Inquiry in Kindergarten
Joanna Villavicencio

Facilitating Inquiry
Jane Bresnick

The Power of Questioning
Wendy Cheong

Observation as a Springboard
Betty Mott

Stewards of a Vernal Pool
Beth Kraft

Inquiry in the Middle School
Julia Marrero

Resource Reviews

Literature Links

Technology for Learning
How Does Technology Support Inquiry?
Bob Coulter

“I wonder if my ball will bounce off the ramp?”
Inquiry Learning / Readers’ Choice

A year ago, *Connect* asked its readers to suggest a topic for this March-April, 2000, issue. We received a number of diverse suggestions, but no common theme emerged. Then, in conversation with staff members of the Exploratorium in San Francisco, we heard about teachers participating in the Exploratorium’s Institute for Inquiry who were writing about their classroom work.

Looking back on readers’ suggestions, we realized that inquiry, problem solving and helping students to find successful questions to investigate were common to many of the ideas we had received.

**The result:**

This issue features six articles, all by teachers in the Bay Area of San Francisco, working at different grade levels and with a variety of school populations. All the articles deal with helping students to engage in inquiry learning within their classroom settings. The teachers are skilled and have worked together extensively in the Exploratorium’s professional development project, the Institute for Inquiry.

In their classrooms, they face a variety of challenges and their approaches vary, based on the age group, student needs and other factors. We believe that these teachers’ own work with inquiry learning leads them to tell valuable and intriguing stories about students becoming questioners, investigators and communicators. Many of these students look closely at the world around them and raise significant questions that can extend their learning remarkably.

A NOTE TO READERS: In our last issue, we announced an upcoming interview with teacher-author Allyn Snider, one of two educators who are lead authors for the K–2 curriculum, *Bridges in Mathematics*. That interview will appear in the May-June issue of *Connect*.
Inquiry by Teachers

By Doris Ash, Cappy Greene and Marilyn Austin

This introduction to the work of six teachers was contributed by staff members of the Exploratorium’s Institute for Inquiry.—EDITOR

The Exploratorium is a renowned museum of science, art, and human perception located in San Francisco. Physicist Frank Oppenheimer founded the museum in San Francisco in 1969 as a place to introduce people to science by encouraging self-discovery through a process of asking questions that lead to further understanding. That process is the basis for the Exploratorium’s philosophy of science education.

For more than 25 years, the museum has been experimenting with inquiry-based science learning in partnership with teachers and schools in the San Francisco area and across the country. As part of the museum’s Center for Teaching and Learning, the Institute for Inquiry provides elementary educators with programs for exploring, examining, and discussing the nature of inquiry. One facet of this program is the Teacher Learning Group, comprised of teachers from San Francisco and nearby Marin County, all graduates of the Institute for Inquiry.

The Teacher Learning Group

This group of teachers has used classroom-based research to infuse inquiry into student learning and into their own teaching practice. The Learning Group has had an emphasis on reflective practice, collaboration and discussion and practitioner-based work using the classroom as the laboratory.

Over the past six years we have seen tremendous growth in the professional skills of a changing group of teachers. As they undertake inquiries into their own practice, they consciously identify the subtle steps that allow inquiry to grow for their students. Often they begin by working with the process skills of science, observing, questioning, predicting, interpreting, communicating, etc. Teachers model the skills students need to allow process understanding to grow: they model questioning, use planning templates, introduce reflective thinking, and emphasize de-briefing and group-sharing skills.

Self-reflection

While these teachers are guiding inquiry in their own classrooms, they are simultaneously doing an inquiry into their own classroom practices. Their inquiry shares the same process skills that they model for their students. They are inquiring into student learning, using student work as the data.

To do this formative assessment, there must be a mechanism for gathering, interpreting, and making decisions about student progress and for matching the pedagogical techniques that will move students forward. But these next steps also inform the teacher’s own practice. This intertwining of actions of both student and teacher is the basis for self-reflective practice and professional development.

The Learning Group provides opportunities for collaboration within a safe and supportive environment where there is constructive feedback on classroom research and practice. Our Learning
Group consists of teachers across many grade levels and areas of interest. They have found that children of all ages can be successful at inquiry. They know that inquiry can be practiced outdoors and indoors and in a wide variety of content areas. We find this diversity to be enriching to us all.

Featured in this issue of Connect are six case studies of science inquiry in the elementary classroom written by participants of the Teacher Learning Group. Each article explores some critical aspect of inquiry:

JOANNA VILLAVICENCIO looks at the classroom environment and kindergarten inquiry into light and color;

JANE BRESNICK explores the facilitation of inquiry into force and motion in the first grade;

WENDY CHEONG examines the role of questioning in a sound unit in second grade;

BETTY MOTT discusses the role of observation in a third-grade creek study;

BETH KRAFT looks at inquiry and project-based learning in a year-long inquiry in the fifth grade;

JULIA MARRERO explores how inquiry leads to content while exploring a sixth-grade unit on the water cycle.

As we have observed these teachers work to change their practices to be more effective, and then share their experiences with their peers, we realize that this is professional development that comes directly from them and from their classroom experiences. The teachers have honed their skills so that their classrooms have become demonstration classrooms. We have brought participants from other seminars to observe them. These members of the Teacher Learning Group have become mentors in their schools and in their districts, have led workshops for incoming teachers and have presented their work at several professional conferences. You will find examples of their exceptional work throughout the pages of this issue of Connect.

Doris Ash, Marilyn Austin and Cappy Greene, Science Educators with the Exploratorium Institute for Inquiry, also want to thank Exploratorium Executive Director Goéry Delacôte, Center for Teaching and Learning Director Dennis Bartels, and Institute for Inquiry Director Lynn Rankin for their ongoing support.
When the shades are pulled up in my kindergarten classroom, sunlight beams in through the windows. Early in the school year I give mirrors to the children so they can explore the light that shines in. They enthusiastically manipulate their mirrors, experimenting and discussing their captured sunlight, spontaneously sharing and copying each other’s discoveries. At “debriefing” sessions, they build their science vocabulary by talking about the path of light. They are delighted to use terms like “reflection,” “projection,” and “screen” as I paraphrase their statements and model the new words for them. Soon the language of light is part of their everyday talk.

For my kindergartners, this exploration serves as a way to begin investigating interesting light and color phenomena. It also begins the process of asking and answering their own questions, which is at the heart of the inquiry experience.

Since being part of the Exploratorium’s Teacher Learning Group over the past four years, I’ve used the study of light and color not only to build an understanding of science content for my students, but also so they can practice using materials and learn the process skills of inquiry (observing, questioning, interpreting, etc.). As the children mature in their ability to communicate, they also build their vocabulary and knowledge of light and color and learn how to design their own investigations.

Tools of Inquiry

Once the children are comfortable using their mirrors, I give them new tools to use, such as prisms. Prisms allow the children to explore what happens when light is bent. It’s a magical event when we learn how to make rainbows!

