Natural Scientists: Children in Charge

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Introduction

Hanahau`oli, which means "happy work" in the Hawaiian language, was founded by Mr. and Mrs. George Cooke in 1918, in Honolulu, Hawaii. It is a coeducational, nonsectarian, elementary day school offering an eight-year program that begins with a four-year-old junior kindergarten class, continues with multiage classes of grades K–1, grades 2–3, and grades 4–5, and culminates with a sixth-grade class.

Hanahau`oli is a small school whose philosophy reflects the teachings of progressive educators, especially John Dewey. We encourage firsthand experience with the community and nature, encourage children to ask questions to guide their learning, and emphasize collaborative group projects, classroom decision making, and discipline integration to promote understandings about how the world works and the many ways to express what has been learned.

A social studies/science based curriculum has always been the foundation of the Hanahau`oli program. Because there is a clear connection between science and the nature/condition of society, it is natural to connect science with the social studies program when appropriate. The overlap between the two does not imply that one can substitute for the other; each has its own questions and approaches to answering them and, yet, each promotes similar habits of the mind. Science and technology emerge from particular historical and cultural contexts and it is only natural that the lines between the two subject areas will be blurred at times. Yet, we must not substitute one for the other nor should we assume that by teaching one we are teaching both.

Thematic units form the basis of each class offering, with skills and concepts integrated within that context. The conceptual strands build upon each other as children progress through the school. Content is selected to support the development of understandings about the world that allow students to encounter new information with a framework for comprehending it rather than accumulating information that does not connect to broader understandings. Content studied in our science program relates to the overriding themes of constancy, change, and systems. The disciplines of math and language arts are integrated through unit experiences.

This chapter reports the results of refining our practices to allow young children to begin to develop inquiry process skills. In previous years we addressed the process skills of science because we felt they were vital to all learning, not just in science. Our participation in National Science Teachers Association (NSTA) conferences, reading NSTA publications, and reflecting on how we taught science in our classroom resulted in experiences for children aligned with *Best*

Practice: New Standards for Teaching and Learning in America's Schools (Zemelman, Daniels, and Hyde 1998).

It is our belief that inquiry shapes and guides all learning experiences. As teachers we believe that children construct meaning by interacting directly with their world, develop useful skills and understandings from real-life problems and situations, demonstrate different strengths, and develop at different rates. We allow children's prior knowledge, experiences, and questions to influence the units of study and investigations.

At Hanahau`oli, we believe that children are born scientists. What motivates their learning and our thematic units is their endeavor to answer three key questions: *Who am I? How does my world work? Where do I fit in that world?* Their search for answers allows them to be in charge as they inquire about their questions, pose possible theories, plan investigations to collect data, assess results, and share them with others.

In the multiage classroom we will discuss in this chapter, there are two teachers and 26 children. The strength of the group comes from its diversity. This mixed-age group is heterogeneous, made up of an equal number of boys and girls from various ethnic and socioeconomic backgrounds and with varying abilities and talents.

Three types of opportunities for children to experience being a "scientist-in-charge" are available in our classroom:

- thematic units designed around important content that is developmentally appropriate and supports developing concepts;
- extended investigations that emphasize the scientists' extensive data collection, recording, and analyzing; and
- unplanned experiences (within units, as extensions of them, or totally serendipitous).

In our classroom of grades K–1, children are guided in active and extended scientific inquiries in all three types of experiences. We find that doing more investigations develops the understanding, ability, and values of inquiry as well as knowledge of science content. In this chapter we discuss our "Food as a Basic Need" unit. In this unit children learned about the origin of different foods, the variety of food chains in their lives, and the importance of balance in food chains. The children learned that the source of most of their food and an integral part of food chains are plants; furthermore, the animals they eat also eat plants to survive. Given the importance of plants, they were asked, "What do plants need to survive?" The children quickly responded that plants need the Sun, air, water, and soil to live and grow. We guessed this knowledge was based on previous experiences, something they had heard, read about, or seen on television. For some, the knowledge was probably from planting experiences they may have had in the past. But, when the children were asked, "How do you know that plants need the Sun, air, water, and soil?" there was silence. This was a perfect teachable moment. With varying degrees of support (depending on the needs of the groups), six groups of children, as scientists, designed six different investigations to find out if plants need air, light from the Sun, heat from the Sun, water, soil, or fertilizer to survive.

