EVEN MORE EVERYDAY SCIENCE MYSTERIES

STORIES FOR INQUIRY-BASED SCIENCE TEACHING

Even More Everyday Science Mysteries

Stories for Inquiry-Based Science Teaching

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Finally I would like to dedicate these words to all of the children out there who love the world they live in and to the teachers and parents who help them make sense of that world through the study of science.

Preface

Teaching and Interpreting Science

Over the past nine years my wife and I have had the privilege of being nature interpreters in the Everglades National Park. We were warned that interpretation was different from teaching. We were not supposed to be lecturing about the names of birds or plants but helping the visitors tune into the beauty and value of the park. In fact, we were told that our major goal was to help the visitors make "an emotional connection to the resource (the park), not to teach."

So, it would seem that teaching and interpreting are quite different entities. I'm not sure I agree, or perhaps it is that I hope that they become more like each other. Synonyms for *interpret* are "enlighten, elucidate, clarify, illuminate or shed light on." *Teaching* is also defined as "to enlighten and illuminate." Most dictionaries, it is true, do not include "to help make an emotional connection to…" in their definitions. But I think this may be a great idea, in science as well as in all other subjects.

Science is a construction created by humans to make sense of the world. Over the centuries, science has been invented, reinvented, and modified. It follows, or is supposed to follow, certain rules by which it operates. At first it was known as natural history or natural philosophy, and debate was its favorite mode of operation. Later Galileo opened the door to direct experimentation, and scientists such as Kepler, Tycho, Newton, and Darwin showed how the interpretation of data can lead to explanations and theories that allow us to predict, with fair accuracy, events and everyday occurrences, or to develop the technology to do tremendous things, such as to send humans to the Moon.

This book is based on everyday occurrences and the desire to understand and enjoy them. It is paramount that the teacher and student make "emotional connections" to the world they are trying to understand. An emotional connection to a flower or worm or insect may not be absolutely essential to knowing about it, but making an emotional connection to each and every critter on our planet and to its place in the ecosystem helps us see how we are involved, along with every *other* thing on our planet, as a fully participating part of the entire system.

One does not develop *values* out of knowledge alone. Values are what we do when no one is watching (for example, walking to the trash can to deposit litter even though no one is around to witness it). A value is apparent when we compost our vegetable matter or recycle our aluminum, glass, and paper or take our own bags to the market, even though there is no law to demand it. We do so because we have made an emotional connection to our planet. Thus I posit that we need to help our students make emotional connections to the enterprise of science and to understanding how our world works, as best we can interpret it.

Visitors to the Everglades National Park should be impressed, for example, by the realization that the plants they are viewing have survived six months of drought and six months of deluge (the Everglades is semitropical, with wet and dry seasons). They should understand that the plants have survived the two things that usually kill them, underwatering and overwatering. Most visitors know this about plants, and we build on this everyday understanding to motivate the groups to look for those attributes each plant has developed to adapt to this harsh climate. They begin to notice the waxy leaf covering, the shapes of the leaves, dormancy behavior, and other special features that mitigate the damage of too much water; however, these same plants also retain water during those times when there is little available. Visitors are awed when they meet baby barred owls that find this environment to their liking. Thus, the emotional connection is made. Hopefully, this leads to an understanding of the importance of protecting such an environment.

The students in your classroom can have the same experience. They should, whenever possible, make that emotional connection to the ocean, to a lever, to the condensation of water on a glass, to forces that affect their lives and their bodies, and certainly to the process of science itself. And I believe that I can safely say that without some emotional connection to topics in a curriculum, little will really be learned, remembered, and understood. This is why stories about children who live lives like theirs can help them make these connections.

Recently, a poem appeared on my desktop, which seemed to support some of the things that I have been advocating in my work in these volumes of everyday science mysteries. I ask you to remember the words and thoughts as you plan your teaching.

Leisure
by William Henry Davies (1921)

What is this life if, full of care,
We have no time to stand and stare.
No time to stand beneath the bough
And stare as long as sheep or cows.
No time to see, when woods we pass,
Where squirrels hide their nuts in grass.
No time to see, in broad daylight,
Streams full of stars, like skies at night.
No time to turn at Beauty's glance,
And watch her feet, how they can dance.
No time to wait till her mouth can
Enrich that smile her eyes began.
A poor life this if, full of care,
We have no time to stand and stare.

