outlook evolved. She urged: "we could do it multiple times … you have to get one second more than one time in order to know that the right time is there" (Transcript, 2005).

In the playfulness of doing many trials came more thoughtfulness about experimenting. If Andrew forgot to say stop; laughter cathartically related the experimenters with the onlookers. When her times varied, Devin asked me: "there's a lot of human error involved, right?" Andrew instantly concurred, saying "a lot!" Spotting Devin, he said, "I'm not saying on your part!" Amid this teasing was the link making Devin and Andrew part of the same time instrumentation.

Figure 1. Left: One student (right) lets go of the weight from a string tied to a coat-rack support, while others hold the rack and time the swing. Right: readjusting the length of the pendulum string.

One reading was way off. On their own, the students stopped to critique their experiment. Anna supposed the pendulum's release height might affect its time but Lucienne disagreed: Galileo found only length mattered. Then Lucienne suggested: "do you guys want to make an average of all these times?" After experimenting resumed, Annamarie, in her role of taking data, noticed that "the last two [*times*] were really close" to each other. To her, the closeness in these numbers showed that there was more consistency in *doing* the experiment. Once she collected ten runs since the break, Annemarie read off the data. Devin computed the average at .94 seconds. She concluded the string had to be longer yet. Reflecting on how the experiment evolved, Annamarie asked me: "is it really ok that we just kind of ignored the first ones, because … there were some things that we needed to straighten out?" Responding that experimenting is about revising and redoing, I observed that they would go on finding more to change.

Andrew brought up the children's story; Chima never spoke of the rock stopping, but we saw it does. As Annamarie drew on the previous week's discussion to reconstruct the relationship between a pendulum's diminished arc and slower speed, she gained clarity about Andrew's question of its stopping, and said: "clearly at the end point, that's a change in time, right, and it is no longer moving…" Annamarie's highlighting of the endpoint helped Lucienne to speak what was troubling her, and Lucienne said: "if you have the same length of string … I thought Galileo meant that it took the same time for it to come to a stop." Devin read aloud from Galileo: "when suspended from the string pulled from 90 degrees or one half of a degree, it will employ the same time in passing through the least as through the largest of these arcs" (Galileo, 1638/1914,

p. 97, 141). To Devin, it was clear that Galileo meant that the time was the same for big and for small arcs but Lucienne still wondered: did he meant the time to come to a stop, or to go through one arc? As Devin reread Galileo's sentence aloud, Annamarie's insight about the endpoint helped her to articulate this subtle distinction in Galileo's text to Lucienne and the others. Devin said: "he says, "it would employ the same time in passing through the least as through the largest of these arcs." So if it is going to stop, it wouldn't be in an arc so it would have to be still moving [for the time to apply]." Now as Lucienne finally concurred, Devin remarked that that Galileo had made this great discovery but did not boast about it: "he's a humble man".

It was the class' discovery too, woven from many sources and observations in discussions, historical reading, and experimenting. Much remained for us to refine, as shown in the disparity between the half-meter length of the class' experimental seconds pendulum, and the full meter length of a true "seconds" pendulum. What the class created was more than an answer, it was awareness of consistencies in nature and of their own investigative *and ever-evolving* process. This process encompassed observant concerns about the slowing motion; imagining a boulder and a pebble; improvisation with string, mounts and timers; and confusion in relating Galileo's text to what they saw. Trust was growing through the class' interactions, from trust in each other's role in timing that became apparent as more consistent readings, to trust in the integrity of each other's ideas. For example, through Devin's respect for Lucienne's interpretation of time-to-stop and Annamarie's analysis of stopping, Galileo's text became more accessible. Galileo was part of this community too, moving from cryptic words to being at the crux of the students' observations, to exemplifying a scientist's humility.

Periodicity again engaged us on the day two musicians in our class, Peter and Lucienne, shared their project work with the guitar. Both were curious to see the vibrating string's waveform. Peter had once observed it while playing his guitar in the flickering light of his computer screen, and both had read about it in a historical account (Figure 2, left; Sauveur 1701). I brought out a strobe light. Awhile passed before anyone saw the faint effect. Andrew wanted the room lights off. An emergency light would not go off so Aaron and Andrew climbed on the table, duct-taping black cloth over it.