This year we have also introduced a new focused and extended exploration of weather, hoping children will begin to understand that while weather changes from day to day, even in Hawaii some months are warmer or colder than others, and some months are wetter or drier than others. During this exploration, the children also have the opportunity to practice using simple tools such as a thermometer to measure the temperature. This nine-month investigation, which includes collecting data about temperature and organizing the information into monthly charts and graphs, helps children see the patterns of average temperatures, getting cooler in the fall and winter and getting warmer as spring progressed.

Both studies allowed us to emphasize science as a social endeavor. The inquiry process provides children with opportunities for scientific debate within the classroom community with cooperation, shared responsibility, and respect. Children worked in teams as they designed and carried out their plant investigations. Children also worked in teams as they designed and tried out their wind and rainfall measuring tools. Throughout the process of "being a scientist," children were encouraged to "try out" their ideas and questions on their classmates as well as to respond to their classmates' ideas and questions. In this way children taught and learned from each other. These scientific debates and discussions were successful because they occurred in a safe environment where diverse ideas were respected. This safe environment had been established earlier in our classroom and each member of the classroom (children and adults) practiced well-defined collaborative skills.

In many aspects of the school day and our units of study, children are in charge. Children conduct our morning meetings. Social issues are brought to the group for resolution. Children feel empowered to bring to the group problems or suggestions of better ways to do something. Children's ideas and questions influence units of study. They work in teams on challenges (for example to design a wind measuring tool) and to design and carry out investigations to answer their questions. The children know that while the teachers have the final authority, there are 28 (26 children and 2 teachers) important members of our class who have input into how things are done.

Our "classroom agreements" help to establish a safe environment where all children and their ideas are valued and where all children are free to ask questions and share diverse ideas. The children practice collaborative skills including problem solving and compromise. We, as teachers, also trust the children and the process. We give up some control and trust that the direction the children lead discussions or activities is of value. We often find that the children's ideas take us to more relevant and appropriate places than what we had planned. These are the conditions that form the basis of scientific inquiry in our classroom.

Thematic Units: Shared Leadership

The inquiry process is the foundational element of all of our science studies, whether they are thematic units or extended investigations. Using the Hanahau`oli School science curriculum, *Benchmarks for Science Literacy*, and the *Atlas of Science Literacy*, we developed Intended Learning Outcomes (ILOs) for our thematic units. The ILOs for our "Food as a Basic Need" unit were: (1) Children should begin to understand where the food they eat comes from, (2) Children should begin to understand how food chains work, and (3) Children should begin to be aware of the importance of protecting/taking care of the plants and animals in their ecosystem/environment (stewardship).

Each unit of study begins with focusing questions to determine children's ideas and perceptions. Focusing questions for this unit were "What is food?" "Where does food come from?" and "What do you want to know about food?" Children have previous experiences and knowledge about food and these questions help the teachers learn more about their perceptions and plan accordingly. All the children's responses were recorded on a chart with their initials written beside them. At this time it is not important if responses are "right" or "wrong."

Next we ask the children about questions they might have about food. Some examples were: "What is chocolate?" "What is salt?" "How is ice cream made?" "How is pizza made?" "How do we get food?" During this question asking time, we allow the children to respond to each other's questions. We do not investigate every question ("Why is the sea salty?") because some explanations are difficult to understand given the children's developmental level and lack of previous experience. Sometimes we need to just provide quick and easy answers that they can understand. Sometimes we wait for a better time to elaborate or deal with their questions.

During our "Food as a Basic Need" unit, children research the origin of chocolate, salt, and vanilla. In response to the question "What is salt?" a child brought a container of ocean water to share, which we allowed to evaporate. This unplanned learning experience demonstrated the value placed on children leading. To answer some of their other questions, children made pasta, pizza, and ice cream from scratch. We assisted them in tracing the ingredients back to their sources. For example, the children learned about the vanilla plant/bean being the source of the flavoring of the vanilla ice cream they made. Visiting a farm, a food distributor, and a grocery store allowed children to follow food from its origin to the dining table. After the visit to the grocery store, the children created a grocery store in the classroom and dramatized various roles they had observed during our visit; this is an example of the intersection of science and social studies. There were shoppers, checkers, and stockers, with the store manager role being the most coveted. At the beginning of our unit, when we informed families about the ILOs for the unit, one family offered a visit to their home to help the children learn about the food chain of Jackson Chameleons. They also learned about food chains through learning trips (Hawaii Nature Center and Lyon Arboretum), games, internet research, literature, and videos. These experiences allow children to construct meaning about food and food chains by interacting directly with their world.

