

A Discussion Paper About INFORMAL SCIENCE EDUCATION and INQUIRY

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INFORMAL SCIENCE EDUCATION

We learn all the time. Much of that learning takes place in our daily lives, at home, in our neighborhoods, in the park, going out to movies or museums, watching television, reading books and magazines, talking with friends and family. We don't have to be sitting at a desk, or in a classroom, to acquire scientific skills and knowledge.

In fact, if we want to understand how the natural, physical, and social world works, the best place to be is right in the middle of it, watching, smelling, touching, listening, doing, wondering.

Informal science education captures the opportunities for teaching and learning science in the places and spaces of our lives. It refers to both casual and planned experiences. The settings may include science and natural history museums, zoos and botanical gardens, parks and playgrounds, community and youth organizations, and media—radio, film, video, books and magazines, television, and the Internet. Or the kitchen, backyard, and pizza parlor.

“Informal,” “nonformal,” and “free choice” are all terms that have been applied to learning outside of school. They each have nuances and histories. “Nonformal” has often been used in the international literature, to refer to educational efforts in countries that lack a public education system. “Informal” means to some people the serendipitous learning that comes from daily encounters with scientific phenomena—what floats or sinks in the bathtub, the arc of a baseball as it travels from the impact with the bat to the outfield, how insects get caught in the patterned trap of a spider web. “Free choice” is the most recently coined of the three phrases, and highlights the voluntary, self-directed, and non-sequential nature of the experience. We tell you this so you have the keywords if you want to search for more references.

We use the National Science Foundation language of “informal.” The NSF was the first to recognize and support the role of community organizations, museums, and media as rich resources and essential partners in the educational process. In 1984, the NSF created the Division of Informal Science Education, based on the recommendation of a ground breaking publication, *Educating Americans for the 21st Century: A Report to the American People and the National Science Board* (NSB, 1983).

Since then, the NSF's efforts in Informal Science Education have been dedicated to promoting scientific literacy, public understanding of science, and participation in the scientific and technological enterprise, particularly by groups that have been underrepresented in these fields.

There is a link between informal science education and equity. Until the 1980s, the traditional approach to science education in schools was to sort and eliminate. Certain groups—at that time particularly white males—had more access to the kind of educational preparation that would keep them on the track to higher level mathematics and science participation. Informal science education deliberately counters this inequitable access, and creates ways for everyone to learn and do science. It promotes the idea that diversity enriches, in fact is essential to the quality of the science we do,

because the questions we ask drive the development of knowledge. The more diversity of experience people bring to the questions that are asked, the greater the likelihood that science will move in new and important directions.

We also like the word “informal” because it says to us that science isn’t about rules that someone else makes up. It’s about discovering the order and the laws of nature from the stuff all around us, exploring it, getting messy, and making sense of what we experience.

Informal Science Education is . . .

FUN

Learning is joyful. Informal science education brings out the wonder and shares the amazement of discovering the secrets of life on earth and the universe beyond. Everything is food for investigation, and the informal environment gives us the freedom to support children’s interests and questions. The fun we’re talking about isn’t just games and play. It includes serious study and concentration and hard work. But that seriousness isn’t imposed on the children. It comes from their interest and desire to know. To be able to know something deeply and do something well is satisfying.

Forget what you hear about “seat time,” and that the sign of learning is a quiet classroom or a well-behaved child. Welcome laughter and encourage children to talk to one another as they observe and explore. The “order” in the room will come from children intent upon finding out.

ACCESSIBLE AND EQUITABLE

It is up to us to make it easy for every child to participate—whatever their level of formal educational preparation, their particular talents and skills, their abilities and disabilities. Here are a few tips and connections to resources for further help:

Recognize “multiple intelligences.” There is a large literature now that says people are smart in lots of ways, that there are different kinds of intelligence—artistic, verbal, kinesthetic.¹ For those of us running programs, there are several messages:

- People learn through a variety of means—visual, auditory, physical.
- People learn most readily when you tap into their particular gifts.
- Everyone comes with a set of talents that it is up to us to uncover and support.

Don’t wait to “accommodate.” Assume children with disabilities will be involved and engaged. Have tables that are wheelchair height. Check out the websites and computer programs you use to make sure that they are accessible for children with visual impairments. Identify signers and other resources to support the Deaf community. Most materials and tools can be adapted for easier grips and use by children with cerebral palsy or other motor impairments. Make it clear that *all* children are expected and all children can do science.

¹ See, for example, works by Howard Gardner, such as *Multiple Intelligences: The Theory in Practice*, New York: Basic Books, 1993; and by Robert Sternberg, such as *Metaphors of Mind: Conceptions of the Nature of Intelligence*. Cambridge and New York: Cambridge University Press, 1990.