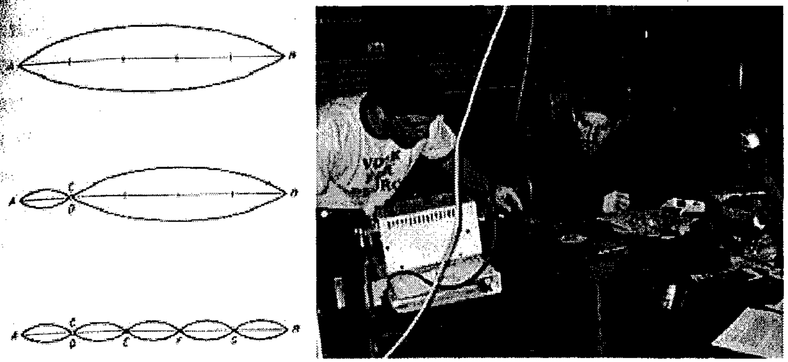

Figure 2. Left: Historical diagram of waves on a string (Sauveur 1701). Right: Dialing a strobe light (white box on left) through different frequencies to match the vibration of a plucked string on the guitar.

The added darkness made a huge difference. Everyone was enthralled. Waves on the string stood out, warbling, wobbling, and becoming still where frequencies of string and strobe nearly matched. On playing chords, Lucienne exclaimed "oh look at that!" Peter detected; "the smallest dissonance… awesome." More explorations followed. Peter invented an experiment (Figure 2, right): to select a guitar string whose frequency he knew as 660, and have Aaron dial the strobe meter to see where they matched. He said: "I'm going to start playing a note…. We'll see if it comes out to roughly what it should be." The perfect match at 660 on Aaron's meter, astonished Peter: "it's crazy that it came that close." This experiment with its matched frequencies was inextricable from the class community and their fluidly evolving experiences of plucking the guitar string, darkening the room, adjusting the strobe, wondering at the wave.

### 'Simple Experiments' with Mirrors, Light Rays, and Liquid Nitrogen Ice Cream

The next part to my story is from the class' work with mirrors, and shows how a plane mirror came to be far more complex than anyone anticipated. When the course started, the students initially considered such activities too "simple", obvious, beneath them. Only in observing these things themselves did they find there was much going on they did not understand. Peter later reflected:

> There were some [in class] who thought they'd known exactly what the outcomes would be, and I myself had thought… that I knew…. Needless to say …(probably all) of us, myself included, had been dazzled… when experiments… had not gone as we expected. [Some] experiments were complex, but it was the

> seemingly simple ones that seemed to stun everyone the most when their basic assumptions had proven false. (Tusi 2005)

The mirror activity we did the fourth week was such a seemingly "simple" exercise having a surprising outcome. My idea for it originated in the class' curiosity about mirrors of long ago. A reading on ancient mirrors reported that wealthy Romans had metal mirrors large enough for someone to see their entire body (Melchior-Bonnet 1994, p. 11). I asked the class to consider the size that such a mirror would have to be, by exploring as a test case the size on the mirror occupied by their whole head's image when viewed at different distances (for another treatment see Kipnis 1993). Lucienne could not picture how there could be any specific mirror size, and said: "Cause if you have a tiny mirror … it seems like if you back away a lot you could see yourself … eventually you are going to get … where … you can see your feet." Samantha had backed six feet away from a mirror at home, and said her image appeared nine feet away. Andrew queried "you don't think it's double?" Jenniemae, who had used a reference gauge, said: "When I did it, I thought my reflection was the same distance away [i.e. inside the mirror], because … I could see the ground floorboard … I had a better sense of perspective."

I suggested doing this together. Anna held our oval mirror while Lucienne and Jenniemae took turns backing away while watching their head's image. At first, Anna had the mirror at waist-level but her viewers kept prodding, "Higher Higher" until it was finally at face level. It took practice, walking and holding, walking back and forth, to get where someone actually saw their face throughout the whole course of backing up. Noticing something odd, Lucienne said "I don't think it [*image*] changes in size at all."