During the learning experiences children were asked for their ideas and observations. Children were continually asked, "What do you think?" and "Why do you think that happened?"

For example, to understand how food chains work, we played a popcorn food chain game to demonstrate the importance of balance in a food chain. In this tag game, some children were birds and others were crickets (the birds' food). While the crickets were "eating" plants (gathering popcorn spread around on the ground in plastic baggies) the birds were hunting the crickets. When a cricket was tagged by a bird, the contents of the cricket's baggie went into the bird's baggie. We played the game several times, varying the number of birds and crickets. When we played with 10 birds and only 3 crickets, there were not enough crickets for the birds to eat so many of the birds "died" because they did not have enough food. We ended each game with questions such as, "Why do you think many of the birds died?" and "What would happen to the plants that are food for the crickets if there were no crickets left to eat them?" Similar questions were asked after games in which there were few birds and a lot of crickets and an equal number of birds and crickets.

Scientists often carry out extended investigations. Like scientists, our students, with support, carried out a school-year-long weather investigation. We began the study by discussing, observing, and learning about different types of weather. The children brainstormed and agreed on different weather symbols to be used to record the weather on personal weather calendars as well as the classroom weather calendar that is used by our class "meteorologists." They also recorded the morning and afternoon temperatures on the classroom weather calendar.

Wind velocity and rainfall impact children's lives (e.g., clothing they wear, outdoor playtime) and are concrete and measurable forces of nature. With a partner or partners, the children invented tools to measure both wind velocity and rainfall. The wind and rain tool projects focused on both the learning process and the learning that occurs when something works or does not work as planned. The learning process was social in nature, giving children opportunities to collaborate in creating a particular item such as a tool to measure wind velocity. When the tools were completed, the children had opportunities to share their inventions with their classmates, discuss their own efforts, and respond to their classmates' questions.

The students decided that their wind tools should have a light part that moves in the wind and a heavier part that would be used to hold the tool. They also decided the wind tool should indicate various wind speeds to be effective. After some initial planning, brainstorming of ideas, and some trial and error, the student groups built wind tools that met the criteria. One was selected by the class to be used each day by the class meteorologists. Wind speed was then added to the classroom weather calendar.

After brainstorming what would make an effective rainfall measuring tool, the children, in small groups, drew up plans that included how their tools would work and wish lists for supplies. When supplies were gathered, each group constructed its rainfall tool. The completed tools were left outside for a couple of days to test their effectiveness. Two major problems arose in many of the rainfall tools: materials such as cardboard tubes and boxes and paper cups did not withstand getting wet or the tool was not stable and fell over. Groups then made adjustments to their tools, as scientists do when something they have done does not work. Some tools were redesigned using waterproof materials such as plastic cups.

When the rainfall tools were strong enough to withstand the elements, they were placed in an area on campus that allowed the tools to measure the rain (and not water from the lawn sprinklers). Daily rainfall was recorded on a cup, with a line marking the amount of rain and one of nine descriptors signifying how much rain fell. New descriptors for the amount of rainfall were decided by the children on days different amounts of rain were measured. Some descriptors included "a very lot," "a lot," "medium," "a little," "a drop," and "none." These descriptors allowed the children to compare how much rain fell from one day to another. Rainfall cups were saved each day, giving the children unplanned opportunities to explore the idea of evaporation as the rainfall collected in cups from earlier days "disappeared." As observations were made, students shared their ideas about what they "knew" about evaporation and asked questions about what they would like to know.

Over a few weeks, the children measured rain using each group's rainfall tool. Children observed that some tools captured more rain because the collection container was bigger or the container may have had a larger opening that allowed it to "catch" more rain. As scientists would do, the students decided that there should be only one rain tool for consistency and accuracy in comparing rainfall from different days.