As they investigate, both in the classroom and out, each student learns how to observe and record information about light and color in their personal science notebooks. Children start to compare observations found outside the classroom with the investigations they do in class. They begin to see many ways to do research, and their observations become part of the repertoire of resources that we draw upon for further science explorations.

In our classroom, inquiry is also facilitated by a useful tool called the “Round Light Source” (RLS), a powerful lamp covered with a cylindrical box. The box has four rectangular windows where light beams shine through. Masks with narrow light slits or colored gels: red, green and blue, can be attached to the windows, enabling the children to experiment with either white or colored light. For instance, they can use mirrors to project colors onto a screen, or mix the lights to make new colors. I use the RLS as a learning station in my classroom, just the same as a sandbox and blocks.

These activities allow my students to use their skills in manipulating sophisticated materials and in sharing new ways...
of communicating and investigating. Three or four children typically sit together to investigate. As they learn to mix colored light, there are happy shouts: “Look! I made yellow!” “Hey, that turned green!” “Where’d the red go?” followed by looking at each other’s work and finding out how this magic was accomplished.

Inquiry path

As the children explore light and color with these tools, I guide them to follow a structure that helps organize their investigation. Built into the structure is the expectation that each child is accountable for his or her own question, materials, recording, and work time. I have divided the structure of the work into these five parts:

1. Form a question
2. Make a plan
3. Do the investigation
4. Record and report
5. Reflect, revisit, and plan again

Each child states his or her interest in the form of a question. I carefully model questions and write them down for all to see (Fig. 1). This question, and the materials used to investigate it, become the plan for the activity that follows. Children work individually or in small groups. I work with them by observing, questioning, supporting their efforts, and redirecting their investigations. I actively reflect their activities back to them in my own words, which helps when they report their work to others later on. I also help them manage their time. When the investigations are finished, each member of the class reports to the others. As the children tell what they observed, I write the observations on a chart. Sometimes the children write and draw their own reports.

In the beginning, the children have a hard time articulating their discoveries, so I help them “find” the right words to explain what they discovered. This is a crucial step, since it sets a tone that allows each child to “own” the experience while communicating it accurately. Each person profits by comparing the experience being reported with his or her own. Since this is a group activity, I’m careful to validate each child’s individual contribution - an easy task with 4- and 5-year-old children!

As their experiences build throughout the year, the children in my kindergarten class constantly report and reflect on color and light interactions all over the school, as well as at home. It’s exciting to see evidence that the children understand the concepts of light and color. When a student makes a rainbow by maneuvering some “found” object in the path of a light beam, the satisfied look on that child’s face tells you that a concept has been understood because he or she has actually predicted what was going to happen. Often, the children who have the hardest time engaging in regular classroom work will shine in inquiry.

We are now ready to revisit and plan further investigations. I ask students if they want to repeat their experiments or if they would rather try something else. Children approach revisiting in different ways: some try what another person did; others repeat or vary their first plan in some way. Thus the cycle of inquiry, plan, work, record, and reflect is repeated.

Concepts

As my kindergartners learn how to question, plan, and communicate, they also learn about the concepts of light and color. At the same time, their experiences

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Each person profits by comparing the experience being reported with his or her own.

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A SELECTION OF THE KINDERGARTNERS’ INQUIRY IDEAS AND PLANS:

Xandria asked: “If I mix yellow and orange and pink, can I make gray?”
Veronica and Jacy asked: “Will blue and green light make yellow?”
Austin, Geron and Jerrick asked: “Can we make yellow? Can we put it on a screen? Can we put yellow on the table?"
All the students above planned to use the round light source, color gels, mirrors and screens.
Kevin asked: “What colors are in the rainbow? I plan to use the RLS with white light and a prism.”
LaVelle asked: “Can I put the rainbow from the CD to the screen? I plan to use the light from the window [sunlight], a CD and a screen.”
are supported by many other classroom activities. For example, the children are taught to use water-color paints and to predict what new colors they can make by mixing them. In one of our more cooperative projects, we mix food coloring and water in a clear pan on top of the overhead projector. As the colored pigments combine, they are projected on the wall and ceiling, making larger-than-life color mixtures that the children can observe.

Whenever possible, I use a still or video camera to record investigations. I’ve had the best results with a digital camera, which has allowed me a variety of ways to print out images. One powerful way of sharing is to print out the children’s work on overhead transparencies. In this mode, the entire class can share investigations together. Seeing pictures of themselves is highly motivating and helps the children stay focused as they describe what they did or what will happen next. It’s also easy to write and rewrite statements right on the transparency, thus modeling the writing process. Children can even have their own copies on paper. It’s very powerful for children to have their work “published,” as well as publicly acknowledged.

As a teacher I have learned much from my interaction with the Institute for Inquiry Learning Group and from my own four-year exploration into children’s inquiry learning. The different phenomena of light and color are fundamentally interesting and connect children to the real world using sophisticated tools, language, and ideas. I have seen how language develops during the inquiry process. As children share what they see, they find words to express and refine their thinking. As my students have taught me over and over again, kindergartners can indeed do inquiry.

Joanna Villavicencio is currently on leave from her position as a kindergarten teacher in the San Francisco School District.
Imagine stepping into a classroom buzzing with scientific activity. You see children working in small groups on the floor, at tables, in all parts of the room. Heads are bent together in deeply-focused observation or discussion. The language meaningful, occasionally punctuated by the thrill of discovery, “Oh, that’s so interesting!” When asked what they are doing, children say: “I’m trying to see if this big ball can knock the blocks down,” or, “I want to see which ball can roll the farthest,” or, “I wonder if I can make the ball go up the ramp.”

These are first graders independently exploring the laws of physics, or, as they experience it, experimenting with balls and ramps. While many educators may be doubtful that children as young as five or six years old have enough background knowledge, skills, stamina, or initiative to engage in independent investigations in science, I have found that they can and will, with great success.

In my first year doing inquiry in a kindergarten classroom, I focused on my own role as facilitator. I was interested in learning how to guide my students’ work and was trying to determine how much to offer into their activities (both materials and advice). After first concentrating on modeling the process skills of inquiry (observing, questioning, interpreting, etc.), I set out this year to use inquiry to teach content, and find ways to assess it.

**Exploration: Getting to know the materials**

In my first-grade class this year, we began by getting acquainted with the materials and phenomena in a “Balls and Ramps” kit. During this unstructured exploration time, children discovered interesting aspects of how things worked, and their natural interests were sparked. They also formed theories from which questions would later arise.

At first, the class was presented with balls of various sizes and weights, as well as pieces of cardboard, toilet paper rolls, scissors, and tape. The students made roads for their balls. I purposefully did not talk about inclines. Yet, as they worked in pairs, they all designed their own, “hills in their roads.” Some experimented with roller coasters, sending their balls not only downhill, but uphill as well. Though they did not yet have the vocabulary to describe what was happening, they were dedicated to making those balls move up and down.

As a group, we took a walk around the room to view the various roads everyone had made, and began to notice differences and similarities. Students shared results of how their balls traveled.