"Everyday Miracles"

I am often asked about the origin of these everyday science mysteries. The answer is that they are most often derived from my day-to-day experiences. Science is all around us as we go through our routines, but it often eludes us because, as the old saying goes, "The hidden we seek, the obvious we ignore."

I am fortunate to be surrounded by a rural natural environment. My daily routine is predictable. I arise, eat breakfast, and then walk with my wife through the woods for a mile or so to exercise our Australian shepherd and ourselves. Our dog acts as a wonderful model as she exhibits her awareness of every scent and sight that might have changed over the past 24 hours. Her nose is constantly sniffing the ground and air in search of the variety of clues well beyond our limited senses. As we walk, we look for our "miracle of the day." It may be a murder of crows harassing a barred owl or a red-tailed hawk flying over our heads with a squirrel in its talons. It might be a pair of wood ducks looking for a tree with a hole big enough for a nest or a patch of spring trillium or trout lilies. In the late summer, it could be a clump of ghostly Indian pipe and a rattlesnake plantain orchid in bloom or a hummingbird hovering near a flower fueling up for its long trip south. Today it is a gigantic, beautiful, mysterious, salmon-pink mushroom, never before noticed. Sounds from the road bring questions about how sound travels, and as we arrive home, we see crab apples, the worms in the compost pile, and the new greenhouse whose temperature fluctuations have plagued us all summer.

Textbooks are full of interesting information about the planets, space travel, plant reproduction, and animal behavior, but very little about how this information was developed. Our world is full of questions, many of which are investigable by children and adults. Our senses and mind are drawn to these questions, which stimulate the "I wonder…" section of our brains. We are intrigued by shadows, by the motion of the Sun and Moon during the daytime and the stars and planets at night. There are mysteries at every turn, if we keep our minds and eyes open to them.

I am amazed that so many years have passed without my noticing so many of the mysteries that surround me. Writing these books has had a stimulating effect upon the way I look at the world. I thank my wife, a botanist, artist, and gardener, for spiking my awareness of the plants that I glossed over for so many years. We can get so caught up in the glitz of newsworthy science that we are blind to the little things that crawl at our feet, or sway in the branches over our heads, or move through the sky in predictable and fascinating ways each and every day. One can wonder where the wonder went in our lives as we teachers get caught up in the search for better and better test scores. The stories spring forth by themselves when I can remember to see the world through childlike eyes. Perhaps, therein lies the secret to seeing these everyday science mysteries.

Writing Everyday Science Mystery Stories

When I first started writing stories, I tried the idea out with a seminar of my graduate students. We selected science topics, wrote stories about phenomena, and added challenges by leaving the endings open, requiring the readers to engage in what we hoped would be actual inquiry to finish the story. We also added distracters—children's ideas and misconceptions—that were intended to double as formative assessment tools. Over the course of the semester we wrote many stories and tried them out with students in classrooms. The children enjoyed the stories, and we learned some important lessons on how to formulate the stories so that they provided the proper challenge.

Things to think about as you write your story

Does your story…

1. address a single concept or conceptual scheme?
2. address a topic of interest to your target age group?
3. try to provide your audience with a problem they can solve through direct activity?
4. require the students to become actively involved—hands-on, minds-on?
5. have a really open-ended format?
6. provide enough information for the students to identify and attack the problem?
7. involve materials that are readily available to the students?
8. provide opportunities for students to discuss the story and come up with a plan for finding some answers?
9. make data collection and analysis of those data a necessity?
10. provide some way for you to assess what their current preconceptions are about the topic? (This can be implicit or explicit.)

For years afterward, I used the idea with my graduate and undergraduate students in the elementary science methods classes. In lieu of the usual lesson plan, my class requirements included a final assignment that asked them to write a story about a science phenomenon and include a follow-up paper that described how they would use the story to encourage inquiry learning in their classrooms. As I learned more about the concept, I was able to add techniques to my repertoire, which enhanced the quality of the stories and follow-up papers.

I found that teachers benefit from talking about their stories with other teachers and their instructor. They can gain valuable feedback before they launch into the final story. We organized small-group meetings of no more than five students to preview and discuss ideas. We also designed a checklist document, which helped clarify the basic ideas behind the concept of the "challenge story." (See box.)

As usual, practice makes for a better product and finally my students were producing stories that were useful for them and were acceptable to me as a form of assessment of their learning about improving their teaching of science as inquiry.