After two and a half months of measuring rainfall, the number of cups saved and the number of rainfall descriptors made the rainfall investigation difficult to manage. The problem and the three goals of measuring rainfall (measure daily rain, measure monthly rain, and compare monthly rainfall throughout the year to see if some months are rainier than others) were brought to a classroom "community circle." The class brainstormed several ideas and discussed the pros and cons of each until they agreed that daily rainfall should be tallied on charts for each month. They also agreed on a reduced number, five instead of nine, of rainfall descriptors to use. These suggestions met all three goals and solved the problem because cups would no longer have to be saved each day. Students volunteered to help design and construct the rainfall charts to be used for both the current month (January) and for previous months, using the saved rainfall cups. At the beginning of each new month, children made a new rainfall chart.

Children also volunteered to design and construct a chart and graph to help organize daily weather reports (weather, temperature, wind speed, and rain) that would allow them to compare monthly trends in weather. Examining the charts and graphs as the months progressed helped the children understand the idea that weather changes from day to day but some months are warmer or colder than others. The students also learned the science process of collecting data over time and to draw conclusions. They learned that the average monthly morning temperature was lowest in the months of January and February; a similar pattern occurred in the average monthly afternoon temperature. The average monthly morning and afternoon rainfall graphs showed a similar pattern. Using the data, the children concluded that the months of January and February were the coolest and rainiest this school year.

Throughout the study of weather, children made suggestions and decisions about weather tools and recording weather. They were asked to work together (listening attentively, respecting different ideas, and cooperating) to problem solve and propose solutions to any problems that arose. They took ownership for their learning and the procedures used to study weather. Just as important as the content learned, the students learned and practiced a variety of social skills.

Unplanned Inquiry: Children in Charge

Sometimes unplanned opportunities extend or expand on planned inquiry. There are generally two possible starting points for these investigations: (1) an observation or experience or (2) a perception from a past experience. They can arise as extensions of units, perceptions expressed by children during units, or totally serendipitously like when a queen bee lands with her hive-mates on the metal play structure or a child brings a caterpillar to class.

After learning about the importance of food chains and the negative impact litter has on them, the children decided to do a school campus cleanup as an extension of the "Food as a Basic Need" unit. They divided into teams, gathered the necessary supplies, and set off to different parts of the campus. While on "litter patrol," one student observed that some parts of the campus had more litter than others. When his group returned to the classroom, he asked, "Which part of campus has more litter than others?" With teacher support, he designed an investigation that included dividing the campus into different areas, defining what constitutes a piece of litter (Does size matter?), and created the investigative process. He invited his classmates to join him and got five volunteers. Once a week for three weeks, these children collected and counted litter and organized their data on a chart and finally on a graph, an opportunity to develop useful skills from a real-life situation. At our weekly Friday assembly, the group shared what they had learned with the entire school community and challenged them to litter less. While the student and his group needed some support, they were independent during most parts of the process because of previous investigative experiences. The "litter" investigation, while it gave children an opportunity to answer their own question, was also an opportunity for teachers to assess their understanding of the process of investigation. This is an example of applying information learned and the process of inquiry.

Examples of investigations that come from perceptions or previous experiences are the investigations the children designed in response to their perceptions that plants need the Sun, water, soil, and air to survive. We will use these investigations to further illustrate the accompanying flowchart titled "Exploring the Process of Being a Scientist." Throughout the plant investigations, varying degrees of support and guidance were provided to the children depending on their need. Some groups were more independent with the process than others.