After the students experienced and reflected upon the concept of the “incline,”
I introduced the formal term to them. Because they had already discovered it for themselves, they were able to understand the concept better than if I had showed it to them initially. This gave them a sense of ownership over their discovery.

Because I consider reflection a critical component of inquiry, I asked students to draw and write about their experiments. In drawing and writing, students can look back on what they thought occurred and why. In this case, students were instructed, for homework, to draw the road they had created, show how the ball moved, and write a sentence describing this. The following day we used the homework papers to remind us of our experiences with the balls and roads. The students’ work provided various models for recording data.

Observing and learning to ask questions

After my students discovered the concept of the incline, we looked at ways to create different inclines by changing the angle of a board. As we worked, I modeled questioning for the class by asking: “I wonder what will happen if I roll my ball down this ramp?” “I wonder what will happen if I hold the ramp up higher?”

I asked students to try rolling balls on different ramps and observe what happened. It was not important that a particular angle of incline be used, or a particular ball, or even a particular sequence of actions. The pairs of students chose their work space, devised their own ways in which to hold up the board, determined their own pacing, and voiced their own “wonders.” Some students went beyond the directed focus, trying out two ramps in a V-shape, rolling a ball down one and watching it roll up the other.

Following these activities, we again came back to the whole group to review. By this time, the children had had enough experience with the materials to focus on some very reasonable “wondering” for further exploration. I wrote down their “I Wonder” ideas on chart paper to remind us of what we were thinking.

More questions and mini-investigations

The students’ mini-investigations were done in three parts: “I wonder . . .” “My plan . . .” and “I Found Out . . .” We started by reviewing the activities of the previous day. The “I wonder” questions that I had modeled for them received a lot of response from the group. As I expected, they practiced their own “I wonder . . .” questions, thus following through on my modeling. Children began to expect to discover answers to their own questions. The process of investigation became meaningful because the ownership came from student work, not from a worksheet created for them.

With the knowledge the students had acquired through their free explorations, and with the ability to come up with questions that could reasonably be tested, the children were now ready to move forward with their own mini-investigations. After a warm-up brainstorming session, the children were asked to write their questions by following the: “I wonder . . .” template. We used these questions to identify small groups of students with similar interests.

Some students were interested in speed, others in distance, and still others
What separates true inquiry from play are the processes of observing and questioning, and then developing and following a plan of action.

Lessons learned

After several years of examining my role in facilitating an inquiry-based science unit, I have learned that teacher modeling of the processes of inquiry is the most crucial element.

After being given ample opportunity to freely explore the materials, the students will either continue to “play around” or begin to study and work on meaningful discoveries. What separates true inquiry from play are the processes of observing and questioning, and then developing and following a plan of action. This process leads to more inquiries that are progressively more focused and meaningful.

Modeling questioning gives the children a sense of what is reasonable to ask, given the constraints of materials available and location in or out of the classroom. Making plans helps students to see ways in which they can use their prior knowledge to seek answers to their questions. Following through with a plan demonstrates the expectation that we really do want to find answers, and that it is possible to do so. The students’ belief in this expectation results in better observing, better questioning, and better inquiry practice overall.

As the facilitator I have found that I am able to guide the direction of the students’ investigation toward the discoveries of specific content matter. If I want my students to understand that a rolling ball can be a force upon another object which would cause that object to move, I can position a block at the bottom of my ramp and ask, “I wonder what will happen to the block when I roll my ball down the ramp?” Content learning is not accidental in this process. It lies in the carefully guided modeling and questioning of the teacher/facilitator.

Jane Bresnick is a 1st-grade teacher at Ulloa Elementary School in San Francisco, California.
The Power of Questioning

By Wendy Cheong

Over the past four years, as part of the Teacher Learning Group, I have been exploring the role of questioning to advance inquiry skills in my second-grade classroom. When I started doing inquiry in my classroom, I allowed all questions the students asked to be investigated. I found, however, that having children do investigations based on all of their questions wasn’t moving us toward the content, or some of the process skills, that I wanted to teach.

Over the past year, I have come to see that if I limit the questions to a manageable number like five or six, students maintain ownership over what they want to investigate, and we also move towards the content I need to cover. This intermediate step has been very helpful in getting me closer to my goal.

Getting started

I use district-adopted science kits in my classes. Before I start teaching a unit, I familiarize myself with the concepts of the kit and how the activities can support them. Over the years, however, I have moved away from teaching the lessons from the kit as described in the manual, and towards a combination of kit-learning experiences and more student-directed investigations.

When I use the sound kit from Insights, for example, I begin by choosing lessons that allow students to become familiar with the kit materials, become curious, and raise questions. I purposefully choose kit lessons that lend themselves well to exploration.

Modeling questioning

While watching the children explore, I encourage them to ask questions about whatever seems curious to them. Because students often have difficulty asking questions, I support them in various ways. For example, I model techniques and ask a lot of open-ended questions, such as: “Can you tell me what you are trying to find out with this instrument?” or “Is that what you expected to hear?” Eventually, the children get used to hearing the kinds of questions that can lead to investigations.

I practice active listening to the children’s responses, since their questions often come in the form of statements. Then it’s up to me, the teacher, to help turn their statements into investigation questions by asking things like “Do you mean . . . ?” or “Is this what you are asking?” I acknowledge and record all of their questions.

I always start by modeling how to ask questions that can be investigated, and eliminating or re-wording those that can’t be investigated easily. By inviting students into the process of recognizing questions that can be investigated, I find that I can help them to be better questioners, do investigations based on their questions, and get to the content I am responsible for teaching.

Constraining the question

After our classroom explorations with sound, the children generate a number of questions, many of which overlap in how they relate to the concepts. I have learned to constrain and refine these questions. I begin by grouping similar questions. If students ask 12 or 15 questions about a particular facet of sound, for instance, I do an intermediate step to collect the questions according to the concepts I
know I need to teach. I work with the children to re-word some of the questions, and also give a lesson on how to sort questions into different groups. By working with the children we narrow those 12-15 mixed questions to about 4 or 5 more directed ones. This way, students still have ownership over the questions they can choose and investigate. In addition, I know I will be able to draw out the content and make it more meaningful, and the discussions children have at the end of their investigations are richer. Although they work on different questions, they discover many of the same concepts because the questions overlap.

Using this process, children become more self-reflective when they ask questions. They know what questions are, which ones will lead them to doing tests, which might be more like reference questions, and which can easily be answered with a “yes” or a “no.” They also get a feel for which questions may be too big because we don’t have the materials, or which questions may seem too difficult unless we can change them somehow.

Once we have the questions narrowed down, I give children their investigation criteria, which include working with a partner or two, choosing a question to investigate, and creating a plan and a materials list. The students write down their questions and how they will do their investigations, so they have a written form of what they are going to do on that day. Each group has a question, a plan, and a list of necessary materials.

I train myself to look for at least one thing that I can bring to the whole group during discussion time.