Offer multiple pathways, formats, and ways to experience and experiment. Use a variety of approaches and media that allow children to use different senses. Provide opportunities for them to observe and record that go beyond looking and writing. Use drawing, feeling and making physical models, recording with tape recorders. Ask the children what works best for them, and how they would like to proceed. Draw on the work that AAAS and many others have done on including people with disabilities in science.²

VOLUNTARY

If you're conducting family events or special workshops, folks are coming because they think you're going to offer something worthwhile. If you're running an afterschool program, chances are you're responsible for the children's whereabouts. But otherwise, there is nothing compulsory about their participation. We want children to be involved because the activity and the subjects are so compelling that they're irresistible. Learning becomes something that we do because we want to, not because we have to.

SELF-DIRECTED

When people explore museums or choose a program to watch on television, they are in charge, deciding where to go, what to see, what to do.

As much as possible, put children in charge of their own learning. Help them learn *how* to learn. Encourage children to ask questions, especially those that they are burning to know the answers to. Give them the tools and support to pursue those questions. Create spaces where they can explore independently, safely and creatively. Help them see how what they've done connects to something they already know or did.

HANDS-ON AND EXPERIENTIAL

Learning is active in the informal environment. You can have tables to work at and chairs to sit in, but the focus is on doing, using your hands, and nose, and feet, and bodies. Rather than telling, give children the opportunity to feel it and understand it from direct experience. Children will learn about the laws of motion if they are observing their own and others' actual movement, and dropping objects and watching what happens, and playing with ramps and balls, and building their own roller coasters.

It is also important to have children reflect on the experience, to talk about what they felt, observed, think they learned. Portfolios, collections of what they have gathered, and field journals can help them track their process. Help them connect back to the questions they asked, and to the questions scientists have asked or are currently asking. The decision about whether to tell them about the particular scientific principles is a tougher one. Some folks say the children will discern the science from the experience, others believe that it is important that they know that it connects to a body of scientific knowledge.

² See for example, Stern, V., Summers, L., Brewster, S., & Hamper, M. *Access Science: Themes and Variations*. Washington, D.C.: American Association for the Advancement of Science, 1998; and Wahl, E. "Can she really do science?" in Rouso, H. and Wehmeyer, M.L., *Double Jeopardy: Addressing Gender Equity in Special Education*. Albany: State University of New York Press. 2001.

OPEN-ENDED

The informal environment is not on anyone else's time schedule. There is no required curriculum that must be learned and tested within a constrained period of time. A question or a project can go on as long as the child's interest can be supported.

The process of investigation itself is open-ended. Scientific inquiry involves following leads and clues along a path of discovery and accumulation of evidence. While an activity or project can certainly be planned, the informal environment makes possible a process more akin to what real scientists experience—changing their plan when the evidence points in a different direction from their original idea.

NON-SEQUENTIAL

Of course we want to lead children through topics and ideas in a logical and thoughtful way. But the informal environment also gives us the chance to capture the Science in Everyday Experiences, those wonderful teachable moments. You can stray from the topic of the day.

Accumulate experiences. Collect stuff. Identify patterns and categories. Give children lots of different ways to experience and understand a physical or natural phenomenon. When they're ready to organize it and make sense of it, they'll let you know.

INTENTIONAL

This may seem like a contradiction given what we just said, but you probably have some clear goals in mind. You may want to get children excited about subjects that they thought were dull or not for them. You may want to get them on an educational track and career path that has not been welcoming to women, people of color, or people with disabilities. You may want to introduce them to the latest technologies, or new applications of science to industry.

All these require a course of action that is deliberate. So even though the mood is light and the environment is relaxed and open, the plan for changing the status quo about who participates in science requires strength and determination. Set your goals carefully and develop strategies that are likely to put you on a path to achieving them. Evaluate how you're doing toward reaching these important outcomes.

A HABIT OF MIND

Informal science education communicates that learning takes place all the time. It is a life skill, and a lifelong venture. We are building "habits of mind" so that children know they can learn, and know how they learn well. We want children to recognize the resources available to them, to take advantage of everything that's around them, and to be aggressive about getting access to educational and career opportunities.

Informal Science Education focuses on

CONTENT

The core of the experience must be exposure to the actual content of science. That doesn't mean providing facts in rote fashion. It does mean identifying the main concepts, the "big ideas," the scientific principles that an exploration will introduce.

Even with open-ended questioning and an inquiry process, you have to know where you're going. You need to know enough about the science so that you can guide the process, provide the tools for investigation, and help children get to the next step.

Providing up-to-date, accurate content in science and mathematics is probably the biggest challenge you'll face, especially if you're not trained as a science educator or you don't have a lot of mathematics and science in your own background. So what can you do?

First, acknowledge that the adults are learning with the children. Many of us adults are "undereducated" in science—never had access, never learned it, forgotten what we did know. Even those of us who have had more formal science education exposure are likely not to be up on the current questions or research in many fields. Often our job is to educate ourselves, educate the parents and other adults who are part of the children's lives, *and* educate the children.

