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Introducing Investigation into the Teaching and Learning Experiences of New Teachers of Science

by

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Introducing Investigation into the Teaching and Learning Experiences of New Teachers of Science

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ABSTRACT

School students, and their teachers, seldom have opportunities to investigate something in nature. Yet children's development, as perceived by Piaget, and historical scientists' learning, involves investigation. We acted to include these investigative responses and historic resources into our work with new science teachers. We did this in the context of the university science education course required of twenty-five preservice teachers of middle school and high school. We codeveloped and cotaught this course as a research process, including: activities with materials; personal investigations of nature and the classroom; reflective writing and discussions on historical readings; and personal philosophies of education. We engaged the teachers as investigative learners, hoping that the activities we created would encourage them to adapt these experiences into their teaching. The new teachers deepened their understandings of learning through drawing, observing, and investigating. This paper presents layered experiences that evolved within the course, discussions, teachers' reflections, and two investigations: a squash seed's growth and daily observation of the moon. As these new teachers prepared to take on full classroom responsibilities, they felt tensions between exam-driven constraints on school curriculum, and the questioning processes of their investigative learning. In reflection, we feel their work raises a question: can teacher education courses become places where teaching and learning evolves investigatively?

Introduction

Genuine investigation combines eye, heart, hand and mind as we interact with the world, trying to make sense of what we feel, find, make and think. It has longstanding roots in the history of sciences, arts and crafts, and in each of our lives, beginning with a newborn's motions toward things outside itself. Yet in schools, investigation is so rarely supported as a means of learning that it seems anachronistic. Teachers tell; students answer back, making a cycle uninterrupted by personal questioning and exploration.

We hoped to disrupt that cycle before it settled into the practice of new teachers of science. We acted on this hope by offering experiences to new teachers that provoked their involvement in investigating, and by asking them to prepare such experiences for their own school students. We did this in the context of the university science education course required of preservice teachers of middle school and high school science. We developed and taught this course as a research process involving ourselves, materials, the teachers and their classrooms.

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We aspired to create a course in which new teachers could develop a critical stance toward teaching and learning, and learn through their own inquiry.

While student investigation is uncommon in school science, many precedents identify it as belonging essentially to the science experiences that are provided to children and young people. For example, John Dewey's Laboratory School put young children into experimental and craft settings to learn by acting on their own curiosity (Dewey 1897). The standards for science education produced by the US National Research Council (1996), and adapted by many state and local school districts, emphasize that "inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (p. 3). Such policy statements about inquiry appear to redefine what high school science could be, to move students from passive reception of knowledge to action in its creation.

Yet somehow the science classroom itself too often becomes an environment closed off to students' active involvement. The commonplace school science labs, that are programmed to replicate a particular result, do not allow for investigative thinking. As few involved in teaching and learning have genuinely investigated a subject area, investigation is seldom evident in educational practice. This disparity between classroom practice and investigative experience mirrors the ways science teachers are trained, which typically omit investigation. However some recent efforts address this disparity by involving new teachers in laboratory work (McComas 1995) and teacher research (van Zee 1998)), self-reflection (Helms 1998) and science investigations of their own (Shapiro 1996, Bencze & Bowen 2001, Bowen & Bencze 2001).

Starting with the teachers themselves, makes a beginning for investigation involving both teachers and their students. This paper presents layered experiences that evolved within the course we invented, as all of us noticed what it was like to learn investigatively, and thought about introducing investigation into classroom work. The teachers' discussions, reflections, and investigative writing relate the details, tensions and insights that emerged as learners became researchers of their own science questions.

Researching and Teaching Investigatory Science

Teaching and learning investigatively evokes observations, activities, relationships and values in teaching and learning that differ, and somehow invert, many customary features of classroom usage. Investigation changes ourselves and our perspectives on science in ways that are enabling, for learners to act, research and question on their own, to learn something new.

Our forming ideas connected with Piaget's researches on the development of learners' ideas, and Eleanor Duckworth's extension of this research into teaching. By observing his own children from infancy, Piaget observed that children's understandings change as they interact with something (Piaget 1936). While taking in what something is like, children may find that their familiar ways of relating to it prove insufficient. This disquieting "disequilibrium" may move them to "accommodate" those familiar ways in response to what is new and different about this subject. In accommodating themselves to the subject, the children extend what they can do and apprehend, in relation to something in the world.

These studies, undertaken to research the growth of children's minds and actions, offered insights for facilitating that growth. While interacting with children to follow their development in this process, Eleanor Duckworth realized she was also teaching them (Duckworth 1991). That is, the children's knowledge and understandings evolved in the very process of engaging with the subject matter and the teacher (Duckworth 1973). As a researcher, Duckworth worked to provide a safe space for children to express their own thinking about some problem and act on it, using materials germane to the problem. By participating, the children became aware of more dimensions in the problem and their thinking developed. So the children were learning, and she, as the teacher, responded to their learning by extending the problem, questions, or materials in ways that might further engage them.