When Anna took her turn (Figure 3), Lucienne put tape onto the mirror around the outlines of Anna's imaged face.

Figure 3. Viewing the mirror image of your face while backing away from the mirror.

Anna backed up, in her words "believing that my face would obviously shrink in the mirror." (Tsui 2005) Surprise deepened with some realization that things seen in mirrors are not quite what one might expect, in what she spoke while moving: "… my face … if I keep like … It's weird. It still fits between the lines!" An effort to measure both head and its taped image was inconclusive; not quite a ratio of 2/1. Peter tried it too. He interpreted the outcome along with the shift from viewer's perspective to that of the mirror plane which had eluded the class and left them with flawed expectations. Peter said: "[At] a different distance, it [*the image*] looks like a different size because you are further away. So you look smaller *to you*, but in the mirror, you are still the same… size."

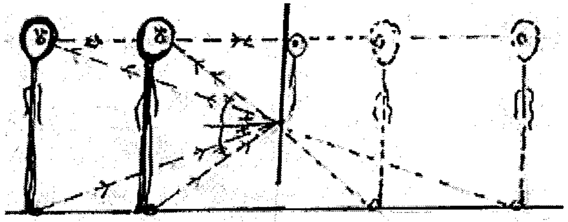

Figure 4. Ray diagram for a person viewing their full body in a mirror at two different distances from the mirror. A ray passes from the person's foot, to the mirror, where it reflects at equal angles to their eye; another ray, normal to the mirror, passes from eye, to mirror, back to eye. The height occupied on the mirror, by the image, is the same for both positions of the person.

At the board, I sketched the ray diagram (Figure 4) for someone viewing their own reflection at two positions, relating it to what the class previously worked out about equal-angle reflection. But I soon became aware that my synthesis was not in contact with theirs. For them, the heart of this exploration was a shift in view of an image seen as a whole, as Peter said, not its composition from linear paths. Anna's end-of-term project, however, to make visible the ray of light moved the class more into observing these light paths. Anna prepared a fishtank of dirty water dosed with cream. Her classmates shone flashlights and laser pointers into it. So much creamer went in that soon the flashlight's glow, and even the laser's, was only a diffuse scatter, but Anna's jello better showed the laser's straight path.

Anna wanted to see "how light reacts to smoke and vapors" (Tsui 2005). To do this, we poured the lab's liquid nitrogen into a Styrofoam cup in another clear fishtank. Here the laser's linear red path appeared, as did the vaprous glow of the forming cloud. Anna incited a new challenge at low temperature: mixing up the café's creamer and sugar with liquid nitrogen. Would it make ice cream?! That phase transition was tricky to reach, but Aaron persisted in stirring and readjusting milk and coolant proportions, Peter in checking the confection, and Andrew in supplying more "liquid N". We all had some – even the reluctant teacher – helped by Aaron's open encouragement and Andrew's repeated assurance, "it's good, it's good."

Wonderful questions arose – such as were we eating "liquid N" itself? -- spontaneous and genuinely evoked by what went on in the fishtank. The class as a community created new optical effects, such substances as ice cream, and understandings of light's paths and their own development as experimenters. Anna reflected that original historical experiences: "of awe and puzzlement are similar to our own...[S]imple observations are crucial in the understanding of something new...[O]ur seemingly insignificant comments ... in class over... a simple beam of light are important...in the exploration of science" (Tsui 2005).

### Light Bulbs and Roslindale Substation

The last case from the class explorations concerns light bulbs; here, the light bulb, which we use everyday without thinking about them, aroused confusion, delight, and understanding. One week, after they had used two-lead bulbs in class, I sent everyone home with a flashlight bulb, battery and wire,. No one reliably lit this bulb. So I posed the materials again to the whole class. Soon, bulbs glowed, tentatively for some, with increasing brilliance for Peter and Aaron who teamed up batteries, adding in more until they blew it out.