There are lots of resources available that can give you a start, including the Standards documents (National Academy of Sciences, *National Science Education Standards*, 1995), (NCTM's Principles and Standards for School Mathematics, 2000) and guides to implementation that extend beyond the classroom, such as the *Pathways to the Science Standards* series published by the National Science Teachers Association (2000). A good source for background information on the scientific principles and processes are science books written for children. For activity guides, children's books, and content resources, check out the AAAS Directorate for Education and Human Resources, <http://ehrweb.aaas.org>,³ and the National Science Teachers Association, <http://nsta.org> or for mathematics, <http://www.nctm.org>.

Among your friends, acquaintances, and colleagues there are probably people who are either self-educated in an area of science or technology, or formally trained. College and graduate students in the sciences and in science education are another source.

But most important is to set up relationships with science-rich and content-rich institutions, and with science educators and scientists you can call on. You can invite them to do formal presentations, have conversations with the children about what they do and the questions that they ask in their work, serve as mentors or guides. But you also want some "advisors" you feel comfortable enough to call or email with a question, no matter how basic. Some sources include:

- Your local science or natural history museum, zoo or botanical garden, planetarium or observatory. Visit to gather the information provided in the exhibitions and public spaces.

³ See, for example, *TechLinks for CTCs: Science, Math, Health & Literacy Activities for Community Technology Centers*, 2001; *Black church Health Connection Project Manual: Hands-on Life Science Activities*, and the *In Touch* series, 1995.

Make contacts with the people behind the scenes—the exhibition designers, the curators, the researchers and graduate students, the education staff. Many of them are eager to do educational work in addition to their day jobs, or as part of their day jobs.

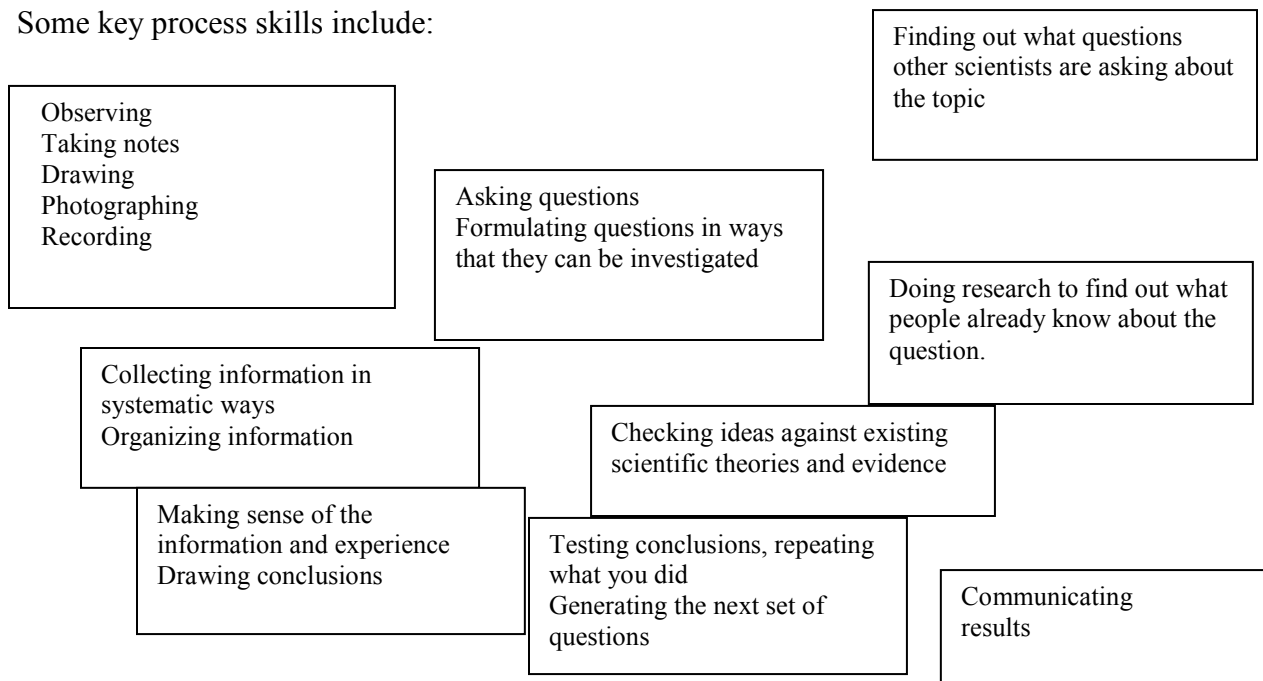
- Scientific and professional organizations. The alphabet soup of organizations to contact is full of people who are anxious to support the development of young interest in science, especially among children from underrepresented groups. AAAS has the whole list, but a few examples are SBE and SWE (Society of Black Engineers, Society of Women Engineers), AWIS (Association of Women in Science), SACNAS (Society for the Advancement of Chicanos and Native Americans in Science).