To support this active development among groups of learners -- adults as well as children -- Duckworth evolved "teaching\learning research" (Duckworth 2001) as a description of how a teacher can interact with students and support their development. The work interactively involves the teacher in engaging learners with some subject matter, questioning and supporting what they do and think, and reflecting on what develops. The subject matter is provided in its complexity as a whole, which learners can question or act on directly. To study density means pursuing actual trials with water, wood, oil and small capped containers (Duckworth 1986); to study a poem means responding to its words, with all the associations and questions that raises (Schneier 2001). By following what intrigues them, learners make their own entries to the subject and work out its consistencies, such as that equal weights of different materials float (or sink) differently in water (Duckworth 1986), or that a poem's wording suggests who it might be about (Schneier 2001). By dealing with the subject as it is, any accommodations learners make in their thinking must reflect something authentic about its nature -- even if still incomplete. By seeing both potential and incompleteness in learners' ideas, the teacher can create experiences that open the subject yet further and keep learners' activities and thoughts going.

Investigative work in science reflects this view of learning. Doing science involves placing real phenomena under study, direct experimental tests, forming and revising ideas in response to what happens. Wondering about something, seeing it by different views, accommodating to new evidence, are all integral to how scientists develop understandings of phenomena and materials. We found support for these impressions in the history of science. For example, the fascination of engaging with something while only partly understanding its behavior, is expressed in Galileo's first telescopic sightings (Galileo 1610).

Science's exploratory qualities, welcoming surprise, imagination and playfulness, mesh with the ways learners deepen their engagement with something. We felt these connections offered productive possibilities that <u>learning</u> happens in the <u>doing</u> of science.

Settings of School and Curriculum; Inquiry and Testing

The new teachers were simultaneously immersed in the two different academic environments of private university and public schools. Daily they moved between widely different roles and practices. In negotiating their way, the teachers experienced internal and external tensions from the institutional structures and curricular expectations.

The new teachers were masters' degree candidates. Each already held an undergraduate degree in the subject they intended to teach. The university teacher education program stated its commitment to concerns of equity in schooling, reflective practice in support of developing deep understandings among learners, and values of inquiry, cooperation and diversity.

Each new teacher fulfilled a clinical experience in public school classrooms. The school placements subjected the new teachers' work to the system of standards and assessments adopted by the state. This framework prominently emphasizes students' agency in their own learning. However, to enforce these frameworks and make schools accountable, the state instituted subject area exams that are administered to each child at certain grade levels and constitute a "high stakes" event. Resulting scores correlated strongly with the ethnic and SES backgrounds of the tested children. Thus, the combined reform measures of "frameworks" and assessment exams projected conflicting directives on the new teachers.

Preparing Investigative Experiences

We developed the design and teaching of the course as a structure supportive of the teachers' investigatory work with nature and teaching (Cavicchi et al 2001). We shaped the course experiences, investigative and reflective assignments, and readings to offer diversity in materials, subject areas and modes of observing and interrelating. Each teacher's responses would be different, modulated by what each knew, noticed and tried. And, by making their own unique entries to phenomena of nature, teaching, and learning, the teachers were initiating processes that could only proceed through their own personal investigative involvement.

The structure we developed involved a combination of active and reflective work The active work included classtime activities, tours and demonstrations arranged by us, along with an individual investigation conducted outside of class. The reflective work included readings, papers written in response to readings, a case study of an episode in their classroom, a written statement of teaching philosophy, development of an investigative activity they planned to use in their classroom, and a final reflective paper. Along with this work done by the course participants, we (the course teachers) also wrote journals, and discussed our teaching concerns together. Weekly, we developed new activities and composed questions for readings and discussion; thus the research reflections evolving from preceding class experiences informed what we did next in our teaching.

Our weekly class activities were designed to evoke an observation or question. In making such a response to the materials, we hoped the new teachers would begin to imagine ways of pursuing something further. Thus, the activities were not intended for reproducing answers or techniques, but for seeing how entries to science can come about.

As a class, we watched the sunset weekly from the building's roof (Figure 1). We sprouted seeds; grew plants and crystals; composted leaves, dissected cow's eyeballs, flowers and batteries. Some lit a flashlight bulb with wire and battery or explored a large magnet's pull (Figure 2). They etched copper with nitric acid and reacted scents. They invented and tested toy boats. The class also visited a rare book library; a museum of scientific instruments; a research biology lab; a computer lab; an environmental engineer's presentation on water treatment, and a show of demonstration experiments in physics and chemistry.

Figure 1. Teachers observing and drawing the sunset from a rooftop viewing area.