At the board, the class tried to diagram the bulb (Figure 5, left). Two prongs went down from the fine wire that glows but no one could see where they terminated in its base. Peter asked to break one open; I said yes! He cracked it so carefully the filament stayed intact. They hooked up a battery; the filament glowed, smoked and went out. Peter and Aaron dismantled the tiny bulb's base, but without identifying the electrical path. Next I provided small bulbs that had no base to obscure the two filament prongs' exit. No one could get them lit! Smoke appeared at the battery tops where a wire coming from the battery base was twisted into *both* leads of the small bulb. Devin however, clamped a wire to each lead, connected these across a battery, but saw no light! We rechecked all the connections, a tiny glow appeared, barely discernible in the lit room. The battery line-up of Aaron and Peter was soon applied to boost the light (of this higher-voltage bulb).

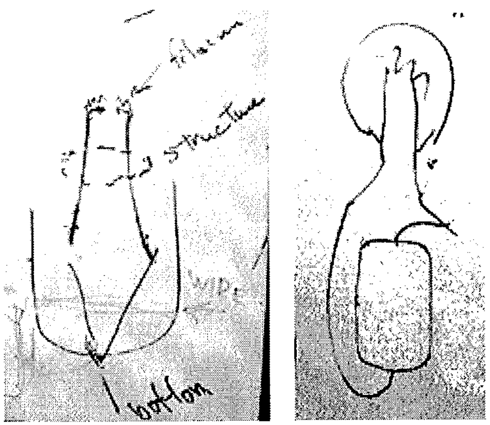

Figure 5. Left: Class blackboard diagram of the filament inside U-shaped bulb casing, showing class uncertainty about how the filament leads exit the bulb. Right: Blackboard diagram showing that filament leads exit the bulb and contact with wires that end on opposite terminals of the battery (rectangular shape).

For the class, Devin sketched what she'd done: battery contacts meeting the two wires of her globe bulb (Figure 5, right). Jenniemae said both battery ends had to be involved. Taking off from that, Anna completed the circuit reversibly in her mind, saying: "like the battery has two ends, one [filament] prong has got a positive and one ... has ... a negative? ... And wires are connected to the positive ... and negative side of the battery. It completes like the circle." Devin brought up the enigmatic flashlight bulb; how could Anna's idea work where it had, as she thought, "two wires coming out of the bottom?" I asked how else wires might be involved. By a thought experiment, Peter pictured attaching a wire to each battery end and then using these wires to light a flashlight bulb, he asked: "So does one wire go to each?"

By reflection and question integrating the class' experiences, Peter inferred how the circuit got through the obscuring casing. Yet this circuital analysis was unstable. Later on, Peter and Aaron produced so many shorts, they claimed "a cloud of smoke always ends up ... out of everything we do." Only after redoing connections in one "failed" experiment, did Peter "take a step back" to recover again in a new context, his circuital "discovery".

When we visited the Burndy Library's Historical Bulbs, Samantha made a visible analogy between our class' explorations and historical ones; she wrote: "...experimentation, as we have learned, is obviously try everything that occurs ...; Galileo and Ptolemy clearly thought up every variance...the common theme is perseverance and imagination; observing each variance, in every possible way" [Pitchel 2005].

In contrast with the delicate bulbs, electrical history took on an immersive scale during the class visit to a 1911 power substation of Boston's transit system (Figure 6, left). Peter described it in these words: "When entering the building, I had no idea what was going on … In the center there were three enormous converters … Behind the control board … the multitude of wires, fuses … amazing. … [Tusi 2005]" Andrew said "the basement offered a whole other world of exploration. [Lix 2005]" There was also a human story to be told, hinted at by the closet toilet, ladder to the ceiling, "DANGER" signs (Figure 6, right), and stray work gloves. As much as the grand space and its electrical installation had the power to transport us bodily to another time, it also raised the question: was it safe to work here?