PROCESS

Science is a process. It's dynamic. Scientific knowledge advances because people ask questions and then pursue them, systematically searching for evidence.

Building children's skills to do science is as important as conveying content. Process and content go hand-in-hand. Content without process leads to the false idea that science is simply a static collection of facts. Process without content may result in children having fun but learning very little about how the world actually works.

Some key process skills include:



There are other “process” skills, though, that can help children engage with and learn about the physical world. Encourage children to

- Mess around, and get messy—dig in the dirt to find worms, get elbow deep in bubble water, drip oobleck over the counter.
- Take things apart—dissect machines and specimens, with scientific instruments and hardware tools.
- Look at things from all different angles—turn it upside down, lie on your back and look up.
- Guess, make mistakes, and come up with nutty and out-of-the-box ideas and explanations.

Children need to practice being alternative thinkers. They need support to challenge and question, to take intellectual risks and to think out loud. Getting the answer right is valued in many formal classrooms. Make it clear that in this informal education space, mistakes are ways to try out ideas. And farfetched ideas often result in amazing discoveries.

TOOLS AND TECHNOLOGY

Tools are essential to the process of inquiry and to advancing scientific knowledge. Lots of children, but especially those from underrepresented groups, have less access than others to tools and technology.

You don't need fancy equipment. Handheld microscopes, magnifying glasses, mirrors, rulers, measuring cups, and calculators will do. Hammers, vyses, and screw drivers, even pots and pans, hair dryers and combs can teach children about physical processes and form and function, help them appreciate accuracy and precision, and move them from intuition and hunches to testing and collecting evidence.

Then they can appreciate what technological invention can do for science. Galileo's telescope provided the physical evidence for Copernicus' intellectual theory that the sun, not the earth was the center of our universe. Today's telescopes allow us to look back 13 billion years and see the afterglow of the Big Bang, supporting a theory that until ten years ago was considered an unlikely explanation of the origin of our universe. Supercomputers made it possible to sequence the human genome in far less time than even the scientists engaged in the effort had thought possible.

How do you create an informal science environment?

LET THE WALLS SPEAK

Set up your space to invite children to touch, hear, smell, explore, take apart. The early childhood center is a great model for an informal science education space whether you're serving 4-year-olds or 14-year-olds, or children along with parents and their siblings. Organize so that you have stations and areas, with materials, books, and tools that children and young people can use to explore and pursue their questions. Put everything at a height that can be explored by the children and adults who will use the materials. This can apply to a child's room at home, a single event (we're always rearranging furniture when we do a workshop!), or an ongoing program.

Plaster the walls with posters and questions and images of all different kinds of people engaged in a wide range of activities that draw on science and mathematics understanding. Post questions and photos of projects and investigations in process, with captions drawn from the children's own commentary and their interactions with adults and peers.

If the space is not yours to control—you're in someone else's classroom or a common room in a community center—set up portable boxes, commandeer storage cabinets, and get lots of post-it easel paper and double-sided masking tape.

AND GO BEYOND THEM

The bricks of your building or the wood of your house, the geology on which it rests, the birds and the trees on the block, the social and cultural history of your neighborhood are all there to be tapped to create an informal learning experience.

Your immediate environment is fertile ground for scientific learning. Everywhere are physical and natural phenomena to be observed—the striated rocks that turn out to be from the last glacial age, the slide and the swings in the playground, the suspension bridge over the river, the dirt under your feet, the moon and the stars, the air all around you. They are the treasures in your own backyard.

Then go outside your own neighborhood, to the places where you can take children and adults to see and learn more. Extend the bird study by visiting the natural history museum, the zoo, or the Audubon Society. Take playground physics to the science-technology center or to an engineering firm that designs and builds such equipment. Observe the universe at the planetarium or observatory, or join up with the local amateur astronomers with their telescopes for stargazing events. Put the local learning into larger context, and then bring the children and the adults back home to put it all together and create their own field journals, exhibitions, and models.

COLLECT

Stuff. The objects of our environment tell the stories of lives and cultures, of adaptation and evolution, of the geologic record and the origin of our universe. They give us things to build with, to break apart and analyze into component parts. They tell us what they are made of, what we are made of. Every thing can serve as the beginning of an inquiry in the informal science environment.

So dig and scrounge and pick up things that other people will think you're crazy to want! Collect from home. Collect from outside. Collect from construction sites. Collect when you go to the beach. Collect when you walk down the street. You never know what useful things people will throw out. We once found a whole collection of broom handles on the curb; they made terrific dowels for building big structures. Pick up rocks, leaves, sand and dirt, nests (abandoned of course), feathers and the fur that your cat shed on her favorite chair. Bring in tools of all kinds, scientific and fix-it, and stuff to build with.