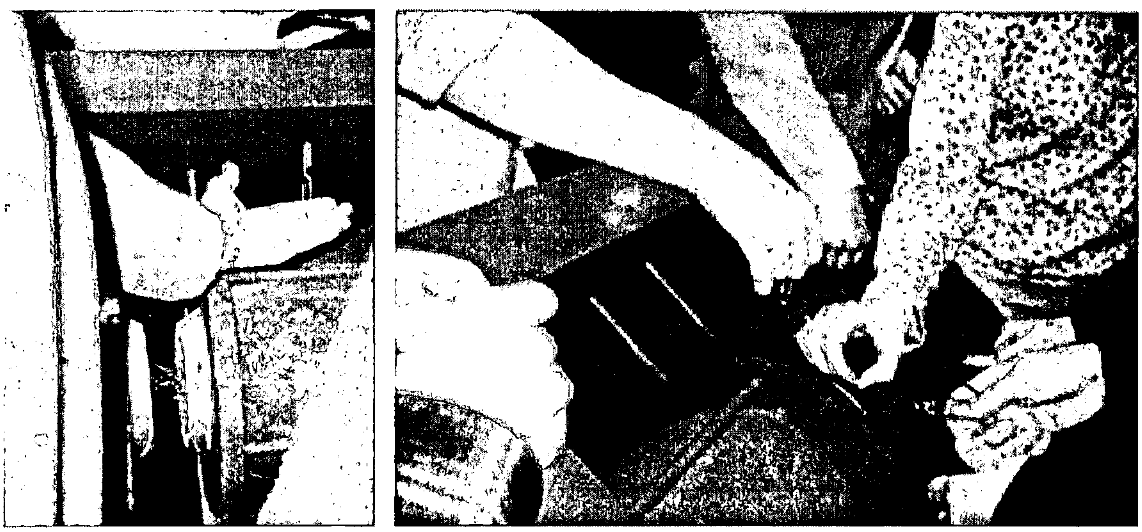

Figure 2. Teachers testing a strong magnet's pull on paperclips.

We observed that some teachers were finding connections between their own investigations and their teaching. Other teachers held back from investigating, and also expected to get directions on "how to teach science''. This significant difference among the teachers showed the direct personal immediacy of investigation. It cannot be externally communicated other than by one's own direct experience.

This posed a continual struggle for us in preparing investigative experiences. We knew that in their classrooms, most new teachers were expected to perform authoritatively, to hold both questions and answers to those <u>same</u> questions, to inform and correct students. Yet we suspected this authoritative stance would inhibit their longterm development as teachers. We believe that the work of teachers is, and can be, thoughtful and researching. So we chose to always add some further resource, as fresh entries for teaching and learning science.

Understanding Nature through Observing and Illustrating

One of these entries was art. Doing art brings us to act, try something out, sense it differently, reimagine it -- which changes what we understand.

One session early on combined history, examples of scientific illustrations, drawing from observation, discussion and writing on using art in teaching science. We began the class by visiting a rare book library, where we looked at historical zoological illustrations, from sixteenth century woodcuts of fanciful beasts to Audubon's quadrupeds. Then we gave the teachers time to draw (Figure 3). This was difficult; many had not drawn since grade school.

Figure 3. A teacher making a drawing.

In starting discussion , one teacher objected: "...It's hard for me to sit down and really draw something carefully...I don't really know why I'm doing it..". Another was conflicted over allowing time for drawing when the school curriculum is so pressured by tests:

> ...unfortunately there's these standards that the school is telling me I need to teach ...I need to keep moving moving moving, and how to incorporate these things [*ie drawing*]?

One teacher had encouraged his students to draw. He spoke of their growing awareness of learning:

> At first they thought drawing was kind of tedious but after they started seeing how things changed that they were drawing, they got a big kick out of it because they could go back and see: "Oh it started like that and now it's like this". And it helps them when they write...because they actually took the time to observe by drawing...it's making them better writers too.

Another middle school teacher spoke about allowing <u>more</u> time for drawing:

> We originally thought...20 minutes...But we have them do it for 45 minutes because the students were really involved in what they were doing ... A lot of it is their own investigative focus...

To one teacher's insistence that schools make a "huge barrier" to activities like drawing, another responded:

> I don't think anyone would disagree [*about the "barriers" in schools*] but I don't think it's all black and white either... There's also shades of gray and certainly working toward that is better than giving up.

These new teachers were experiencing the counterpulls of black & white -- and shadows; of state & school requirements -- and living students. But these opposing pulls do not resolve into steady balance; the teachers were finding themselves in "disequilibrium", in Piaget's sense, about what it meant to teach and learn; to develop, or to "give up".

Prior to this class, we asked the teachers to write from the historical readings. Their essays reveal how the teachers grasped art's synchrony with science. We excerpt from their papers below:

> I was struck by the many details included in Audubon's writing, especially the careful measurements of the porcupine, and I wonder if he would have been so driven to record such details if he did not also draw ... A careful drawing requires a great deal of attention to detail, and probably encouraged the artist to be a more careful observer in all aspects of life, an important skill for a scientist to possess (Kelly Warner, Oct. 5, 2000).