Doing the investigation

Before I begin an investigation, I train myself to look as I go through each group for at least one thing that I can bring to the whole group during discussion time. For example, I might find three common approaches for discovering the same idea. I would make a mental note of this observation and bring it up as a way to start the discussion: “Did that happen in your group?” I might say, or “Here’s a technique that works well…”

While children do the investigation, I watch as demonstrations of particular concepts emerge. I use those pieces to ask probing questions during class discussions. I also use open-ended questions as a way to formatively assess what the children know while they are working on their investigations. This serves as a way for me to think about what I need to do for each child to take his or her own next steps.

Lessons learned

I did not always realize the power of questioning. These days, I see myself as a guide that helps the student’s scaffold, reword, and constrain their questions, to help move them towards knowing how to do independent investigations.

In a classroom of twenty second-graders, abilities are all different and children may not be able to understand the same things at the same times. Now I am able to reformat kit lessons that support both children’s questions and the ability to move toward big ideas. I was not always sure how to use these kit experiences to connect concepts about sound for the children, but I predicted that questioning might help me to find a better way.

I think it is especially important to model for children their own reflection and to listen to their statements and help turn them into questions. I want my students to start to internalize this whole process and to look at their work in a more critical way. That way, they’ll be able to think about their experiences and their learning, what they know and what they need to know next.

Wendy Cheong teaches 2nd grade at Jefferson School, San Francisco Unified School District.

by Anton
In my third-grade class, I use observation as a springboard for the development of the inquiry process. The school year begins with several lessons that help students develop their observational skills. Children start by doing various activities that involve close observation of different kinds of objects. They may observe something as familiar as a cracker, for example, or something that is less familiar to them, and then have the class match their description with the object.

Each child begins the year with a large composition book. Recording their observations in this “science journal” leads to the questions that drive students to craft their own investigations. These investigations ultimately lead to a meaningful understanding of the content being presented. The journal becomes the place for documenting observations, writing questions, and suggesting inquiries. These journals become part of each child’s portfolio, which is shared with parents during conference periods, and then become my source of evidence as to whether science standards have been met.

Learning how to observe

Throughout the school year, I guide my class through a number of activities designed to develop their observational skills.

Students begin by making miniature ecosystems from clear, two-liter soda bottles. First, we cut off the top five inches of the bottle. Then students fill the bottoms of their bottles with an inch or two of small pebbles, a sprinkle of aquarium filter charcoal, three to four inches of garden soil, and two or three backyard plants such as ferns, baby tears, and grasses. Water is added until the soil is moist, and the cut-off top of the bottle is put back in place to cover each little terrarium.

When the terrariums are ready, they are placed on the windowsills so that they get enough light. Then students draw pictures showing what the newly-planted ecosystems look like. As the school year progresses, students continue observing and recording changes in their terrariums. They observe the water cycle, seasonal activity, and plant cycles. As some plants die and others sprout from seeds hidden in the soil, questions begin to appear in student journals.

The value of creative questioning

Students should have many opportunities to practice observations in order to come up with the questions that I call “wonderments.”

Once a week, my students have the opportunity to write their “wonderments” in their science journals. They begin with the date and then write a question about something they’ve observed. For example:
“I wonder why when you see someone in the room yawn, you yawn?”

“I wonder why snails leave a slimy trail?”

“I wonder why the plastic cup sticks to the plastic plate when the cup and the plate are wet?”

“I wonder why the pH of the creek is 9 today?”

Wonderments can come from anywhere, although many come from a student’s experiences during science class.

After writing down the question, the student draws a detailed picture representing the question, followed by a possible explanation. Students often go back and change their explanations after having many experiences messing about or collecting evidence. They begin to see that a question is a bridge between what they know and what they don’t know, or want to know.

**Creekside investigations**

For my third-graders, all this observation, questioning, and recording of information leads to a year-long study of a nearby creek. Because it’s a seasonal body of water, it offers a lot of dramatic changes for students to observe. It’s also a great place to write poetry and to draw.

Our study begins with a “Meet-the-Creek” trip. Students conduct a few simple tests, collect data, establish “creek manners,” and become year-long stewards of the creek. At first I model what needs to be done, then they record the weather, the colors they see, air temperature in the sun and shade, and the pH of the water. Students also draw at least two of the plants and animals they notice.

On our return from a creek visit, one student, designated as the “debriefer,” calls on the other students to name or describe

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**OBSERVATION: TAM VALLEY SCHOOL CREEK**

**Plant life**

[Brown toad plant] [Thistle] [Grass] [California blackberry]

**Animal life**

[Green bug] [Dragonfly] [Orange and Black Spider] [Turkey Vulture] [Tadpole]

*These drawings are part of Rafi’s observations which also included weather conditions, air and water temperatures, pH, an inventory of litter and some notes about changes since the last visit: “Dirtier water, less animal life, high pH, plants are not as alive.”*
the plants and animals they noticed. This information, along with weather conditions, Polaroid camera shots, information about the pH of the water, and any other data collected, is entered on a computer and becomes part of our Web site and each student’s individual creek journal.

With each visit, the students become more proficient and capable. More questions are written down, and more tests and responsibilities are added to carry out. Students carry their own test supplies and have small white dry-erase boards to record their results. They share the data they collect, putting all the information on their observation forms, even if they did not conduct a particular test themselves, so each has an overall picture of the creek.

Once the rains start and the creek begins to flow, other tests are added so that everyone in the class is working on a test and has a job. It is important that each student have a responsibility. When all the children are actively involved, you do not have to concern yourself with discipline, as the inquiry itself keeps them interested.

The creek study takes a new direction every year. Each class has its own personality, and the children raise different questions, so each inquiry is different. Students decide the direction of the yearlong creek study themselves.

The first year, for instance, we monitored temperature, weather, plants, animals and change. The second year, students wrote poems and drew creek pictures with pastels. These poems and drawings were published in a Tam Valley School Creek Poetry Collection, and shared at a school board meeting.

This year, our third year of this investigation, began with questions from the students: “How can we keep the creek clear of litter?” “What can we do about all the dog litter that is increasing at such an alarming rate?” “Where do the spiders go in the winter?” Questions about the pH level led to an investigation about pH and how it affects the plant and animal life of the creek. More questions came forward, along with the need to collect and discuss the evidence observed at the creek.

Excitement filled the air after the first rains when the students observed some dramatic changes. The pH returned to 6.7, but there seemed to be no fish in the creek. Where had all the fish gone? Why had they disappeared when there was more water now than before? Why do the fish in this creek seem to prefer muddy water to clear water? All of these questions have become valuable starting points for our creekside investigations.

Reflection

Three years into this process, I have found that observation activities provide a strong foundation for beginning the inquiry process in the classroom. This process gets kids directly involved in their learning. It motivates them to look for answers, solve problems, and formulate their next steps in learning. It doesn’t happen overnight, and there have been both successes and failures along the way. It requires that a teacher be willing to take learning risks along with his or her students, and to provide the structure and tools necessary to assure accountability for learning while meeting state and local standards.