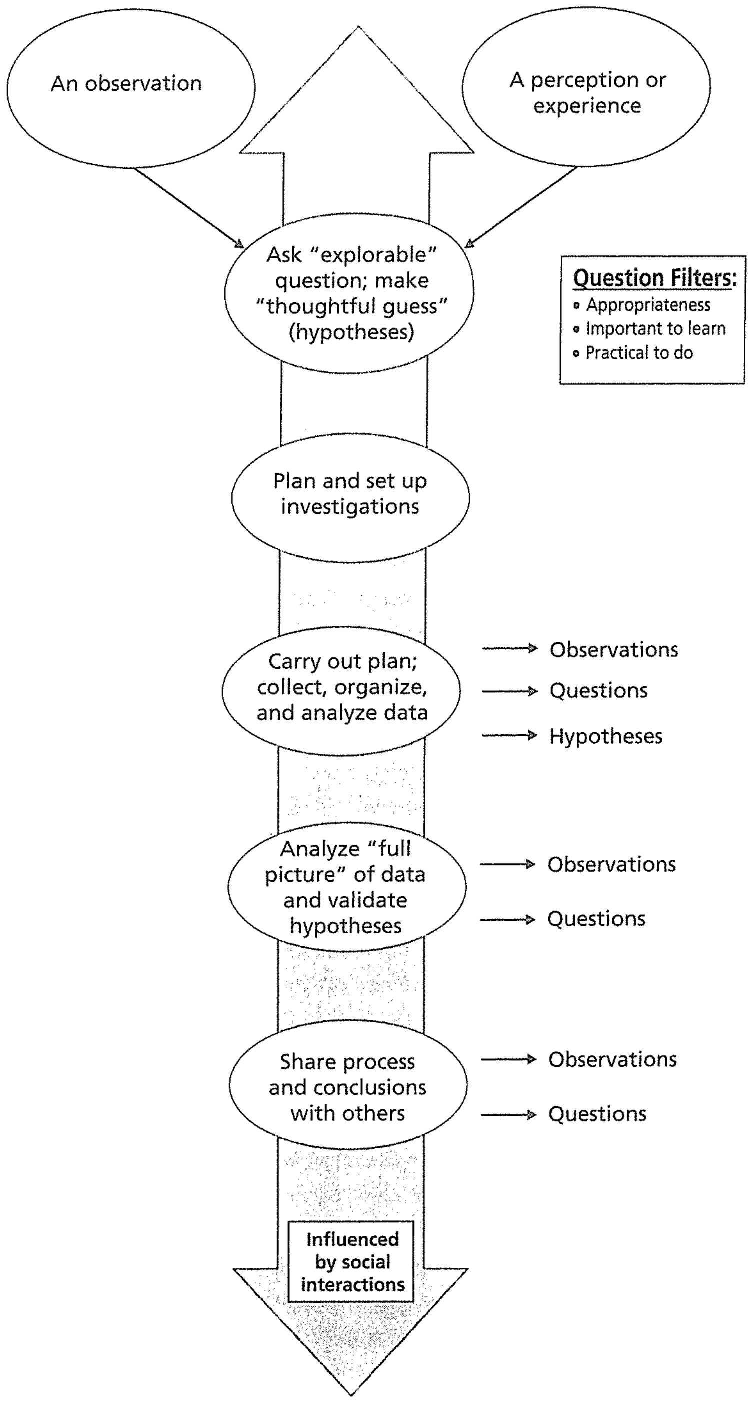
Both the litter and plant investigations were opportunities for scientific discussions and debate among the children in our classroom. Sharing ideas and observations, perceptions, and experiences may have helped others "see" something they had not seen before. Children asked each other questions and answered questions posed to the group by other classmates. They challenged each other's thinking as different ideas were worked through.

Children as Inquirers

In our classroom, children act like scientists to answer their own questions or scientific questions. Our flowchart, "Exploring the Process of Being a Scientist" (Figure 1, p. 22) shows the steps of the process and notes how social interaction is integral to every step. We find that we struggle with the messiness of science. While it looks like a linear process in the flowchart, in reality, any step in the process could return investigators to an earlier step.

During the first formal step of the process, an "explorable" question is asked and children make "thoughtful guesses" or hypotheses to answer the question. The question can be initiated by the students or guided by the teacher. Questions need to go through filters before they are investigated. The question needs to be explorable or doable. The question should be developmentally appropriate. The *Benchmarks for Science Literacy* (AAAS 1993) and *Atlas of Science Literacy* (AAAS 2001) are good resources to check for developmental appropriateness. It is important to remember that just because a child can repeat words does not mean a concept is understood. The question also needs to be something of importance to learn. Children are then asked for their ideas about the question and to make "thoughtful guesses." During this time the teacher's job is to "prod," to help clarify the children's thinking. This is not a time to judge ideas as right or wrong but to understand their thinking based on previous experiences, developmental level, and what they have been told.

Figure 1. Exploring the Process of Being a Scientist



Although appearing linear, the inquiry process is actually dynamic.

The larger question preceding the plant investigations was, "What do plants need to survive?" Children quickly responded that plants need air, sunlight, water, and soil. It appeared to us that the children did not truly understand the needs of plants. We asked, "How do you know?" and "How can you find out if that is true?" After some discussion, the children divided themselves into investigation groups to find out if plants need air, light from the Sun, heat from the Sun, water, soil, or fertilizer to survive. They were first asked to formulate an explorable question such as "Do plants need air to survive?" and then propose their "thoughtful guesses" about it.