> When we connect our hands with our ideas we move our thinking. We may have started thinking one thing, but with the application of our hands and work we uncover questions that develop into other work and other questions, and this is a repeating process.
> ...Drawing or painting takes time. We must, by necessity look very closely at our subject. And inevitably we learn more about the subject because we have spent time with it and become intimate with the details. (Sandra McCarron, Oct. 5, 2000)

> Leonardo da Vinci used his own sketches of the human body to learn about anatomy...I reflected on my education in which I always drew out what I was reading so that I could better visualize. When studying the respiratory system I would draw the lungs with all its branches...It was as if I was actually dissecting the human body on my own piece of paper. ...Many people believe that the best way to learn is by doing. Drawing a process can serve as the ``doing" on the road to understanding (Jennifer Quinn Oct. 3, 2000)

> Through the articles that we have read and the observations I have made, both as a student of science and as a teacher of science, I can say that art is essential to the true and deep understanding of natural science. Without art, we are left with only words and diagrams. And while these are important tools for understanding scientific concepts, I have yet to see a classroom full of 10th graders as strongly inspired by words and diagrams as I have when those 10th graders walked into my class with pride beaming from their faces the day they came in with their own artistic interpretations of scientific material. One cannot deny that art inspires. (Erica Mirich Oct. 5, 2000)

Drawing remained an element in what the teachers did. For these new teachers, drawing made something happen in their thinking about nature and teaching that might otherwise have remained abstract. In part because drawing was new for most, it offered a way into science that was not already crowded with other connotations -- a way that let them become learners too. Drawing slows us down, to stop and see what is there. And that pause and close notice of some real thing is prelude to any full engagement -- and to investigation itself.

Investigative Projects and Reflections on Learning

Outside of classtime, the teachers were assigned two projects: a personal investigation of some natural phenomenon chosen by them, and the preparation of an investigative experience for their classroom. The personal investigations ranged widely: raising mealworms or fruitflies; photographing and sketching autumn foliage, or migrating birds; weekly measurements of a Labrador puppy's growth; daily records of the weather, or clouds, or the moon; exploring mixtures of household chemicals; growing rock candy crystals, or plants, mushrooms, or vegetable molds; investigating the buoyant force on submerged objects; exploring how plants take up water; tracking pigeon behavior; designing and testing competing features of a roller coaster track simulation. Many of the teaching projects were an outgrowth of these personal investigations, such as: drawing clouds during class and recording weather measurements with instruments made by the students; mixing various liquids and powders and observing what happens; using a spring's stretch to compare the buoyant force's effect on floating and sinking objects.

Most teachers had never before been asked to investigate something of their own, as one teacher remarked:

> ...this past semester ... is the only time in my entire “academic” career that I have been asked, and been given time, to conduct a personal, long-term, science-based investigation based on my own questions and curiosities...(Collins, Jan. 16, 2001)

Some teachers could not find a place to start. Accustomed to learning science from books, they felt they already knew the explanations to everything. Yet eventually, even these commenced a study that became investigative and personally meaningful.

Developments by Investigation

It was in the details of the teachers' personal investigations that these profound internal understandings about teaching and learning took shape. What they noticed changing in some natural phenomenon and in themselves, was both embedded in the scientific materials and freeing of their minds. Below we trace these active developments across two investigations: watching a seed's growth, and daily observation of the moon. With these teachers' observations of a plant or the moon, came new concerns for them as learners and teachers. The experience of development happening from within, through what each did and tried, changed how each teacher envisioned the work of classrooms.

Steve Collins, a former interpretive instructor for the National Park Service, was caught by what developed in something small: a seed collected from a butternut squash he had eaten. At our first class, Steve placed it on moist felt to sprout and took it home. A week later, the seed appeared “doomed”; its coating had blacked with mold. After he moved it to a warmer spot, something happened. With excitement, Steve recorded “IT SPROUTED” and drew in detail the white rootlets emerging from the seed's split-open casing (Figure 8, left). A week later, its fuzzy stalk was two inches high (Figure 8, right), terminated by a pair of leaves which soon curled back to expose “a developing bud” (Figure 9). Steve noticed how the serrated edge of the emerging true leaf distinguished it from the seedling's first leaf (Figure 10). Through watching how the vine did not lengthen while the new leaves emerged, Steve began wondering about the plant's energy expenditure. Did the plant's growth slow when the energy stored in its seed was used up?