As the years went by, teachers began to ask me if my own stories, which I used for examples in class, were available for them to use. They encourged me to publish them. I hope that they will provide you with ideas and inspiration to develop more inquiry-oriented lessons in your classrooms. Perhaps you may be motivated to try writing your own stories for teaching those concepts you find most difficult to teach.

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Introduction

Case Studies on How to Use the Stories in the Classroom

I would like to introduce you to one of the stories from the first volume of *Everyday Science Mysteries* (Konicek-Moran 2008) and then show how the story was used by two teachers, Teresa, a second-grade teacher, and Lore, a fifth-grade teacher. Then in the following chapters I will explain the philosophy and organization of the book before going to the stories and background material. Here is the story, "Where Are the Acorns?"

Where Are the Acorns?

Cheeks looked out from her nest of leaves, high in the oak tree above the Anderson family's backyard. It was early morning and the fog lay like a cotton quilt on the valley. Cheeks stretched her beautiful gray, furry body and looked about the nest. She felt the warm August morning air, fluffed up her big gray bushy tail and shook it. Cheeks was named by the Andersons since she always seemed to have her cheeks full of acorns as she wandered and scurried about the yard.

"I have work to do today!" she thought and imagined the fat acorns to be gathered and stored for the coming of the cold times.

Now the tough part for Cheeks was not gathering the fruits of the oak trees. There were plenty of trees and more than enough acorns for all of the gray squirrels who lived about the yard. No, the problem was finding them later on when the air was cold and the white stuff might be covering the lawn. Cheeks had a very good smeller and could sometimes smell the acorns she had buried earlier. But not always. She needed a way to remember where she had dug the holes and buried the acorns. Cheeks also had a very small memory and the yard was very big. Remembering all of these holes she had dug was too much for her little brain.

The Sun had by now risen in the east and Cheeks scurried down the tree to begin gathering and eating. She also had to make herself fat so that she would be warm and not hungry on long cold days and nights when there might be little to eat.

"What to do ... what to do?" she thought as she wiggled and waved her tail. Then she saw it! A dark patch on the lawn. It was where the Sun did not shine. It had a shape and two ends. One end started where the tree trunk met the ground. The other end was lying on the ground a little ways from the trunk. "I know," she thought. "I'll bury my acorn out here in the yard, at the end of the dark shape and in the cold times, I'll just come back here and dig it up!!! Brilliant Cheeks," she thought to herself and began to gather and dig.

On the next day she tried another dark shape and did the same thing. Then she ran about for weeks and gathered acorns to put in the ground. She was set for the cold times for sure!!

Months passed and the white stuff covered the ground and trees. Cheeks spent more time curled up in her home in the tree. Then one bright crisp morning, just as the Sun was lighting the sky, she looked down and saw the dark spots, brightly dark against the white ground. Suddenly she had a great appetite for a nice juicy acorn. "Oh yes," she thought. "It is time to get some of those acorns I buried at the tip of the dark shapes."

She scampered down the tree and raced across the yard to the tip of the dark shape. As she ran, she tossed little clumps of white stuff into the air and they floated back onto the ground. "I'm so smart," she thought to herself. "I know just where the acorns are." She did seem to feel that she was a bit closer to the edge of the woods than she remembered but her memory was small and she ignored the feelings. Then she reached the end of the dark shape and began to dig and dig and dig!

And she dug and she dug and she dug! Nothing!! "Maybe I buried them a bit deeper," she thought, a bit out of breath. So she dug deeper and deeper and still, nothing. She tried digging at the tip of another of the dark shapes and again found nothing. "But I know I put them here," she cried. "Where could they be?" She was angry and confused. Did other squirrels dig them up? That was not fair. Did they just disappear? What about the dark shapes?

How Two Teachers Used "Where Are the Acorns?"

Teresa, a veteran second-grade teacher

Teresa usually begins the school year with a unit on fall and change. This year she looked at the National Science Education Standards (NSES) and decided that a unit on the sky and cyclic changes would be in order. Since shadows were something that the children often noticed and included in playground games (shadow tag), Teresa thought using the story of "Cheeks" the squirrel would be appropriate.