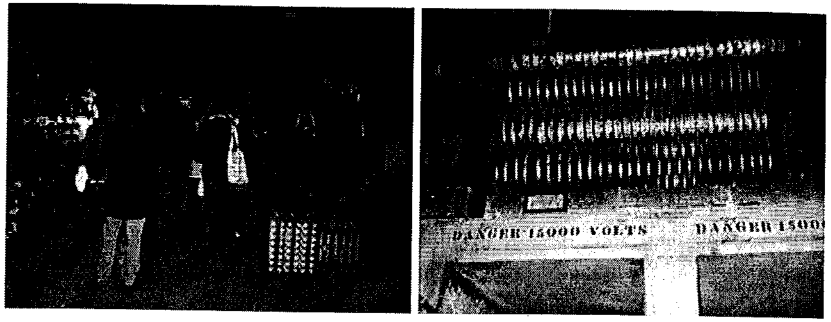

Figure 6. Left: Inside the 1911 power substation, with control panel on the left, and rotary converters on the right. Right: Danger signs in the work area.

While the historical light bulb display accentuated creativity and diversity, the message of what the class called "Roslindale Substation" bore more on community – both the historical network of streetcar lines, passengers, conductors and electrical trainees, and our class experience. How deeply history and community pervaded the class showed in the final session, when Aaron pulled out a "Roslindale Substation" specimen light bulb! He ceremoniously dissected it alongside modern bulbs including an "Energy Saver" fluorescent, a long straight florescent tube, and an ordinary incandescent.

The broken Roslindale bulb passed, from hand to hand, carried wonder and intense curiosity (Figure 7). And the reflections that arose along with it bespeak a community having the organic life that Dewey and Hawkins advocated. We see this from Lucienne's personal awareness in writing

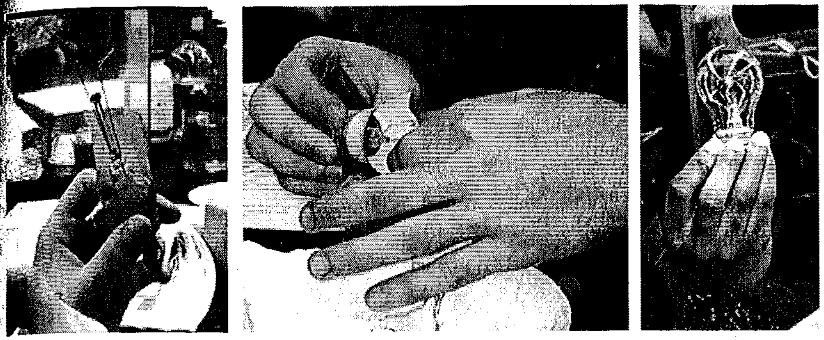

Figure 7. Historical dissect bulb (left) and modern bulbs (dissected, middle; intact, right) in students' hands.

> As much as I am developing an adventurous spirit, I am also learning about how I learn and how I approach unknowns" (Pierre 2005)

to Samantha's sensitivity to the evolving whole:

> It was during class when we bounced ideas and observations off each other, that I began to see the web of thought processes that could stem from a simple activity" (Pitchel 2005),

to Andrew's inclusion of the class with the flow of science history:

> Who knows, one of us might be the modern day Galileo, Aristotle, Plato, or Bern Dibner (Lix 2005).

**Community, History, and Experimenting**

The historical record inspired members of this class, both for what they noticed about the natural world, and for how they went about learning and exploring more. The students developed a sense of early historical research, not just through word and example, but also within their own experience in empowering ways. They were not "recreating history", but instead creating experiments, *being* Galileo by treading that ground anew for themselves. Lucienne realizes herself as an "adventurous spirit"; Andrew wonders about being the next Galileo.

At the start of the term, doing science experimentally was unfamiliar. As the class became involved in developing experiments and community of their own, the experiences of science history gained relevance in questions and issues that mattered to them. For example, when Devin reread Galileo's insight about pendulum swing times, the class's understanding of pendulum stopping became clearer, while Aaron's dissection of historical and modern bulbs provoked comparisons in materials and design. An aspiration for teaching science emerges from these narratives and examples: that *our students* may become the explorers and adventurers in their own lives and for the future.

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All further quotations from class discussion are excerpted from the class transcripts of fall 2005.

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