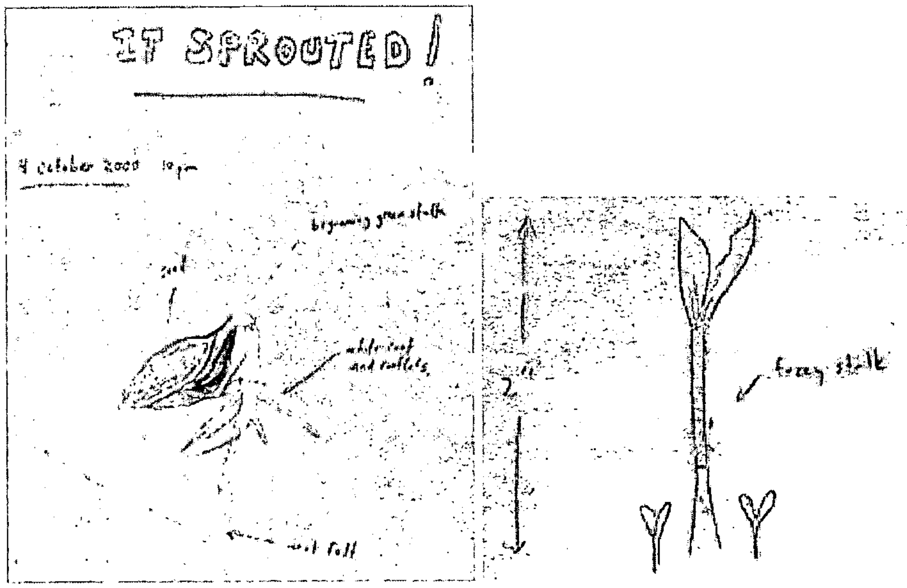

Figure 4. Left: Steve's drawing of a sprouting butternut squash seed. Right: The sprout one week later.

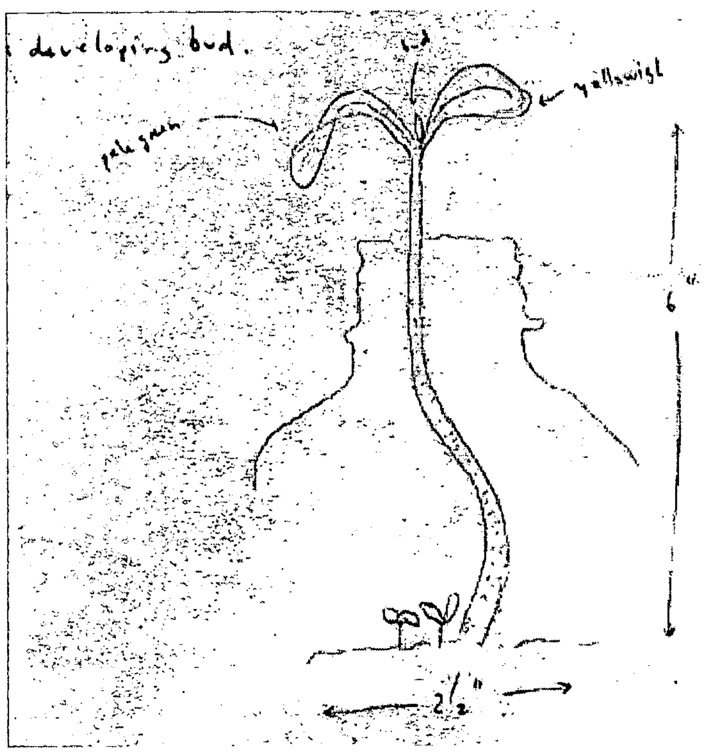

Figure 5. Steve's drawing of a bud appearing between the sprout's first leaves.

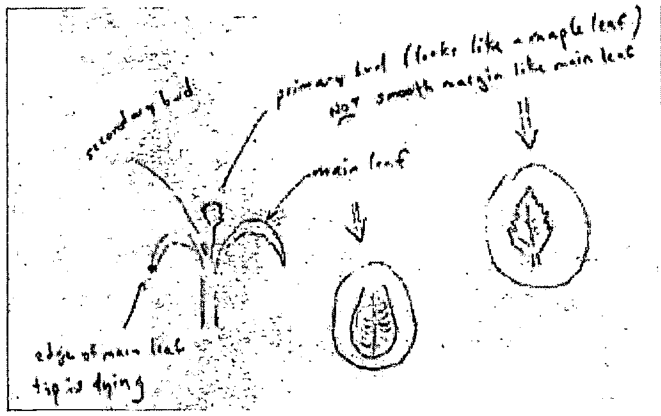

Figure 6. Steve's observation of the true leaf's form.

The plant's death (after a repotting) cut off further direct observations, such as about whether its vine would branch. Yet, along with efforts to sprout apple seeds, Steve's thinking about growth continued. Next he wanted to observe and understand:

(1) How do *other* plants grow? and (2) *Why* do plants grow the way they do?

He realized that these new *questions*, which were fully his own and grounded in observation, represented a development in himself, when he wrote:

> For the learner to truly arrive at a meaningful conclusion, it must be the learner who crosses the threshold of understanding. No one can create knowledge for someone else. This is a deeply personal act. And the nature of true investigation, and not the illusion of textbook experimentation, is also intimately personal. (Collins, Jan. 16, 2001)

That a single seedling -- closely watched -- brought about such depth of development for a teacher, shows the potential within any engaged and reflective work with nature. In this, more than making new understandings of some phenomenon, it is ourselves as teachers and learners, that changes.