Betty Mott is a 3rd-grade teacher at Tamalpais Valley School, Mill Valley, California.
Local ecosystems make the best life-science labs. I have known this since my own childhood explorations into the woods and ponds near my home. I have since watched the invaluable learning that takes place when children spend time freely exploring the natural world around them, seeking answers to their own questions, exploring, and discovering, while at the same time developing new questions to be answered yet another day.

As a fifth-grade teacher, I was aware of how valuable it would be for my students to have this kind of experience as part of their science learning. After considering the idea for a while, I realized that a seasonal pond (vernal pool) near the school where I teach would make the perfect “natural classroom.” I applied for several grants to get financial support for such a project, and within a few months I had $3,500 in grant money, an outline for studying the pool, and the excitement and enthusiasm to get it started. My participation in the Institute for Inquiry Learning Group provided the peer support that was so helpful during this time.

I approached the project in an inquiry-based way. I began by introducing several “starting point” activities in the classroom so my students could begin exploring the distinct properties of water. As they worked, the children became familiar with the process skills needed to do scientific investigations: observing, questioning, predicting, recording data, and communicating. I encouraged questioning by setting up a “Water” question board in the classroom. After each investigation, students would reflect in their journals and then share their findings with the class. During this time, students were asked to think of questions they might still have about their investigations. At any time, they could ask questions and/or write their questions down on index cards. All questions were read aloud and then posted on the question board.

After many of these water investigations, we narrowed our questions down to the best investigable questions. Students selected the question that interested them most, and then got together with peers who were interested in the same question. With their partners, they designed tests, wrote up materials lists, investigated, created ways of recording information, shared what they discovered and, through the process of their own investigations, came up with more questions to be investigated. This was the approach we took throughout our year-long study of the vernal pool. It served as a model of how to do our investigations.

Learning at our “outdoor lab”

When my students began studying the vernal pool, their first investigation was guided only by this open-ended direction: “Learn all you can about the vernal pool.”
Students began by getting the tools and materials they needed, such as turkey basters, tubs, nets, and magnifying glasses. Each child also had a clipboard for recording information. From this initial investigation, questions about the pool’s ecosystem began to emerge.

The pool became our outdoor lab. We never went without a purpose or an inquiry to investigate. Each trip (which lasted between one and one-and-a-half hours) encouraged more questions and more inquiry investigations. We kept an ongoing “Vernal Pool” question board in the classroom.

Since the pool is seasonal, it fills with the winter rains between December and May. The rest of the year, from June until December, it’s just a dry indentation in the ground. Although we made few trips out to the pool during this dry period, we did go out in November to learn about the native plant life with a docent from the California Native Plant Society. I wanted the students to see the area before it filled with water so they could better appreciate the natural changes that occurred when it became a viable pool.

I was amazed at how quickly the project took flight. My vision became theirs, moving from a teacher-initiated project to a student-generated/student-guided project with me as facilitator. My students’ enthusiasm and motivation propelled a naturally spiraling process. They asked questions that led to research and investigation. This process generated more questions, which created more enthusiasm and more investigation. By mid-February, the project was in motion and fueled by the students’ energy and inquiries.

**Back to the classroom**

I found that many of the questions initiated outside the classroom could be answered through in-class investigations. At one point, for instance, the students became fascinated by how small insects known as water striders, or caddis flies, could walk across the pool’s surface. This generated questions around the concept of surface tension. As a result, I found many ways for my students to explore and develop their own understanding of the mysteries around the concept of surface tension in the classroom.

Our vernal-pool studies also took us to unexpected places outside the classroom. For example, we took several field trips to local water-treatment and sewage plants. These experiences stimulated questions around water purification. Once again, I was able to help students understand the issues of the seriousness of water pollution and the difficult task of purifying water by doing a variety of investigations in the classroom.

In the classroom, we talked about what was needed to sustain life in the vernal pool and then created a microcosm of the pool within a 10-gallon glass tank. We collected pond water, algae, a variety of aquatic plant life and insects, egg sacs, and the tadpoles of frogs, toads, and California newts. Students took turns observing the in-class pool and reporting observations and changes to members of the class.

This student-made environment was also important in stimulating observation and investigation. For example, one group watching the tank noticed a caddis fly burrowing into a newt egg sac and eating the developing embryos. Of course, this disturbed the class, and they began to wonder why this was happening, especially since they had assumed that aquatic insects were
not meat eaters. One hypothesis was that the food source for these insects was so scarce in our artificial environment that the caddis flies were being forced to become carnivores in order to survive. Another possibility, of course, was that these aquatic insects really were carnivores. Suddenly, we had a new investigation to pursue. The class decided that the best way to find out was to go out to the pool and observe these insects in their natural environment, which is exactly what we did.

The project in retrospect

Because of the enormity of the vernal pool project and my commitments to the grants, it was important for me to continually examine the skills and curricular content I needed to teach in fifth grade, and ways in which to integrate these into our pool investigations. It easily fell into place. I am convinced that watershed studies can be a perfect thematic umbrella. In order for my students to follow the process we designed for pool investigations, they had to use skills from many curricular areas. In addition to science process skills, they learned research skills, communication skills, reading and writing, presentation design and public speaking skills, as well as math skills when measuring things like rate of flow and changes in the pool’s depth. We also made many connections to events in United States history and to waterways.

By the end of the year, my students had became stewards of this local vernal pool habitat. They understood human impact on an ecosystem, both positive and negative, and the meaning of interdependency, the important role each living thing has in maintaining balance in a delicate environment. They learned the importance of being aware, active citizens and advocates for the preservation of their local habitats.

Beth Kraft is a 5th-grade teacher at Lu Sutton School, Novato, California.
Inquiry in the Middle School: Content Learning

by Julia Marrero

When I began teaching ten years ago, my goal was for my students to love science. My own experience had taught me that science is not about memorizing facts, but about doing. As a new teacher, I made the common error of stringing together interesting science activities, most of which were teacher-directed. My students were enjoying science, but without a great deal of critical thought. It was my work with the Institute for Inquiry at the Exploratorium which moved my teaching from being merely engaging to truly inspired.

My collaboration with the Exploratorium began after my first year of teaching, when I signed up for a three-week workshop on light and color. Rather than being taught how to teach light and color, the participants of the class were engaged fully in the learning process. We didn’t just study light and color, we participated in an in-depth investigation of the intricate phenomena involved in the subject. More fascinating than the content was the notion that by taking part in an investigation, the way I looked at the world could change. Through such immersion, I began to notice phenomena which had previously escaped my eye. Shadows and reflections held new meaning for me. I was determined to excite my students in the same way. Later I joined the Teacher Learning Group and through interaction with the other teachers in the group, expanded my ideas about inquiry.

I now guide my sixth graders through three to five scientific inquiries a year.