Activities, materials, books. There are hundreds of great hands-on activities that folks have created over the years to amplify scientific concepts. They will be especially useful if they're part of a story you're trying to tell, or a set of ideas you're trying to get across. Lots of them are great to do at home as well as in afterschool programs or workshops. Many, such as "batteries and bulbs" and "sink and float" have been around for years. You don't need to invent new activities. You just have to locate them, put them together in a reasonable fashion, adapt them to your surroundings and materials, and GIVE CREDIT to the source, whether you are using the material as is (in which case, you need to secure permission to duplicate) or taking off on others' ideas and adapting them. Acknowledging your sources is the legal and ethical thing to do, and it helps children to understand that knowledge is built, piece by piece, and we stand on the shoulders of those who went before.

CONNECT

One of our most important jobs is to foster linkages. Connect to

- Up-to-date scientific content and technologies
- Educational opportunities that can help our children navigate through the formal academic system in ways that will sustain their participation in science and mathematics
- Networks of mentors, role models, internship experiences, career exploration, and job opportunities

We need to build these connections as program providers, as parents and caregivers, and as advocates, at the same time that we teach the children how to secure the resources that can help them and their communities move forward.

So go ahead and be shameless.

- Bug that museum until they give you and your group free admission, and then get them to give you material and guided tours. Make connections to programs and workshops they offer at their place.
- Call that astrophysicist and ask for help in understanding the latest images from the Hubble telescope.
- Convince that genetics lab to let your children observe the process of DNA extraction and replication.
- Work with the environmental center to devise projects in water monitoring or birding or air quality analysis that children and parents can be involved in.
- Invite folks who come from your community and became scientists or use science in their daily work to talk about their paths and what their lives are like.

PLAN

Developing an informal science education program isn't rocket science—unless it's about astrophysics! But it does take thought and care to build an experience that will accomplish the kinds of goals we spoke of earlier. Eric Jolly and Pat Campbell came up with this model for thinking about how to sustain young people's participation in mathematics, but it applies equally well to creating a program of informal science education.⁴

- Engagement. First, we have to capture children's interest and get them involved in science
- Capacity. Then we have to make sure we're building skills and knowledge.
- Continuity. Finally, we have to ensure that the pathways, resources, and support are there for them to move to the next level.

Naturally, you'll be able to engage more deeply, build more skills and knowledge, and prepare for the next steps if you are working with children or children and adults over time. But even in a single event, you can capture their imaginations, share some solid science skills and information, and send them off with ideas for what to do next.

Here's to a successful launch!

⁴ *Upping the Numbers: Using Research-Based Decision Making to Increase Diversity in the Quantitative Disciplines*; Patricia B. Campbell, Eric Jolly, Lesli Hoey and Lesley K. Perlman. A Report Commissioned by the GE Fund; January, 2002.

Selected References

- (1995). American Association for the Advancement of Science. *In Touch With ... Series*. Washington DC: AAAS. For a complete list of publications from the AAAS Directorate for Education and Human Resources, see <http://ehr.aaas.org/cgi-bin/list.pl>
- (2002). Campbell, Patricia, Jolly, Eric, Hoey, Lesli, Perlman, Lesley K. *Upping the Numbers: Using Research-Based Decision Making to Increase Diversity in the Quantitative Disciplines*; Patricia B. Campbell, Eric Jolly, Lesli Hoey and Lesley K. Perlman. A Report Commissioned by the GE Fund.
- (2001). Falk, John H., ed. *Free-Choice Science Education: How We Learn Science Outside of School*. New York: Teachers College Columbia University.
- (2002). The Forum for Youth Investment. "Learning Opportunities for Children and Youth: Expanding Commitments, Blurring the Lines." Takoma Park, MD: The International Youth Foundation.
- (1993). Gardner, Howard. *Multiple Intelligences: The Theory in Practice*, New York: Basic Books.
- (2001). George, Yolanda, Bell, Nathan, Bowden, Gaynelle, eds. *TechLinks for CTCs: Science, Math, Health & Literacy Activities for Community Technology Centers*. Washington DC: American Association for the Advancement of Science.
- (1995). George, Yolanda, *Black Church Health Connection Project Manual: Hands-on Life Science Activities*, and the *In Touch* series, 1995.
- (1987). Hatcher, Barbara, ed. *Learning Opportunities Beyond the School*. Wheaton, MD: Association for Childhood Education International.
- (1995). National Academy of Sciences. *National Science Education Standards*. Washington DC: National Academy of Sciences.
- (1983). The National Science Board. *Educating Americans for the 21st Century*. Report of the Commission, William Coleman and Cecily Cannan Selby, co-chairs. Washington DC: The National Science Board.
- (2000). National Science Teachers Association. *Pathways to the Sciences Standards*. Arlington VA: NSTA.
- (1998). Stern, Virginia, Summers, L, Brewster, S., & Hamper, M. *Access Science: Themes and Variations*. Washington, D.C.: American Association for the Advancement of Science.
- (1990). Sternberg, Robert. *Metaphors of Mind: Conceptions of the Nature of Intelligence*. Cambridge and New York: Cambridge University Press.
- (2001). WahI, Ellen. "Can she really do science?" Rousso, H. and Wehmeyer, M.L., *Double Jeopardy: Addressing Gender Equity in Special Education*. Albany: State University of New York Press.