An earth science major in college, Katie McCuen chose to watch the moon every night as her project. She had read about it in books but never followed it herself. Her study began on the night of a full moon, when she sketched its splendor in a clear autumn sky (Figure 11). She sighted it three nights in a row, looking from different viewing places and times. It seemed similarly round each night: orange, yellow and low when seen early; bright, white and high when seen late.

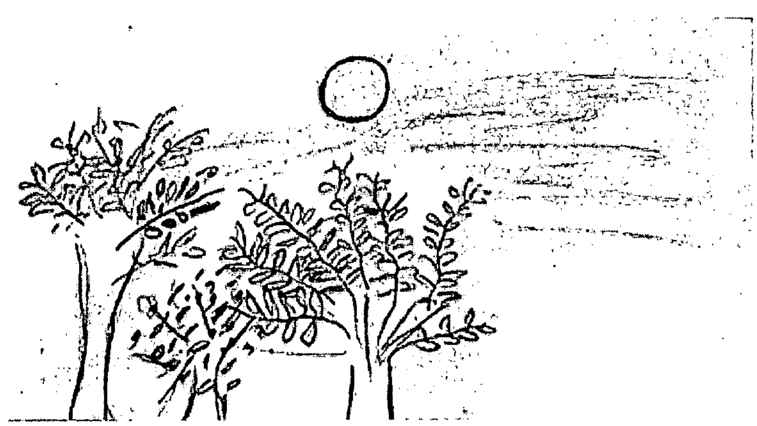

Figure 7. Katie's first observation: a full moon.

Then, although clouds and rain set in, she continued her daily record. Three nights passed with no sightings. When the sky cleared on the fourth night, the moon was not to be found. Katie wrote "Why? Where did it go?" But that morning, rising early for a school field trip, her eyes unexpectedly caught it, overhead. She watched it for hours, losing it around noon. The moon's startling morning appearance raised for her many questions -- that showed what was already developing in her thoughts:

> I am still very unsure of the moon cycle. What is the moon cycle? ... How much does it differ each day? Last Friday (Oct. 13) it seemed to just be rising at sunset, now it was directly overhead at sunrise.
>
> ... I noticed that later in the day the moon kind of appeared to be see-through...the blue from the sky shining through the moon. What causes this, I wonder? (McCuen, Oct. 20, 2000)

Katie pursued these questions the next days by spotting the moon in the daylit sky. For the first time, she marked relative positions between sun and moon, and the moon's arced path in the sky (Figure 12). No longer round, the moon's visible portion was waning and less bright. Yet again, on two clear mornings when she went out to see the moon at the same time, it was nowhere in view. Now her questions showed the developments formed through her attention to observing positions and paths, and the exuberance of her own resourcefulness in learning:

> Has it set already?
>
> Is it still in the sky but just too close to the sun to see?
>
> ...I don't know ...but I will find out!! (McCuen, Oct. 23, 2000)

Another early morning commute put her in view of the moon's *C* crescent (Figure 13); whose beauty shone by the understandings still evolving for her:

> This morning I saw the most beautiful sight -- both the sun and the moon were rising together right next to one another and you could just barely see the little sliver of the moon, and also the outline of the whole moon. (McCuen, Oct. 25, 2000)

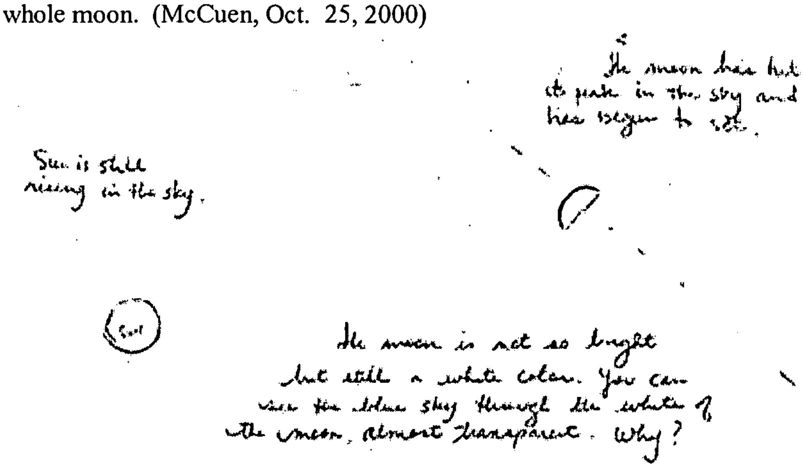

Figure 8. Katie's sketch of the positions of sun and moon.