I measure my success by the level of enthusiasm in the classroom, as well as the level of thinking that goes on there. My students look forward to science and feel confident about their capacity for conducting scientific investigations. Their questions are realistic and grow in sophistication. They can determine which experiments are “fair” or “unfair,” and they readily identify controls and variables in an experiment. Just as we want our developing writers to view themselves as authors, we hope that our budding investigators will view themselves as scientists. My classroom is full of scientists: students who think critically about, care about and reflect on what they are learning. The biggest jump in my teaching occurred when I began to see how almost any unit could be opened up into a scientific inquiry.

The four stages of inquiry

There are essentially four stages my students move through in an inquiry: concept development, planning and prediction, investigation, and summary of findings.

In the first stage, students are given multiple experiences with a single phenomenon. Through this interaction, students develop a variety of concepts and questions. It is ineffective to ask students to come up with questions on a topic before they have concrete experiences with that topic.

As an example, I teach a unit on the physical states of matter. I begin the unit by having students complete a set of stations on physical states; this takes about a week. Their questions often arise directly from their participation at one of the stations. For example, one of the stations the students engage in is designed to show the concept of diffusion. The students simply put a drop of food coloring into a beaker of water and observe what happens over time. Many are surprised to find that the food coloring mixes on its own, thus explaining one of the properties of liquids: molecules in a liquid are constantly moving. This experiment can lead to multiple investigations. Does the temperature of the water change the rate of diffusion? Do all liquids diffuse at the same rate? Does the color of the food coloring affect the rate of diffusion? These questions come from the students. In formulating their questions they are already beginning to un-
understand some of the rules of science: for example, only change one thing at a time.

After students have had multiple experiences investigating phenomena, we come to the second stage of the inquiry: planning and predictions. In this stage students formulate a question, create a plan for investigating their question and predict what they think their results will be. It is extremely important for students to be given feedback on their plan before they begin their investigation. I like to conference with each student or group of students (if they are working together) before they begin their plan. If the question is not clear, the investigation will not work. I point out any difficulties that I see in a particular question though I will allow students to keep a problematic question if they are really wed to it. (Often some of the best learning takes place under these circumstances.)

When students feel confident that they have a solid question, they work on writing their plan. They then share their plans with their classmates, either in groups or as a whole class, for feedback. I also participate in giving feedback to students. I make sure that all students know what they need to bring in for their investigation and what their first step will be.

The third stage is the investigation itself. Here the students are pretty much on their own. I am always amazed at how little they need or want my guidance.

The final stage

The final stage of the inquiry is the summary of findings. I like to tell my students that all scientists report their findings. Often we turn the classroom into a mock conference. I have learned to vary the way in which students report their findings. The first inquiry of the year usually requires a written report as well as an oral one but as the year progresses I sometimes make this stage entirely oral. I made this change after realizing that some students were beginning to associate inquiries, not with the process of investigation, but with the paper they were required to write. The summary itself has three components: restate the question and predictions, describe the investigation, and interpret the results. Students are assessed with a rubric which details each of these components. Towards the end of the year I have students create their own rubric and assess one another.

Last year the students completed the inquiry on physical states, where they learned about the water cycle. While most students investigated questions that arose directly from the preliminary stations, some ventured further. One group decided that they wanted to see if they could make a thermos that would work better than the ones that they used at school. Their goal was to try to keep ice water cold for as long as possible. In their enthusiasm they brought in a bevy of materials: Styrofoam (popcorn, fabric, tape, Play-Doh, and more.) During the process of investigation they researched thermoses on the Internet, adding to their own knowledge of what
helps keep things cold. In the end, their ther-
om didn’t function as well as the commer-
cial ones they had brought in, but this was by
no means a measure of their success.

These students clearly felt proud of their
accomplishment and made it known to me
that they could have spent an addi-
tional week investigating their
question. One of them said they
would never look at a thermos in
the same way again. Then I knew I
had been successful.

Selected entries from one student’s notebook:

1. Weather watches
   A large hole around the moon indicates a cold front.
   The next day it will be cloudy.

2. Procedure for investigation
   I will look at the moon every night to see if there is a
cold front. If there is, I will watch the weather the next
day.

3. Predictions
   I predict that this is actually true, and that it will rain
if there is a hole around the moon.

2-25-98
Moon was not out until 10:30
in the night.
Sunny little wind maybe about
80°F. I predict that it will be
the same weather tomorrow.

3-4-98
Moon was not visible. Last few
days including today have been
warm and sunny. I predict some
weather tomorrow.

3-17-98
Moon was not visible. Same warm
weather. I think the moon is rising
later and later now because
it’s close to summer and the days
are getting longer.

3-18-98
No moon again. Same warm weather
with perfectly clear skies. I
predict same weather tomorrow.

3-19-98
Overcast, couldn’t see moon
or stars. The sky was kind of
glowing and it was pretty
light at night because the light
from down town were reflecting
off the thick layer of fog.
Warm sunny all day. I
predict same weather for

tomorrow.

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at White Hill Middle
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California.
Beyond the Science Kit, edited by Wendy Saul and Jeanne Reardon, is a collection of articles by classroom teachers about their own experiences with using kits and other hands-on materials. The goal of the book is not to argue against the use of kits, but to suggest how they can be adapted to the needs of individual classes and children. These chapters come directly from classroom experiences of skilled teachers, complete with examples of student work and classroom dialogue. Reardon reminds us, “Our best teaching will come from listening to and watching the children with their hands in science.”

Beyond the Science Kit ($24.00 plus $4.00 shipping & handling for first book, $1 for each additional book) is available from Heinemann.

Nurturing Inquiry, Real Science for the Elementary Classroom, by Charles R. Pierce, tells the story of the author’s classroom in Maryland. But in doing so, Pierce examines the theoretical underpinnings of his own teaching. He writes about children’s learning styles and the challenges of encouraging inquiry among students who have had little opportunity for it in the past. The book includes many specific ideas for projects, investigations and communicating ideas.


Inquiry at the Window, by Phyllis Whitin and David J. Whitin, is largely the story of one fourth grade classroom where children’s sense of wonder is both developed and supported. The window of this classroom is where a great deal of observation of birds takes place and this becomes the topic of the students’ long term inquiry. The Whitins use examples from the classroom to elaborate on inquiry learning in very helpful and clear ways. The book includes children’s work, classroom dialogues and explanations of links to many members of the local community.


Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom, is part of the Foundations series now being published by the National Science Foundation. This book contains thirteen diverse articles, including several by authors on the staff of the Exploratorium. Also featured is an excellent chapter by Hubert Dyasi, who has worked extensively with New York City schools, and two useful chapters on assessment, one by Wynne Harlen and another by George Hein and Sabra Lee.


Collaborative Inquiry in Science, Math and Technology, by Dennis Adams and Mary Hamm, argues that scientific inquiry and mathematical problem solving skills can best be encouraged in an atmosphere of cooperative learning. Field tested activities and assessment strategies appear throughout the book. They illustrate specific points, but
they are also well explained and usable in classrooms. Examples include investigations of light, sound, patterns and the use of manipulatives to promote inquiry in math.