INQUIRY
A Discussion Paper
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Inquiry is

- THE PROCESS OF ASKING AND PURSUING QUESTIONS
- A METHOD OF TEACHING AND LEARNING

What the Standards Say About Inquiry

- GRADES K-4
- GRADES 5-8

The Elements of Scientific Inquiry

- OBSERVING
- QUESTIONING
- PREDICTING
- INVESTIGATING
- HYPOTHESIZING
- COMMUNICATING

What Can You Do to Promote Scientific Inquiry?

- ACT AS FACILITATOR AND GUIDE
- RESPECT CHILDREN'S THINKING
- ENCOURAGE QUESTIONS
- CONNECT TO BIG IDEAS, AND TO QUESTIONS THAT SCIENTISTS ASK
- YOU DON'T HAVE TO KNOW THE ANSWER, BUT YOU DO HAVE TO KNOW WHERE YOU'RE HEADED

INQUIRY

Ask the Ant Lion

A little creature, often ignored, succeeded in keeping forty children happily busy for many days.

How was this possible?

Well, why not ask the little creature? Why not ask the ant lion?

Where is it to be found?

Almost everywhere in the soil. In dry and sometimes shady places, such as overhanging roofs, along the walls under verandahs, or even between the buttress roots of trees. In fact, in most dry and sandy places there are tiny conical-shaped pits where, at the bottom of each one, lurks a drab little creature—the ant lion.

The children, when they observed what it did, were stimulated to ask many questions.

What is it?

What does it do?

How does it move?

What does it eat?

How does it catch its food?

Why does it live in little sand pits?

How does it eat?

How does it make these little pits?

Can it make pits in gravel? In flour? In sugar? In ashes?

Does it prefer sand to gravel?

How does it throw things out of its pit?

How big a thing can it throw out of its pit?

Can it see where it goes?

These and many, many more questions were asked. And invariably, the same answer was given to the children: Ask the ant lion; it will give you the answer.

This is the leading phrase throughout the unit. By “asking the ant lion,” the children find answers to their questions, and the teacher to many of his. The exciting thing about it is — the ant lion is always right. The children — or the teacher — may predict incorrectly.

In order to “ask the ant lion” the children had to think out and set up all sorts of experiments. They placed the ant lion in different kinds of situations. The ant lion would never fail to respond and provide an answer.

In the whole series of lessons the children were *told nothing* about the ant lion, but they learned a good deal about it.

They learned by using their eyes and hands, and their brains, they could find a variety of answers to many questions.

The children became acquainted with the process of scientific inquiry. They learned to ask questions which could be answered in trial situations (experiments). They learned to predict answers, and how to set up experiments which would give the answers. They learned that it is not always easy to get at the right conclusion.

In the process they became eager young scientists.

The African Primary Science Program was developed in the late 1960s. It was designed for another continent, in another time. Yet it has much to teach us nearly forty years later, here in the United States.

The tradition of inquiry has a long history. Great thinkers have made the link between the quest for the advancement of knowledge and the advancement of a free society. "Socrates challenged the youth of the city to think for themselves, to question the wisdom of their elders, and to probe the unsolved mysteries of the natural world," notes Peter Dow. Centuries later,

On the eve of World War II, our most celebrated 20th century educator/philosopher, John Dewey, made a persuasive case for the importance of inquiry-based teaching as a way of preserving values in a world threatened by totalitarianism. The scientific method, he said, "is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live."

"Perhaps now, more than ever before," says Dow, "the ability of average citizens to think for themselves may be the best protection in a world of increasing technological and scientific complexity" (NSF, 1999, p. 5).

Inquiry is

THE PROCESS OF ASKING AND PURSUING QUESTIONS

Humans seek to understand and explain. As a species, we wonder, search for insight, and make meaning. There are many kinds of inquiry. Theologians and philosophers may ask why we exist, what came before, what comes after, what the nature of the human condition is. Artists may ask what beauty is and how they can represent it.

What distinguishes *scientific* inquiry from other kinds of inquiry is *evidence*. Scientists ask questions that are formulated in a way that they can pursued through the collection and analysis of data.

Inquiry begins with "I." It starts with the person asking the question. That person's background, experiences, talents, preferences, and ideas influence how the question is asked—and what question is asked. More diversity means that more and different questions get asked. Diversity enriches the scientific enterprise as a whole. In fact, diversity is necessary to good science.⁵

A METHOD OF TEACHING AND LEARNING

Inquiry is an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science.