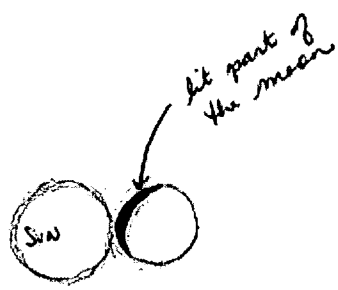

Figure 9. Katie's sketch of the sun lighting the morning moon.

Across the time of New Moon, a week passed -- some days clear, others overcast -- without any sightings. She expected it would be slim, "waxing", and not far from the sun "especially around sunset". Next came the night Katie presented her project to our class. Caught by interest, some classmates went outside to look and together they found the moon's sliver (reversed).

Katie's next observations, of the waxing moon opposite the sun, brought her to associate the moon's shifts in rising time with the sun:

> ... the moon rose with the sun when it was a "NEW MOON" and now its almost a "FULL MOON". And it's rising when the sun is almost setting!" (McCuen, Nov. 8, 2000)

Knowing this relation supported her in looking further. For when Katie reviewed her entire notebook during a conversation with classmate Steve, she came to a startling realization of pattern in its illumination. When the moon is going toward full, its lighting increases nightly from its right side (Figure 14); when it is waning, these changes are inverted (Figure 15).

> This is totally amazing ... It's hard to believe that one could never notice such a thing, but now it seems so obvious and it totally makes sense!!! (McCuen, Nov. 9, 2000)

The insight gained its clarity through the accompanying process of observing and questioning; no previous exposure to the subject had allowed her to make this understanding come alive through the evidence.

Figure 10. Katie's analysis of the moon's successive waxing appearances.

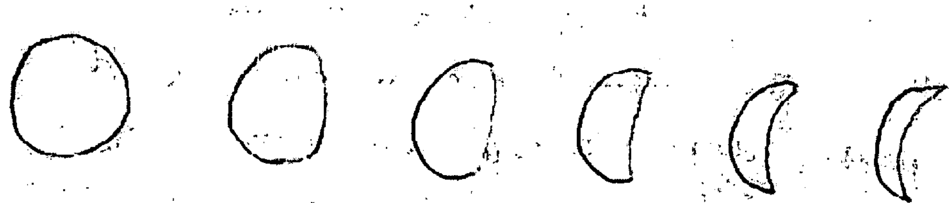

Figure 11. Katie's diagram of the moon's waning appearances.

By continuing for another month, Katie worked out -- for herself -- further patterns in the moon. Her study's consistency enabled her to use past observations in developing new ideas and questions. And her experiences with frustration, doubt -- and trust that she could keep on learning -- became instrumental for teaching, for understanding the perspectives of student learners.

Becoming a learner is intrinsic to becoming a teacher. By experiencing the complexities of some natural subject as learners, we enhance our sensitivity to students' confusions and questions -- and to their need for space to work these out. For the developments in ourselves emerge responsively: to the slow unfolding of a bud, or a surprise sighting of the early morning moon. While these developments cannot be mapped out in advance, we can, as teachers, widen and nourish the surrounding environment, letting these developments find prolific, productive expressions.

Memories from Childhood; Hopes for Teaching

Our impulses for being in the natural world, and sharing it with others, can have longstanding roots that are of a whole with the work of teaching. We sought to evoke those beginnings by assigning reflective writing during the summer before school started, with a later extension of these thoughts as an assignment to write a personal teaching philosophy. The summer assignment included readings from scientists' childhood memories (Durrell 1956, Feynman 1988, Hawking 1993, Hammonds 1986, Keller 1983, Levi 1980), and writing from memories of their own -- with hopes for teaching. The memory papers eloquently expressed a child's wonder for the natural world -- bugs, gardening, storms -- and the new teacher's passion for engaging science students with the excitement each found through these experiences. The philosophy papers looked to where the new teachers wanted to go in their teaching and professional work. They aspired to bring excitement and relevance into science, and desired to form relationships of mutual respect and learning with their students. Several expected their philosophies would mature with their teaching.

Below, we illustrate these writings with selections from the memory and philosophy papers of three new teachers: Sandra and Amos, who were in middle school science classrooms; and Kate who taught high school biology. The distinctive voice of each is integral throughout the paired passages: Sandra's sensitive notice of how acting with nature moves our minds (see her quote above); Amos' concern for seeing the real things and finding science's relevance in children's lives; Kate's political commitment to bringing about change in our relations with each other and nature through her teaching. The new teachers' unique perspectives are enacted through beliefs they have in common: in each child as a learner; in the potential within children's experiences with nature; in the understandings made through children's questions and work.