To begin, she felt that it was extremely important to know what the children already knew about the Sun and the shadows cast from objects. She wanted to know what kind of knowledge they shared with Cheeks and what kind of knowledge they had that the story's hero did not have. She arranged the children in a circle so that they could see one another and hear one another's comments. Teresa read the story to them, stopping along the way to see that they knew that Cheeks had made the decision on where to bury the acorns during the late summer and that the squirrel was looking for her buried food during the winter. She asked them to tell her what they thought they knew about the shadows that Cheeks had seen. She labeled a piece of chart paper, "Our best ideas so far." As they told her what they "knew," she recorded their statements in their own words:

"Shadows change every day."
"Shadows are longer in winter."
"Shadows are shorter in winter."
"Shadows get longer every day."
"Shadows get shorter every day."
"Shadows don't change at all."
"Shadows aren't out every day."
"Shadows move when you move."

She asked the students if it was okay to add a word or two to each of their statements so they could test them out. She turned their statements into questions and the list then looked like this:

"Do shadows change every day?"
"Are shadows longer in winter?"
"Are shadows shorter in winter?"
"Do shadows get longer every day?"
"Do shadows get shorter every day?"
"Do shadows change at all?"
"Are shadows out every day?"
"Do shadows move when you move?

Teresa focused the class on the questions that could help solve Cheeks's dilemma. The children picked "Are shadows longer or shorter in the winter?" and "Do shadows change at all?" The children were asked to make predictions based on their experiences. Some said that the shadows would get longer as we moved toward winter and some predicted the opposite. Even though there was a question as to whether they would change at all, they agreed unanimously that there would probably be some change over time. If they could get data to support that there was change, that question would be removed from the chart.

Now the class had to find a way to answer their questions and test predictions. Teresa helped them talk about fair tests and asked them how they might go about answering the questions. They agreed almost at once that they should measure the shadow of a tree each day and write it down and should use the same tree and measure the shadow every day at the same time. They weren't sure why time was important except that they said they wanted to make sure everything was fair. Even though data about all of the questions would be useful, Teresa thought that at this stage, looking for more than one type of data might be overwhelming for her children.

Teresa checked the terrain outside and realized that the shadows of most trees might get so long during the winter months that they would touch one of the buildings and become difficult to measure. That could be a learning experience but at the same time it would frustrate the children to have their investigation ruined after months of work. She decided to try to convince the children to use an artificial "tree" that was small enough to avoid our concern. To her surprise, there was no objection to substituting an artificial tree since, "If we measured that same tree every day, it would still be fair." She made a tree out of a dowel that was about 15 cm tall and the children insisted that they glue a triangle on the top to make it look more like a tree.

The class went outside as a group and chose a spot where the Sun shone without obstruction and took a measurement. Teresa was concerned that her students were not yet adept at using rulers and tape measures so she had the children measure the length of the shadow from the base of the tree to its tip with a piece of yarn and then glued that yarn onto a wall chart above the date when the measurement was taken. The children were delighted with this.

For the first week, teams of three went out and took daily measurements. By the end of the week, Teresa noted that the day-to-day differences were so small that perhaps they should consider taking a measurement once a week. This worked much better, as the chart was less "busy" but still showed any important changes that might happen.

As the weeks progressed, it became evident that the shadow was indeed getting longer each week. Teresa talked with the students about what would make a shadow get longer and armed with flashlights, the children were able to make longer shadows of pencils by lowering the flashlight. The Sun must be getting lower too if this was the case, and this observation was added to the chart of questions. Later, Teresa wished that she had asked the children to keep individual science notebooks so that she could have been more aware of how each individual child was viewing the experiment.

The yarn chart showed the data clearly and the only question seemed to be, "How long will the shadow get?" Teresa revisited the Cheeks story and the children were able to point out that Cheeks's acorns were probably much closer to the tree than the winter shadows indicated. Teresa went on with another unit on fall changes and each week added another piece of yarn to the chart. She was relieved that she could carry on two science units at once and still capture the children's interest about the investigation each week after the measurement. After winter break, there was great excitement when the shadow began getting shorter. The shortening actually began at winter solstice around December 21 but the children were on break until after New Years. Now, the questions became "Will it keep getting shorter? For how long?" Winter passed and spring came and finally the end of the school year was approaching. Each week, the measurements were taken and each week a discussion was held on the meaning of the data. The chart was full of yarn strips and the pattern was obvious. The fall of last year had produced longer and longer shadow measurements until the New Year and then the shadows had begun to get shorter. "How short will they get?" and "Will they get down to nothing?" questions were added to the chart. During the last week of school, they talked about their conclusions and the children were convinced that the Sun was lower and cast longer shadows during the fall to winter time and that after the new year, the Sun got higher in the sky and made the shadows shorter. They were also aware that the seasons were changing and that the higher Sun seemed to mean warmer weather and trees producing leaves. The students were ready to think about seasonal changes in the sky and relating them to seasonal cycles. At least Teresa thought they were.