Talking Their Way Into Science, by Karen Gallas has been reviewed previously in Connect. We list it here because it is such a remarkable approach to supporting inquiry with young children. Children raise central issues in “science talks” which form the basis for longer investigations. The book reports on the technique in Gallas’s own classroom and beyond.

Talking Their Way Into Science ($16.95 plus $3.50 shipping for first book and .75 for each additional book) is available from Teachers College Press, PO Box 20, Williston, VT 05495-0020. Call 800-575-6566, fax 802-864-7626.

The Science Detective, opens possibilities for inquiry through problems posed in a fictional video about an astronaut searching for extra-terrestrial life. Developed by the SETI Institute, the book and video represent a high level of confidence in the existence of life on other planets. To encourage inquiry, you would have to adapt some of the activities in the teacher’s guide. The material is listed as appropriate for grades 3 and 4. Some of the activities about the solar system could easily be used with older students.

The Science Detective ($54.00 includes book, video and full-color poster) is available from Teacher Ideas Press, PO Box 6633, Englewood, CO 80155-6633. Call 800-237-6124, fax 303-220-8843. Web site address is www.lu.com/tip/

Taking Inquiry Outdoors, edited by Barbara Bourne, has the subtitle, “Reading, Writing and Science Beyond the Classroom Walls.” Like Beyond the Science Kit, reviewed here, it comes from the work of a group of teachers connected with the University of Maryland. This book focuses on science as motivation for reading, research and writing and on ways that conventional subject matter can be integrated to make a more useful whole for students. Chapter authors include eight classroom teachers from preK to eighth grade.


For any of the titles published by Heinemann, contact them directly at: PO Box 5007, Westport, CT 06881. Call 800-793-2154, fax 800-847-0938. They offer 10% discounts on web orders through their site: www.heinemann.com

These Resource Reviews focus on books which can help with discussion and planning of inquiry investigations, but inquiry in the classroom demands good materials and equipment. Synergy Learning is developing a basic materials list for science and math inquiry. To receive a copy of the draft, or to submit ideas, please call us at 800-769-6199 or e-mail: inquiry@synergylearning.org. The annotated list will be published in Connect in the fall of 2000.
These examples of children’s literature have been selected because they raise opportunities for inquiry of one sort or another. But you may disagree. Any high-quality children’s book might raise intriguing questions for a specific child. On the other hand, our choices here might not captivate a certain reader or listener. What do you recommend? Let us know and we will publish your idea or list in a coming issue.

**Weighing the Elephant**, by Ting-xing Ye (Annick Press, 1998), tells the story of a boy and young elephant. The Emperor will take the elephant away unless the villagers can tell its weight. They have two days. The boy, Hei-dou, devises a plan and it works, to the amazement of the villagers. Colorful and detailed illustrations by Suzane Langlois add to the story and allow you to raise other questions about the community, the elephant and the emperor.

**June 29, 1999**, by David Weisner (Clarion, 1995), tells of strange things happening all over the US shortly after Holly Evans launches vegetable seeds in flats into the air, lifted by weather balloons. Her science project may be the explanation for such things as, “Artichokes Advance on Anchorage” and other headlines. The book explains one approach to the scientific method while it is also a work of science fiction that has been enjoyed by teachers and students.

**A River Ran Wild**, by Lynne Cherry (Harcourt Brace, 1992), could be used in relation to a specific study of watersheds. Or, it could raise questions about human behavior, first about ignoring a valuable resource and then working to restore it. Specifically, the book is about the Nashua River in eastern Massachusetts, but the story could apply to many rivers and bio-regions. Wonderful illustrations, large and small, allow for many more questions by readers.

**The Wise Woman and Her Secret**, by Eve Merriam (Simon & Schuster, 1991), tells the tale of a woman who will not reveal the secret of her wisdom. Finally, a young girl discovers it, yet she is amazed, “How can I have found it?” Because, the old woman replies, “The secret of wisdom is to be curious . . . to keep on wandering and wondering.” This is an exceptional book that also includes the criticism that the old woman faces because she believes so firmly that people must find the secret on their own. Illustrations by Linda Graves add to the story and its characters.

**Who Really Killed Cock Robin?** by Jean Craig- head George (Dutton, 1971), is a young adult book with an exciting environmental storyline. Two eighth-graders have set out to discover why this particular robin died. After much investigation, they find the cause in a story that is believable, interesting and informative. Although its neighborly, small town environment would not be familiar to all readers, this scientific detective story remains fresh even after thirty years.

**The Mystery of King Karfu**, by Doug Cushman (Harper Collins, 1996), uses both story and art to tell a story and provide clues to the mystery. Readers can discover more than the text actually tells. The entire book pretends to be the notebook of the famous detective, Seymour Sleuth, with his notes, pasted-in clues and scraps of information. The text and illustrations would be of interest to many primary children, but older elementary students can raise interesting questions from careful study of the book.
Current reform efforts in virtually every discipline promote the idea that students should be actively engaged in inquiry on a regular basis. Efforts to infuse technology into schools complement this agenda, with a common belief that technology is the key to improved inquiry. In many ways this is a plausible goal. After all, why spend the untold millions of dollars which are currently allocated to technology initiatives if they don’t “deliver” a return in the form of better student learning?

To paraphrase an old anti-gun control advertisement, “Technology doesn’t promote inquiry, teachers do.” Despite rhetoric to the contrary, technology by itself cannot lead to better inquiry. In fact, in many current software applications, inquiry is actually undermined as students mindlessly answer multiple choice questions to rack up points toward a grade. A skillful teacher, on the other hand, can promote inquiry in class and employ technology in very powerful ways. The focus must always remain on the teacher’s role, the work the students do, and the overall classroom environment.

The examples presented here show how technology can support and enhance an inquiry environment. Notice that in each example it is not the technology per se which makes the activity valuable. It’s all in how it’s implemented.

**Video in support of inquiry**

Despite the negative stereotype of lazy teachers popping in a videotape when they don’t feel like teaching, video holds great promise as an inquiry tool. For example, a couple of years ago my fourth graders were engaged in an extended study of various biomes of the world. After constructing a robust conceptual structure of what constituted a biome, they were able to make good use of the video to extend their understanding to new regions of the world.

To begin the unit, field investigations near the school grounds helped the students to understand how climate, plants and animals interact to define a particular region as an ecologically distinct biome. In St. Louis, they studied seasonal change in the fall, noting changes in temperature and day length and the impact of these changes on the plant and animal life in the area. Leaves falling and birds migrating are but a few of the responses plants and animals have to living in the temperate deciduous forest.

Equipped with this understanding, they were ready to move into other biomes, applying their basic understanding of the interplay of biotic (plant and animal) and abiotic (climate and terrain) factors. Video tapes of life in deserts, rainforests, and on Antarctica allowed my students to learn about the temperature and precipitation in these regions and how plants and animals adapt to differences in climate. Cacti retaining water or rainforest plants shedding it provided a context for the class of how each region has distinctive features. Too often, students take the local community for granted. By making such deliberate comparisons we made the familiar surroundings a bit more strange, promoting greater ecological understanding and awareness along the way.