Sandra's recollections of childhood moments outdoors with her parents merged into the ongoing currents of her work with students and her children:

> I remember gardening with my father. One day, I think I was about five years old, we planted peas. ... We knelt down and examined the row: How deep is it? How deep should it be? Is it straight? My father talked extremely little, letting me do the talking and just adding his occasional questions: "oh?" or "do you think so?" Then my dad ... poured some hard peas into his hand ... talked about them, about their smoothness, color and size...handed me some seeds ... In this way, our peas were laid
>
> ...
>
> I believe that my parents unconsciously laid the groundwork for my involvement with nature by their simple way of living. My mother, an artist, closely and patiently observed the world around her. My father is most at peace in the garden... I do think that putting the students in the position of poking and prodding with their own hand, and making personal discoveries will help open their minds to further explorations and personal satisfaction. I hope I can help my children and my students discover the fascinations I find in natural science. (McCarron, Sept. 23, 2000)

The involvement of the child is the constant essential in Sandra's beliefs; her ideas for teaching range across all the imaginable ways of facilitating their involvement:

> I believe in the children and in their ability to learn. I believe that teaching needs to be connected to real life... Teachers can foster discovery and active learning by implementing exploratory learning with manipulative experiments and direct observations, encouraging questions in the classroom, providing varied delivery of instruction, establishing effective group work settings, structuring the class for participation by all members, allowing opportunities for self-guided inquiry, and by compelling students to read and write on generative topics... (McCarron, Dec. 2000)

The strange forms of nature at the far-off beach widened Amos' urban upbringing. The memory gave him great trust in the power to be developed through his students' curiosity for nature:

> I'm from Pittsburgh, PA. When I went to Florida for a vacation, I could not believe how different things looked. I had never seen palm trees, white sand, or even the ocean.
> ... I actually touched the different plants and saw the different
> animals in the places where they lived. It was so different from going to the zoo.
> ...I want to bring that same kind of interest and curiosity to the classroom... I also want to create a classroom environment where my students feel like they can ask questions and explore the things they are curious about... as a teacher, I can provide a student with the guidance they may need to turn a question or an idea into something that will change their lives. (Simms-Smith, Sept. 21, 2000)

Amos grounds his teaching on making science truly accessible and relevant to urban students, such as through learning science with everyday things:

> ...It is my responsibility to provide the resources and opportunities for my students to grasp the extent science influences their daily lives. ...If I can teach my students to see how understanding science can assist them in understanding the world, it would go a great deal toward my goals as a teacher and as a learner. (Simms-Smith, Jan. 14, 2001)

Kate's early love of the sea brought her to join a college program in coastal East Africa -- an experience that infused her with new meanings for humans' relations with nature, and for the transformative work of teaching:

> ...I camped with friends on a remote island off...the coast of Tanzania... I swam away from the group... I arrived at the rocks and was in such awe of the beauty surrounding us that I thought maybe our group shouldn't be there- -that perhaps as humans we were ruining another miracle of nature...Then, I remembered that humans, too are a part of it. We are a part of nature, a part of the earth...There was certain vulnerability present in that moment... One of my greatest hopes I have for teaching science, is that I can help students find their own ways to connect with the natural world... I hope to find ways of integrating direct experiences into the everyday classroom experience. For so many, including myself, it is the best way to learn. I also want to share my love and amazement at the intricacies of life and the science of biology, in ways that encourage the students to become involved themselves. (Despres, Sept. 21, 2000)

While Kate perceived how what she most strives for, in teaching, is excluded by many limitations of school and society, her belief in students and teaching is stronger yet:

> ...teaching is an act of both politics and art; it is mastered only through experience and with a substantial amount of faith and love.
> ...As the country begins to understand the value of diversity, education begins to reflect wider inclusion of culture and knowledge. I place myself in that wave of change.... Translating politics into the structured public school classroom...challenges many existing structures and institutional practices... As a public school teacher, it is my goal to be proactive for my students; I intend to search out resources and exciting curricula to help them succeed not only academically, but throughout their life. (Despres Jan. 2001)

All three of these teachers expect to teach in Massachusetts public schools. In their temporary Intern placements, each fared differently. Sandra never felt supported in her efforts to create the interactive environment and activities she believes are so essential for children's learning. Amos, working in a different middle school, learned continually from his Mentors' use of explorative activities with the children. With them, he developed a firm belief that anyone can genuinely learn. In an urban high school, Kate sharpened her notice of what was happening in the classroom, noting details of missed opportunities for learning or personal conflicts among students, and reflecting on how her future teaching might address these issues.

Investigative Teaching in Schools

With these personal beliefs and experiences, the new teachers enter the political world of schools. In reflection, we feel their work raises questions. Can there be space for teachers to act by their own philosophies, and mature in them? What would it mean if schools were places where teachers could be investigators, as well as their students? What questions might they come to, what understandings might they form for themselves? Can investigation -- with its diverse history; depth in experience; uncertainties, risks and delights -- be welcomed into teaching and learning science in schools? How might these experiences challenge and change the environment of `high stakes' testing? And what of the teacher education courses? Can teacher education courses support new teachers in forming their own genuine investigations, and in opening these possibilities for learning among their students?

In closing with questions, we affirm the act of investigation: opening new experiences for teaching and learning.

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