(NSF, 1999, p. 2)

⁵ Cecily Cannan Selby has been a major proponent of this perspective and has just completed a report for the Henry Luce Foundation on the topic "Who Does Science Does Matter."

“Inquiry is central to science learning” say the National Science Education Standards. While this way of teaching and learning is certainly not new, its reemergence in the United States as a favored strategy is recent. John Dewey’s writings had limited immediate effect during his lifetime. Most of us, especially if we weren’t in the science track through high school and higher education, learned science through memorizing and regurgitating facts in the classroom, and repeating someone else’s experiment, with a foregone conclusion, in the lab. Among the first programs funded by the National Science Foundation when it was established in 1956 were efforts to transform science education so that it would more closely resemble how science was actually done.⁶ Until the science education reform movement of the 1990s, most inquiry-based science was being conducted in informal settings, outside of classrooms and schools. In the past ten years, there has been substantial attention paid to how to promote inquiry in the formal classroom as well as the informal setting.

Inquiry builds on children’s natural curiosity about the world. Children’s questions become the basis for exploration and investigation. Adults, in turn, act as guides through that process, and the questions they ask are also open-ended:

- “What do you see? What do you hear? What do you smell? How does it feel when you touch it?”
- “What do you think will happen if...?”
- “What do you think is going on here?”
- “How could we find out more?”

⁶ Among these were the Physical Sciences Study Committee, (PSSC Physics), which included a series of films of physicists in action to demonstrate both the core concepts and the way in which actual scientists investigate them; and Elementary Science Study (ESS), which invented many of the now-familiar hands-on activities like “batteries and bulbs” and “mystery powders.” ESS was ahead of its time, in that neither schools nor teachers were prepared for this approach, which used lots of materials rather than books, and required training in the unfamiliar method of inquiry.

What the Standards Say About Inquiry

When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills.

National Science Education Standards

The Content Standard for Science as Inquiry of the National Science Standards lists the following for grades K-4 and grades 5-8:

Grades K-4

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer.
- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge).
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Scientists review and ask questions about the results of other scientists' work.

Grades 5-8

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Mathematics is important to all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science advances through legitimate skepticism.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

The Elements of Scientific Inquiry

There are numerous ways to present these components. The boxes in the section on process in Informal Science Education are one, and here is another (Ash, 1999, p. 53).

OBSERVING

Watching carefully, taking notes, comparing and contrasting

QUESTIONING

Asking questions about observations, asking questions that can lead to investigations

PREDICTING

Suggesting an event in the future, based on observations

INVESTIGATING

Planning, conducting, measuring, gathering data, controlling variables

HYPOTHESIZING

Providing explanations consistent with available observations

INTERPRETING

Synthesizing, drawing conclusions, seeing patterns

COMMUNICATING

Informing others in a variety of means: oral, written, representational

There are many good guides and articles on scientific inquiry. Here are a few excellent sources:

National Research Council. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington D.C.: National Academy Press. 2000.

Minstrell, J., van Zee, E, eds., *Inquiring into Inquiry Learning and Teaching in Science*. Washington D.C.: American Association for the Advancement of Science. 2000.

Foundations. Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom. Arlington, VA: National Science Foundation. 1999.

What Can You Do to Promote Scientific Inquiry?

ACT AS FACILITATOR AND GUIDE

The role of the adult or “leader” in inquiry is to guide, coach, and encourage. The leader provokes and promotes the questioning process, sets up the situations in which children can observe and construct investigations, provides the materials and tools for exploration and experimentation, identifies additional resources and references, and makes connections to scientists and other institutions that can push the process of discovery along.

Your job is not to provide information so much as to create an environment in which children can seek information. You are not the authority on science. You are the authority on supporting children’s scientific inquiry.

You don’t have to stand in front of the room and tell children what you know or what they should know. Encourage them to talk to each other, and to seek your advice and help when they need it—and give them ideas about where and who else they can seek for input.

Teach children that they are their own teachers, and the world is theirs to learn from.

RESPECT CHILDREN’S THINKING

Children’s questions matter, and they are based on their experience of the world and the imagination and creativity they bring to that experience. They are not weighed down by someone else’s conventions or ways of looking.

Hubert Dyasi makes a strong case for “The Power of Children’s Thinking”:

Young children can and do inquire, and it is important not to underestimate the power of this inquiry. They do so in different ways, depending on developmental level, prior experience, and context. From what we know from cognitive research, the context has to be concrete; the phenomena and objects must be ones children can explore with their senses. But at all ages, children do observe and investigate, collect data, think, reason, and draw conclusions.

The theories children build, whether they are right or wrong, are not capricious. They are often logical and rational, and firmly based in evidence and experience.

(NSF, 1999, p. 26)

You may have heard people say that children’s ideas about science are “naïve” or that they have “misconceptions” that we must uncover in order to correct. What Dyasi is saying is that these are not misconceptions and they’re not naïve. They are legitimate attempts to make sense and explain. Help children to express their ideas and theories, ask them how they got to those ideas, and suggest ways they might go to the next step.