On the final meeting day in June, she asked her students what they thought the shadows would look like next September. After a great deal of thinking, they agreed that since the shadows were getting so short, that by next September, they would be gone or so short that they would be hard to measure. Oh my!! The idea of a cycle had escaped them, and no wonder, since it hadn't really been discussed. The obvious extrapolation of the chart would indicate that the trend of shorter shadows would continue. Teresa knew that she would not have a chance to continue the investigation next September but she might talk to the third-grade team and see if they would at least carry it on for a few weeks so that the children could see the repeat of the previous September data. Then the students might be ready to think more about seasonal changes and certainly their experience would be useful in the upper grades where seasons and the reasons for seasons would become a curricular issue. Despite these shortcomings, it was a marvelous experience and the children were given a great opportunity to design an investigation and collect data to answer their questions about the squirrel story at a level appropriate to their development. Teresa felt that the children had an opportunity to carry out a long-term investigation, gather data, and come up with conclusions along the way about Cheek's dilemma. She felt also that the standard had been partially met or at least was in progress. She would talk with the third-grade team about that.

Lore (pronounced Laurie), a veteran fifth-grade teacher

In September while working in the school, I had gone to Lore's fifth-grade class for advice. I read students the Cheeks story and asked them at which grade they thought it would be most appropriate. They agreed that it would most likely fly best at second grade. It seemed, with their advice, that Teresa's decision to use it there was a good one.

However, about a week after Teresa began to use the story, I received a note from Lore, telling me that her students were asking her all sorts of questions about shadows, the Sun, and the seasons and aking if I could help. Despite their insistence that the story belonged in the second grade, the fifth graders were intrigued enough by the story to begin asking questions about shadows. We now had two classes interested in Cheeks's dilemma but at two different developmental levels. The fifth graders were asking questions about daily shadows, direction of shadows, and seasonal shadows, and they were asking, "Why is this happening?" Lore wanted to use an inquiry approach to help them find answers to their questions but needed help. Even though the Cheeks story had opened the door to their curiosity, we agreed that perhaps a story about a pirate burying treasure in the same way Cheeks had buried acorns might be better suited to the fifth-grade interests in the future.

Lore looked at the NSES for her grade level and saw that they called for observing and describing the Sun's location and movements and studying natural objects in the sky and their patterns of movement. But the students' questions, we felt, should lead the investigations. Lore was intrigued by the 5E approach to inquiry (*engage, elaborate, explore, explain, and evaluate*) and because the students were already "engaged," she added the "elaborate" phase to find out what her students already knew. (The five Es will be defined in context as this vignette evolves.) So, Lore started her next class asking the students what they "knew" about the shadows that Cheeks used and what caused them. The students stated:

"Shadows are long in the morning, short at midday, and longer again in the afternoon."

"There is no shadow at noon because the Sun is directly overhead."

"Shadows are in the same place every day so we can tell time by them."

"Shadows are shorter in the summer than in the winter."

"You can put a stick in the ground and tell time by its shadow."

Just as Teresa had done, Lore changed these statements to questions, and they entered the "exploration" phase of the 5E inquiry method.

Luckily, Lore's room opened out onto a grassy area that was always open to the Sun. The students made boards that were 30 cm square and drilled holes in the middle and put a toothpick in the hole. They attached paper to the boards and drew shadow lines every half hour on the paper. They brought them in each afternoon and discussed their results. There were many discussions about whether or not it made a difference where they placed their boards from day to day.

They were gathering so much data that it was becoming cumbersome. One student suggested that they use overhead transparencies to record shadow data and then overlay them to see what kind of changes occurred. Everyone agreed that it was a great idea.