The critical piece here is the underlying framework which the students developed through extended, first-hand experience on the school grounds. Without this understanding of a biome being defined by the climate, plants, and animals, their study could easily have been just a collection of facts about each region. With their framework of biotic-abiotic interactions,
the students were able to analyze a range of settings, seeing how each region was defined by the same ecological principles, even if the specifics were different in each region. In this context, the often maligned (and just as often misused) videotape took on a powerful role in supporting the students’ inquiry.

New video formats
In the next few years, students will have increasing access to cutting edge tools such as video technology streaming through the Internet or being supplied as live, remote broadcasting through video-conferencing (see for example, the Jason Project at http://www.jasonproject.org, or the Electronic Expeditions program at http://www.stonybrookvillage.com/wardmelville/education/education.htm. Jason links students from around the world on an annual scientific exploration, with live broadcasts sent to institutions such as science centers or universities. The Electronic Expeditions project provides a more intimate link to one or two classes at a time which connect with a practicing scientist who is out exploring an ecologically sensitive salt marsh.

Regardless of the specific project or medium, the underlying principle remains the same: Video serves an important role in bringing students to distant places, but it is up to the teacher to ensure that the rest of the curriculum supports significant inquiry as the core of the experience.

Math challenges on the web
A number of math “problem solving” web sites have sprung up in the past few years., including the Math Forum Problem of the Week contests http://www.mathforum.com/pow based at Swarthmore College and the Mathematics Contest program sponsored by the University of Mississippi and the University of Central Florida http://www.blahblah.edu/math and http://pegasus.cc.ucf.edu/~ucfcasio/problem.html. In these projects, challenging math problems are posted weekly for students to work on and submit solutions online. For the past few years I have used these problems to promote student inquiry, but virtually all of the benefit has been realized off-line. As with videos, the key is in how you structure the class to make use of the problems and the exchange with the online mentors.

The sample problem shown here is typical of the problems posed to elementary students:

Our school is going to have a special treat day very soon! There are two main items that we can order: veggie dogs and hot dogs. In my class of 27 students, 22 have placed orders. There are 15 people who ordered a veggie dog, and there are 10 people who ordered a hot dog.

There are two sizes of hot dogs: large and small. Of the people who ordered only a hot dog, there is one more person who ordered the large size than ordered the small size.

How many people will be receiving large hot dogs?

Students solving this problem successfully will need to employ logic and reasoning as well as some basic computation skills. If they generate a solution, students are invited to submit their solution online to have it checked by an “online mentor.” When I worked as a regular classroom teacher, I made the most of these problems by having students present their work to their peers, who in turn would judge whether it was an adequate solution. In this way, students enhanced their presentation skills as well as their problem solving abilities. It was gratifying to watch students become increasingly articulate about their mathematical thinking both orally and in writing over the course of the year. Also, we developed a real spirit of inquiry as students wrestled with what the problem was asking, what different ways the problem could be interpreted, and which alternative solutions were valid.

In this context, the response from the person online checking the students an-
Debating an answer

For example, the sample problem given here is unsolvable as it is written. Since there is no data given which helps to determine the hot dog size preference for the three students who ordered both a hot dog and a veggie dog, it is impossible to answer the question “How many people will be receiving large hot dogs?” In assessing the validity of the problem as it was written, the students working on it were challenged to think critically about all of the features of the problem and how it could be solved. In this case, critical information was missing, though when this was pointed out in an email message to the coordinator of the project, she insisted that there was adequate information and that students simply needed to read the problem more carefully.

Ironically, a student I was working with on this problem submitted what he knew to be an incomplete solution, giving the size preferences for only the 7 who ordered only hot dogs and pointing out that he didn’t have enough information to go further. The online mentor for that week reviewed his solution, and he was given full credit.

The larger issue here isn’t the contradictory responses which came about from the project staff members. Rather, notice the higher level thinking which the student was engaged in as he:

considered the problem situation,

decided if it was solvable,

articulated his concerns about the problem,

assessed the contradictory messages he received from the two online experts.

That is precisely the kind of higher order inquiry about mathematics which we hope to instill in our students.

The combination of a challenging problem, an inquiry-oriented environment, and the give and take with online mentors about mathematical thinking made it happen. Each of these three facets contributed to a successful learning experience.

And the key to effective use

I believe we should look past the specifics of the technology to see whether the task is engaging and worthwhile, and if it can promote the kind of inquiry you want to sustain in your classroom. There are many great inquiry projects available, most of which can be extended considerably with the infusion of technology. The key, however, isn’t the technology, it’s you as the teacher, the kind of work you ask students to engage in, and the type of classroom environment you create. By modeling a disposition toward inquiry, rewarding creative and critical thinking, and employing technology resources where they are helpful, your class will have richer inquiry experiences.

Bob Coulter is the Instructional Technology Coordinator at the Missouri Botanical Garden, leading teachers and students in a variety of environmental monitoring projects. His new book, Network Science a Decade Later: The Internet and Classroom Learning, co-authored with Alan Feldman and Cliff Konold, has just been released by Lawrence Erlbaum Publishers. A review will appear in the next issue of Connect.
The Pond Viewer

Build a Pond Viewer so you can immediately see microorganisms and other material in a sample of pond water. It can be made from wood scraps, Plexiglas, rubber tubing, nuts and bolts.

Sizes can vary. The one illustrated here is 9" x 12". You will need two pieces of Plexiglas (cut at many hardware stores) at least 2" larger in each dimension that the viewing area you want. Select pieces of wood that are at least 3/8" x 3/4" to minimize splitting. You will need two pieces for each vertical side and two for the bottom of the Viewer, since the wood makes a partial frame on the outside of each piece of Plexiglas.

The top of your Viewer stays open for scooping water. The whole thing is assembled like a sandwich. The sides and bottom are sealed using a continuous length of 1/2" diameter plastic tubing between the two pieces of Plexiglas. Drill the wooden pieces and the Plexiglas and run small bolts through those holes.

Three to five washers (depending on how flexible the tubing is) should be used between the Plexiglas pieces so the bolts can be tightened evenly.

Creating the sandwich is not difficult, but here are a few useful notes:

- Plan to drill holes so that the outside edges of your wooden pieces are about 1/2" inside the edge of the Plexiglas. This will make for a tighter fit.
- To avoid cracking the Plexiglas, first drill very small diameter holes, then drill the size you need for your bolts.
- When you tighten the nuts (or wing nuts), work around the Viewer, tightening each nut a little bit, then go ‘round again to get even pressure on the plastic tubing.

When you have completed this window-like apparatus, attach a string at the top corner bolts to allow you and your students to take samples at various depths. You could bolt a thermometer to the Viewer as well. Your Viewer will provide many opportunities for observation, drawing, discussion and other forms of data collection. Plan to look at the water in the Viewer, and also remove the water samples for observation using microscopes and hand lenses.

This description adapted from the work of Vermont educator, Jackie Gould. Drawings courtesy of Chris O’Brien.