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

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

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Introduction

This paper is based on two beliefs underlying the work I do with my colleague, Fiona Hughes-McDonnell. We believe that science is not just the practice of trained scientists, but it is a process of learning in which every student can participate. We also believe that the community of science need not be restricted to those who agree on scientific explanations; it can be extended to a community of students and teachers who are learning about natural phenomena through observing and trying to understand through their own honest, thoughtful efforts.

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. 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.

This paper presents experiences that evolved within the course we invented, as all of us explored learning investigatively, and thought about introducing investigation into classrooms.

Researching and Teaching Investigatory Science

Our forming ideas connected with Piaget's researches on the development of learners' ideas Piaget observed that children's understandings change as they interact with something (Piaget 1936) and find themselves stretched to extend what they can do and apprehend, in relation to it. While interacting with children to follow their development in this process, Eleanor Duckworth realized she was also teaching them (Duckworth 1991); that children's knowledge and understandings were evolving. She developed this as a practice of “teaching\learning research” (Duckworth 2001) to suggest how a teacher can interact

with students and support their development. The subject matter is provided in its complexity as a whole, which learners can question or act on directly. Investigative work in science reflects this. Doing science involves placing real phenomena under study, direct experimental tests, forming and revising ideas in response to what happens, wondering, seeing it by different views. We found support for these ideas in the history of science: for example, in how Galileo's first telescopic sightings show his emerging understandings (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 learning happens in the doing of science.

Settings of School and Curriculum; Inquiry and Testing

The new teachers we worked with were simultaneously graduate students and interns 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 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.

Preparing Investigative Experiences

Through the design and teaching of the course, we sought to involve beginning teachers in encounters with nature that intrigued them to explore, and in experiences with teaching that provoked them to reflect. The active work of the course included classtime activities and dicsucssions 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. Weekly, we developed new activities and questions; thus our research reflections informed what we did next in our teaching.

Our activities were designed to evoke an observation or question. In making such a response, 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.

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

As a class, we watched the sunset weekly from the building's roof (Figure 1). We sprouted seeds; grew plants; dissected cow's eyeballs. Some teachers explored a large magnet's pull (Figure 2), or reacted acids and bases, or 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 2. Teachers testing a strong magnet's pull on paperclips.

We observed that some teachers were finding connections for this work within their teaching. Others held back from investigating, expecting to get directions on "how to teach science''. This significant difference among the teachers showed the direct personal immediacy of investigation that cannot be externally communicated.

This posed a continual struggle for us in preparing investigative experiences. We knew that in their classrooms, most new teachers were expected to hold both questions and answers to those same questions. Believing that the work of teachers is, and can be, thoughtful and researching, we chose to always add some further resource, as fresh entries for them into 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. In a rare book library, 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 hard; 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.

One teacher had encouraged his students to draw, and said:

> 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.

To one teacher's insistence that schools make a "huge barrier" to this, 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", 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. They grasped art's synchrony with science, as excerpted here:

> 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.
> (Sandra McCarron, 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.

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 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

In the details of the teachers' personal investigations, 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. 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 4, left). A week later, its fuzzy stalk was two inches high (Figure 4, right), terminated by a pair of leaves which soon curled back to expose "a developing bud" (Figure 5).

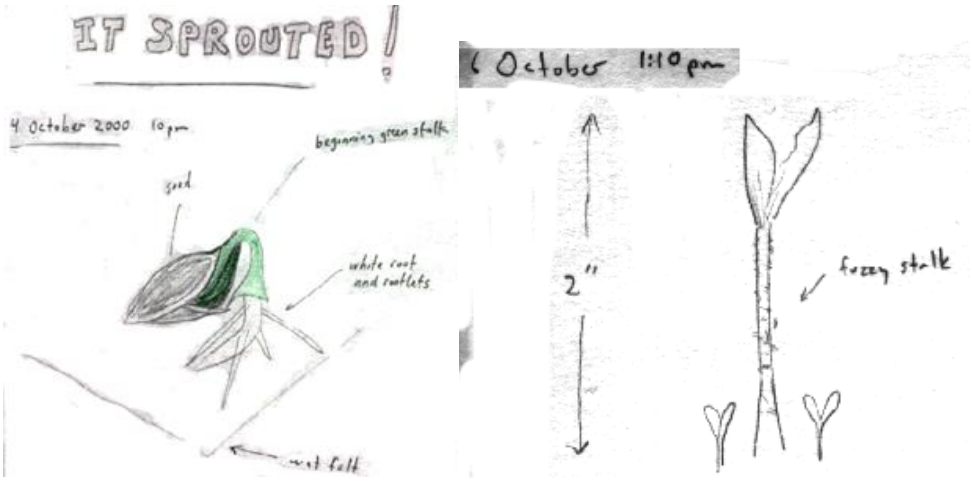

Figure 4. Left: Steve's drawing of a sprouting butternut squash seed. Right: The sprout one week later.

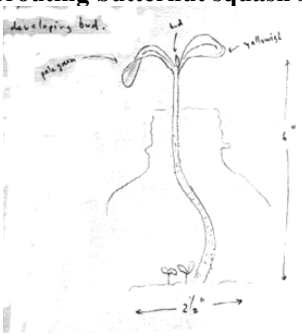

Figure 5. Steve's drawing of a bud appearing between the sprout's first leaves.

The plant's death (after a repotting) cut off further direct observations. Yet, Steve's thinking about growth continued as he asked:

(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 it one clear autumn sky (Figure 6). She sighted it three nights in a row, looking from different viewing places and times, and it seemed about the same.