ENCOURAGE QUESTIONS.

Create opportunities for children to observe, explore, and mess around, as a basis from which they can generate their own questions. Ask questions and encourage the children to ask questions. What is it made of? How did it get here? How is it similar to or different from...? What does it feel like? Look like? Smell like? What do you want to know about it? Ask questions that lead to more questions.

Communicate to children that it's their questions that matter, not answering your question correctly. **Try to avoid questions that require a single right answer or yes/no response:** "Is the male or female bird more colorful?" "Is this a sedimentary rock?" Instead, like the ant lion questions, set up the situation so that children can observe, and your questions and theirs can begin with description—what do you notice, where can we go to continue our investigations?

On the other hand, some questions that seem to be closed-ended can be used to spark interest and get children wondering, especially about things they might take for granted. Rather than giving them an answer, you're challenging preconceived notions: "Do all birds fly? How can we find out?"

It's okay if you don't know the answer. Some things are known, but you may not know the answer.

That's okay. Tell children you don't know either and ask, "How do you think we could find out?"

Some things are not yet known. As of February 2002, astronomers had identified 78 planets outside our own solar system. They're pretty certain that there are more, but they don't know how many, and they don't know if there is life on any of them. That's what scientists do—ask questions that we don't yet know the answers to.

Teach children to be skeptics. Teach them to challenge. The textbook may oversimplify and mislead. The explanation you just got from an adult may be wrong, and the "fact" you just read on the Internet may have nothing to back it up. There may be another way to look at the question. There may be another question to ask that will take the investigation in a different and important direction.

Help children see that we are constantly asking in science:

- What do we know?
- How do we know what we know? What is the evidence for what we know?
- What don't we know? What questions are scientists currently asking about what we don't know?
- What do you want to know?

CONNECT TO BIG IDEAS, AND TO QUESTIONS THAT SCIENTISTS HAVE ASKED OR ARE ASKING.

What happened to the dinosaurs? What's the Big Bang? How do we make a hybrid tomato that will taste good and not get squashed in transit? Is there life on Mars? What is life anyway?

How can you do this if you're not a science person yourself? Connect, connect, connect. Think KEYWORD. Either on-line or off, get in touch with the science museum or the local university. Go to the web page of the science divisions at the botanical garden or the natural history museum. Subscribe to magazines, journals, and newsletters such as *Science News*, which boils down the latest science information into a four-page publication written for a lay audience, designed to be read in 25 minutes.

YOU DON'T HAVE TO KNOW THE ANSWER, BUT YOU DO NEED TO KNOW WHERE YOU'RE HEADED.

You can encourage children's questions, but you'll be able to support their experimentation more readily if you have a sense of how things work and what's connected to what. Children will pick up bird feathers on the street and you can encourage them to describe them and play with them. But it will push that inquiry along if they can think about form and function, because a flight feather looks and behaves differently from a directional feather. You can have them play with the feathers in more productive ways if you know that a flight feather will spiral when dropped, and from there you can move into questions about what the spiraling means in supporting flight and lift. That in turn can take the children into investigations of principles of flight.

Cultivate inquiry buddies. Know folks who are birdwatchers? Consult with them about what they do and what they look for and what they notice. That will give you lots of ideas about feathers, as well as about species and behaviors and migration and adaptation. Know any mechanics? Ask them what tools they use for what kinds of jobs and why, and how they go about figuring out what's broken and how they might fix it. How about an optometrist who knows about lenses and light and refraction, or an amateur astronomer who builds and owns telescopes?

Connect to the science-rich institutions and science educators, professional organizations, and to the industries that apply science in their product development. You're not alone in this adventure and there are people and organizations out there waiting to help.

You only to have to ask!

Selected References

- (1999). Ash, Doris. "The Process Skills of Inquiry." *Foundations. Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom*. Arlington, VA: National Science Foundation. 51-62.
- (1999). Dow, Peter, "Why Inquiry? A Historical and Philosophical Commentary." *Foundations. Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom*. Arlington, VA: National Science Foundation. 5-8.
- (1999). Dyasi, Hubert. "What Children Gain by Learning Through Inquiry." *Foundations. Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom*. Arlington, VA: National Science Foundation. 9-14.
- (1966). Education Development Center, Inc. "Ask the Ant Lion." *African Primary Science Program*. Newton, MA: EDC.
- (2000). Minstrell, J., van Zee, E, eds., *Inquiring into Inquiry Learning and Teaching in Science*. Washington D.C.: American Association for the Advancement of Science.
- (2000). National Research Council. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington D.C.: National Academy Press.
- (1999). The National Science Foundation. *Foundations. Inquiry: Thoughts, Views, and Strategies for the K-5 Classroom*. Arlington, VA: National Science Foundation.