Interesting scientific discussions occurred when the children shared their ideas and asked questions in their groups. As children shared "thoughtful guesses" about plants' needs, others debated those ideas based on their own understandings. A prerequisite for this step is a safe and respectful learning environment where everyone's ideas can be expressed (no right or wrong answers).

The next step in the process of being a scientist is to plan and set up the investigation. During this step, children are "in charge" (with teacher support only when necessary) and should lead the planning process. It is fine if the plan does not work out. Often the best learning occurs when something does not go according to plan. This is the reality of a scientist's work. Take, for example, the student group who planned to make their rainfall measuring tool using paper towel tubes and a paper cup to catch the rain. We knew that it would fall apart after a few rainy days, but instead of intervening, we let the children discover that themselves.

During the planning stage, children need to determine what materials are needed, what the procedure will be, who will be responsible for what tasks, and how data will be collected and organized. The teacher may have to help children with "constants" and "variables" and needs to make sure that the plan is safe, appropriate, and doable. During this stage, the children stimulate each other's thinking, which can result in even more ideas. The planning stage also provides real opportunities to practice compromising, attentive listening, and resolving any problems that might occur.

It was interesting to listen to the children brainstorm ideas as they planned for their plant investigations. Many ideas were shared and students felt safe to disagree and to point out and explain why something might not work. The process was mostly done with respect and cooperation. Because of the ages of the children, we sometimes felt it necessary to offer some guidance. The group that designed an investigation to find out if plants needed air to survive was the most interesting. First, it was suggested that they put a plant in a box so it could not get any air. A boy thought that air would still seep in. Someone else suggested that the plant be put in an airtight cardboard box. The same boy thought the plant would not get any sunlight. Then it was suggested that the plant be put it in a clear airtight container. The boy asked, "How would it be watered?" and said, "Air could get in then when the plant is watered." We knew it would be difficult to isolate the "air" variable. We had done previous research on how it could be done and finally shared with the group an idea of covering plants with Vaseline to keep out the air. This is an example of a time when teachers provided extra support so the children would be successful.

The next step in the process is to carry out the plan and collect, organize, and analyze the data. During this time the best learning occurs when something does not work, when something that the children did not expect happens, or when something interferes with the investigation. When this happens, students can make adjustments to the plan. Teachers need to be understanding with things that go wrong and support children as they analyze what went wrong and what they can do about it. If possible, teachers should let students determine if something has gone wrong with their investigations.

As investigations are carried out, data and observations are systematically recorded and organized by children, with teacher support as needed. Children begin to analyze the data, making observations and drawing conclusions about what is observed or experienced.

As the investigation is carried out, responsibilities should be divided and shared. This step in the process gives children practice working together, sharing ideas with each other, and listening to each other attentively. Students can help classmates "see" or discover something they may have otherwise missed. Children with different levels of experience or expertise can support the learning of others.

Something unexpected happened for the group who investigated the question "Do plants need heat from the Sun to survive?" They put a plant in a cooler (cooled with ice, without a lid), a plant outside in the shade, and a plant in direct sunlight. At first the plant in the cooler grew more quickly than the other two plants. The children concluded that plants do not need heat from the Sun but that they grew better in cool temperatures; they did not separate heat from light. We did not correct their ideas but did urge them to confine their thinking and interpretations. We did not, at this time, get into photosynthesis or any in-depth discussion of the negative impact of light on plant growth. The students' conclusions were logical, based on their observations up to that point. As time passed, the plant in the cooler died while the one in the sun thrived, compelling the children to rethink their conclusion to better reflect their new observations. Their new conclusion was "Plants do need heat."

When the investigation was complete, the children analyzed the full picture of the data to validate their "thoughtful guesses." Teachers support the children by asking, "Does the conclusion make sense?" "Is it logical based on your observations?" "Is there more we can do? Or, are there other sources for information?" There may be more than one way to look at the observations. There may be two or more logical conclusions. It is not always important that the children's conclusions are 100% accurate or scientifically valid. It is fine for children to have temporary information. The process is usually more important than the outcome.