Lore introduced the class to the *Old Farmer's Almanac* and the tables of sunsets, sunrises, and lengths of days. This led to an exciting activity one day that involved math. Lore asked them to look at the sunrise time and sunset time on one given day and to calculate the length of the daytime Sun hours. Calculations went on for a good 10 minutes and Lore asked each group to demonstrate how they had calculated the time to the class. There must have been at least six different methods used and most of them came up with a common answer. The students were amazed that so many different methods could produce the same answer. They also agreed that several of the methods were more efficient than others and finally agreed that using a 24-hour clock method was the easiest. Lore was ecstatic that they had created so many methods and was convinced that their understanding of time was enhanced by this revelation.

This also showed that children are capable of metacognition—thinking about their thinking. Research (Metz 1995) tells us that elementary students are not astute at thinking about the way they reason but that they can learn to do so through practice and encouragement. Metacognition is important if students are to engage in inquiry. They need to understand how they process information and how they learn. In this particular instance, Lore had the children explain how they came to their solution for the length of day problem so that they could be more aware of how they went about solving the challenge. Students can also learn about their thinking processes from peers who are more likely to be at the same developmental level. Discussions in small groups or as an entire class can provide opportunities for the teacher to probe for more depth in student explanations. The teacher can ask the students who explain their technique to be more specific about how they used their thought processes: dead ends as well as successes. Students can also learn more about their metacognitive processes by writing in their notebooks about how they thought through their problem and found a solution. Talking about their thinking or explaining their methods of problem solving in writing can lead to a better understanding of how they can use reasoning skills better in future situations.

I should mention here that Lore went on to teach other units in science while the students continued to gather their data. She would come back to the unit periodically for a day or two so the children could process their findings. After a few months, the students were ready to get some help in finding a model that explained their data. Lore gave them globes and clay so that they could place their observers at their latitude on the globe. They used flashlights to replicate their findings. Since all globes are automatically tilted at a 23.5-degree angle, it raised the question as to why globes were made that way. It was time for the "explanation" part of the lesson and Lore helped them to see how the tilt of the Earth could help them make sense of their experiences with the shadows and the Sun's apparent motion in the sky.

The students made posters explaining how the seasons could be explained by the tilt of the Earth and the Earth's revolution around the Sun each year. They had "evaluated" their understanding and "extended" it beyond their experience. It was, Lore agreed, a very successful "6E" experience. It had included the engage, elaborate, explore, explain, and evaluate phases, and the added extend phase.

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Chapter 2

Using the Book and the Stories

It is often difficult for overburdened teachers to develop lessons or activities that are compatible with the everyday life experiences of their students. A major premise of this book is that if students can see the real-life implications of science content, they will be motivated to carry out hands-on, minds-on science investigations and personally care about the results. Science educators have, for decades, emphasized the importance of science experiences for students that emphasize personal involvement in the learning process. I firmly believe that the use of open-ended stories that challenge students to engage in real experimentation about real science content can be a step toward this goal. Furthermore, I believe that students who see a purpose to their learning and experimentation are more likely to understand the concepts they are studying and sincerely hope that the contents of this book will relieve the teacher from the exhausting work of designing inquiry lessons from scratch.

These stories feature children or animals in natural situations at home, on the playground, at parties, in school, or in the outdoors. We want the children to identify with the story characters, to share their frustrations, concerns, and questions. The teacher's job is to help guide and facilitate investigations, to debrief activities with the children, and to think about the students' analyses of results and conclusions. The children often need help to go to the next level and to develop new questions and find ways of following these questions to a conclusion. Current philosophy of science education is based on beliefs that children can and want to care enough about problems to make them their own. This should enhance and invigorate any curriculum. In short, students can begin to lead the curriculum, and because of their personal interest in the questions that evolve from their activities, they will maintain interest for much longer than they would if they were following someone else's lead.

A teacher told me that one of her biggest problems is getting her students to "care" about the topics they are studying. She said they go through the motions but without affect. Perhaps that same problem is not new to you. I hope that this book can help you to take a step toward solving that problem. It is difficult, if not impossible, to make each lesson personally relevant to every student. However, by focusing on everyday situations and highlighting kids looking at everyday phenomena, I believe that we can come closer to reaching student interests.

I strongly suggest the use of complementary books as you go about planning for inquiry teaching. Five special books are *Uncovering Student Ideas* (volumes 1, 2, 3, and 4), by Page Keeley et al., published by NSTA press and *Science Curriculum Topic Study* by Page Keeley, published by Corwin Press and NSTA. *Science Curriculum Topic Study* focuses on finding the background necessary to plan a successful standards-based unit. The multivolume *Uncovering Student Ideas* helps you find out what kinds of preconceptions your students bring to your class.