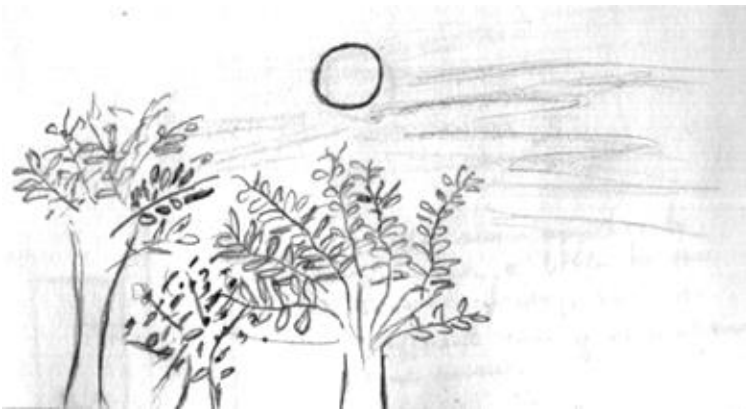

Figure 6. Katie's first observation: a full moon.

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. (McCuen, Oct. 20, 2000)

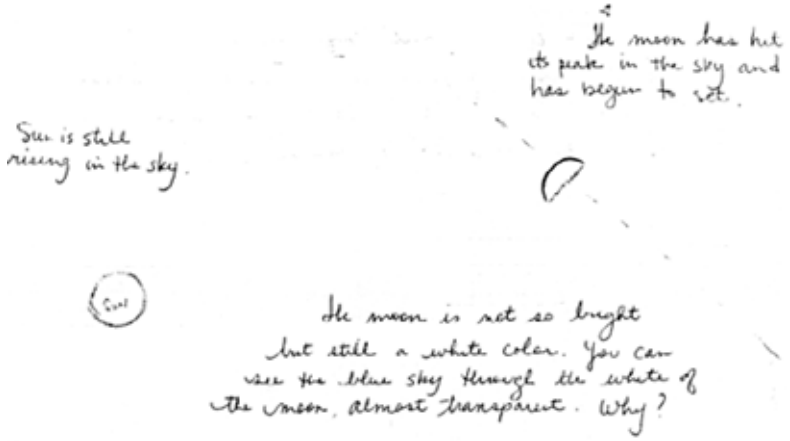

Figure 7. Katie's sketch of the positions of sun and moon.

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 7). Yet again, on two clear mornings when she went out to see the moon at the same time, it was nowhere in view:

> 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)

Getting up earlier yet one day put her in view of the moon's *C* crescent (Figure 8); 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. (McCuen, Oct. 25, 2000)

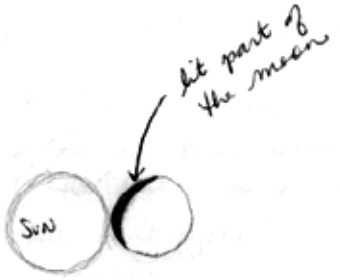

Figure 8. Katie's sketch of the sun lighting the morning moon.

Across the time of New Moon, a week passed without any sightings. The night Katie presented her project to our class, some classmates went outside to look with her and together they found the moon's sliver (reversed). A few days later 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 9); when it is waning, these changes are inverted (Figure 10).

> 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.

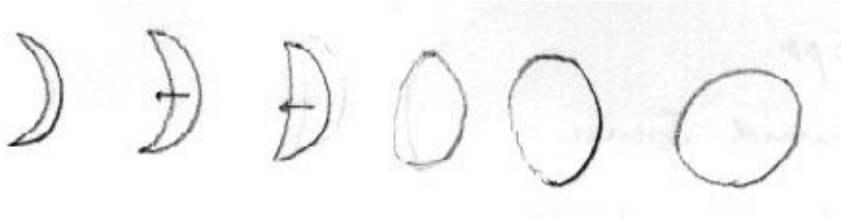

Figure 1. Katie's analysis of the moon's successive waxing appearances.

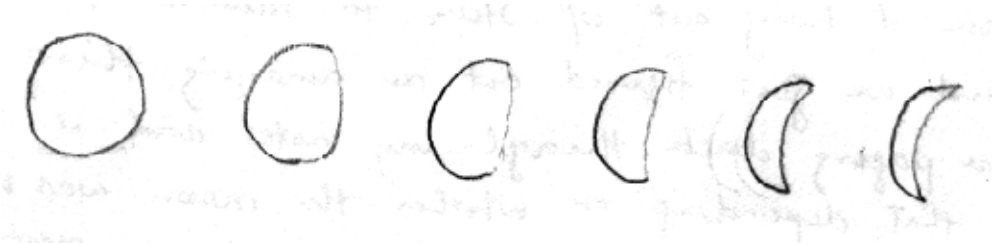

Figure 2. Katie's diagram of the moon's waning appearances.

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

We sought to evoke the teachers' self-reflections by assigning a first paper on their early memories of nature, and a later paper on their personal teaching philosophy. 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.

Two new teachers, Sandra and Amos, were in middle school science classrooms. The distinctive voice of each is emerges: Sandra's sensitive notice of how acting with nature moves our minds and Amos' concern for seeing the real things and finding science's relevance in children's lives.

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

> One day, I think I was about five years old, my father and I planted peas. ... We knelt down and examined the row: How deep is it? How deep should it be? Is it straight? …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 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 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 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)

These teachers expect to teach in Massachusetts public schools. In their 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, their use of explorative activities, and the children. With them, he developed a firm belief that anyone can genuinely learn.

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 state's reliance on assessment through `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.