The student groups made posters to share information with their classmates about their investigations and what they had learned about the needs of plants. On the posters were photographs of students and the plants they investigated, accompanied by text describing what had transpired during their investigations and what had been learned. The children came up with a variety of conclusions such as, "For plants lots of water is better; but for seeds a little water is better." "Plants do need heat." "Plants need light." An interesting conclusion one student made was "This plant needs air to survive." This student understood that only one plant was investigated and did not generalize the idea to all plants. Much is gained and learned by each member when different conclusions are discussed and debated. The focus, however, is on observations and what actually happened.

The last step in the process of being a scientist is for students to share their investigative process and conclusions with others. Children, like scientists, have the responsibility to share what they have learned with the community. There are many ways investigations and conclusions can be shared, such as in music or a song, a poster, a diorama, a book, or a dramatization. Sharing can become a discussion of ideas. Sharing is an opportunity for children to learn from one another.

Different strengths (e.g., artistic, musical, communication, building) are celebrated as projects are accomplished collaboratively and then shared with others. Deciding on and working on a final project is a great opportunity for students to work together toward a common goal.

The plant investigation process was a wonderful opportunity for students to participate in an active and extended scientific inquiry. The investigative process helped children better understand and be better able to carry out inquiry. The children also formulated a real understanding of the needs of plants, based on their own thinking, ideas, and observations.

Assessment: Children and Program

We define assessment as the process of observing and recording (i.e., documenting students' work, what they say, what they do, and how they do it) over time. Assessment in our classroom is authentic and ongoing throughout our units of study and is focused on the Intended Learning Outcomes (ILOs) of the unit. We keep records of our observations of what and how children contribute to our classroom conversations and discussions. We collect representative work of the children over time, such as journal entries and reflections. We also use photos and videotapes to record children engaged in unit-related activities. At various points during the unit, for example, we interview children about their work. We ask questions not only about their experiences and what they have learned but also about their participation in and contributions to the group. All this information forms the basis for assessing what the students are learning. This assessment process allows us to recognize and accommodate children's individual differences concerning learning styles, rates of learning, previous knowledge, direct experiences, and cultures. It also provides students with ways to demonstrate what they are learning through their own interests and strengths. Thoughtful and ongoing assessments of this nature guides our work as teachers: Planning and instruction for individuals and groups and reflecting on our teaching to evaluate how well the unit experiences are helping children to achieve the unit goals. All the information taken together provides the basis for writing summary reports at the conclusion of each unit.

In journal entries during the "Food as a Basic Need" unit the children demonstrated what they had learned. For example, one child wrote, "Orange juice comes from oranges. Oranges come from trees. Workers pick the oranges in bags. And, then they take the oranges to the factory." To accompany detailed drawings about a food chain, another student wrote, "The Jackson Chameleon eats silkworms. The silkworms eat mulberry leaves. Mulberry leaves need the Sun and rain." In a conversation about what she thought was occurring while playing the "Popcorn Food Chain Game," one student demonstrated understanding of the importance of balance in food chains when she observed, "If there are less birds, the birds will probably live because there is a lot of food for the birds." She added, "If there are less crickets, some birds might live, but most of the birds might die because there is not enough food." After a visit to a neighborhood supermarket, the children's dramatization of various roles in a classroom supermarket of their creation demonstrated their understanding of a supermarket's role in providing food for people to eat.

There are many ways the success of our program can be measured. First, our success can be measured in the love and motivation our children have for learning. Throughout the "Food as a Basic

Need" unit it was apparent that the students were excited about the unit of study and motivated by their learning experiences and their investigations. Being able to have influence and ownership over what they studied enabled children to "take charge" and to be actively engaged in their learning. The students were motivated to determine the answers to their own questions about food.

Children's interest in what they were learning was demonstrated by items they brought for sharing. Many students brought in library books and unit-related artifacts to enhance the topic of study. Children often engaged their families in researching topics of interest related to the unit. Following a discussion about whether vanilla was a plant or an animal, some children went home to use the internet to gain information about vanilla that they then shared with their classmates. One child was surprised to discover that vanilla was a plant. Another student brought a bottle of South American vanilla that we used to flavor the ice cream that we made.

Parents frequently told us of interesting conversations initiated by their children about school experiences. When we wondered about salt and its origin, one child's father took her to the beach to get a container of ocean water. Questions arose: "Does all salt come from the ocean?" "If salt is not a plant or an animal, what is it?" The children decided salt is an "other." Sometimes we would overhear and take note of children's conversations at the school that expressed their interests and engagement with specific learning experiences. After learning about food chains, children reenacted food chains in games they played at recess. After learning about the origins of their food, children role-played the "trip" food takes from the farmer to the dinner table. After making pizza, ice cream, and pasta, children replicated the experiences in the sand box and with play dough. Children often excitedly shared with us relevant information and pictures they had found in newspapers and magazines. Months after learning about the effect of litter on animals and food chains, members of an afterschool sports club continued to remind others to not litter and to pick up trash.

What is learned is often extended in other learning activities students choose. After the food chain unit, children wrote books and drew illustrations of food chains of interest to them, including those of a pet turtle and of rain forest animals. Students researched on the internet and read books about the food chains of favorite animals. Small groups of children, with some teacher support, rewrote the words of "I Know an Old Lady Who Swallowed a Fly" to match a food chain they were interested in.

Our program's success can be measured by how children apply the inquiry techniques they have learned. As anticipated, there was a wide range of proficiency in the application of inquiry skills. Because of the young age of our children, many need guidance to carry out the inquiry process. The child who developed an investigation following a litter cleanup to answer the question "What area of our school (campus) has the most litter?" followed, with minimal support, the basic inquiry process when he investigated, "Do plants need air to survive?" Many children got better at asking "explorable" questions and devising their own plans to answer their questions, whether it was to ask an expert, research the question in a book or on the internet, or to do a simple investigation. The children got better and more independent at recording and interpreting data as our weather investigations continued.

The students developed their own theories as a result of their experiences when investigating the needs of plants, as when a child wrote "This plant needs air to live," as opposed to "all plants need air to live." Another student internalized his own theory, "Paper is not strong enough to withstand water," after his rainfall measuring tool (a paper cup attached to a rock so it would not blow away) fell apart following a few days of rain. Later in the school year when the children were learning about materials used to construct shelters, the same boy reminded his classmates of his first rainfall measuring tool attempt and told them that paper and cardboard would not be good materials to use to build a shelter.

As scientists work collaboratively on their investigations, so do our students. The children got better at working collaboratively as demonstrated by their work on team projects at the end of the school year. Team members worked together to accomplish a common goal.

Our program's successes can be measured by the children's understanding of scientific content and our unit Intended Learning Outcomes. Because we focus on the process, "discovery learning" over an extended period of time, and on content that is developmentally appropriate, our children develop a real understanding of concepts. Students demonstrate this in many ways, including participation in learning experiences and discussions, journal reflections, and individual and group projects. Their understanding is demonstrated during class and whole-school presentations when they teach each other.

Data for us are not determined from rubric grading sheets. Instead data are anecdotal and provided by teachers in articulation sessions and through children's progress reports. Students' reports, after they have moved on to the grades 2–3 class, as well as interviews conducted with their teachers, show that the children's earlier experiences with the processes of inquiry have a positive influence on their approach to investigating new questions. The students demonstrate a love for science and continue to ask questions and develop investigations for answering them. It was reported that a "Science Lab" became a part of the grades 2– 3 class's Community Unit for the very first time this year. Many children chose to be a part of the "N-R-G" (energy) group based on the science that would be a part of their group's focus. One student investigated alternative forms of energy by trying several different ways to cook a hot dog. He found that using solar energy and a foil-covered pan worked best but "it took a long time and the sun had to be shining on the hot dog." Another student designed a water wheel to investigate using water to create energy. Another child explored various materials to determine the best conductor of heat. Other students investigated geothermal energy and created a poster to explain how a company is working to harness the heat from our active volcano to generate electricity. In reflecting on the various investigations, one child wrote, "All the investigations made me realize that there are so many ways to make and conserve energy."

A review of "Best Practice in Science" (Zemelman, Daniels, and Hyde 1998) indicates that we were and continue to be on the right track with current recommendations for improving science education in our classroom. Our students are guided in active and extended scientific inquiries through units of study and individual investigations; their investigations develop the skills of inquiry as well as an understanding of science content; they are immersed in an environment that allows them to "take charge" of the learning process; and the social nature of the inquiry process provides opportunities for children to develop collaborative skills as well as respect for ideas that differ from their own. We believe that learning about the world in these ways will support lifelong learning.

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