Another especially useful book is *Science Matters: Achieving Scientific Literacy,* by Robert Hazen and James Trefil. This book will become your reference for many scientific concepts. It is written in a simple, direct, and accurate manner and will give you the necessary background in the sciences when you need it. Finally, please acquaint yourself with Driver et al., *Making Sense of Secondary Science: Research Into Children's Ideas*. The title of this book can be misleading to American teachers because in Great Britain, anything above primary level is referred to as secondary. It is a compilation of the research done on children's thinking about science and is a must-have reference for teachers. Use it as a guide when exploring the preconceptions your students bring to your classroom.

In 1978, David Ausubel made one of the most simple but telling comments about teaching: "The most important single factor influencing learning is what the learner already knows; ascertain this, and teach him accordingly." The background material that accompanies each story is designed to help you find out what your learners already know about your chosen topic and what to do with that knowledge as you plan. The above-mentioned books will supplement the materials in this book and deepen your understanding of teaching for inquiry.

How then is this book set up to help you plan and teach inquiry-based science lessons?

How This Book Is Organized

The stories are arranged in three sections. There are five stories related to the biological sciences, five for the Earth and Earth-related stories, and five for the physical sciences. There is a concept matrix at the beginning of each section that can be used to select a story most related to your content need. Following this matrix you will find the stories and the background material in separate chapters. Please note that the Earth systems science stories purposefully integrate the physical and biological sciences into science mysteries that focus on all aspects of everyday science related to the Earth sciences.

Table 2.1.
Thematic Crossover Between Stories in This Book and *Uncovering Student Ideas in Science*, Volumes 1–4

Story in this book	***Uncovering Student Ideas in Science***			
	Volume 1	**Volume 2**	**Volume 3**	**Volume 4**
Where Did the Puddles Go?	Wet Jeans	n/a	What Is a Hypothesis? What Are Clouds Made Of? Rainfall	Warming Water
What Are the Chances?	n/a	n/a	What Is a Hypothesis?	Where Would It Fall?
Here's the Crusher	n/a	n/a	What Is a Hypothesis?	n/a
Daylight Saving Time	n/a	Darkness at Night; Objects in the Sky	Is It a Theory? Me and My Shadow; Where Do Stars Go?	n/a

	Volume 1	Volume 2	Volume 3	Volume 4
A Day on Bare Mountain	Talking About Gravity; Beach Sand; Mountain Age	Is It a Rock? (1 & 2); Mountaintop Fossil	Earth's Mass	n/a
The Trouble With Bubble Gum	n/a		Doing Science; What Is a Hypothesis?	Is It Food?
Plunk, Plunk	Seedlings in a Jar	Is It a Plant? Needs of Seeds; Is It Food for Plants?	Doing Science; What Is a Hypothesis? Does It Have a Life Cycle? Respiration	Is It Food?
In a Heartbeat	Human Body Basics	n/a	Doing Science; What Is a Hypothesis?	Is It a System?
Hitchhikers	Functions of Living Things	n/a	Does It Have a Life Cycle?	Adaptation; Is It Fitter?
Halloween Science	Is It Living?	Is It a Plant? Needs of Seeds; Is It Food for Plants?	Doing Science; What Is a Hypothesis? Does It Have a Life Cycle?	Adaptation; Is It Fitter?
Warm Clothes?	The Mitten Problem; Objects and Temperature	n/a	Thermometer; What Is a Hypothesis?	Warming Water; Is It a System?
The Slippery Glass	Is It Made of Molecules? Wet Jeans	Ice Cold Lemonade	Where Did the Water Come From?	n/a
St. Bernard Puppy	n/a	n/a	Doing Science; What Is a Hypothesis? Sam's Puppy	Standing on One Foot
Florida Cars?	The Rusty Nails	n/a	Doing Science; What Is a Hypothesis?	n/a
Dancing Popcorn	n/a	Comparing Cubes; Floating Logs; Floating High and Low; Solids and Holes	Floating Balloon	n/a

Each chapter, starting with chapter 5, will have the same organizational format. First you will find the story followed by background material for using the story. The background material will contain the following sections:

Purpose

This section describes the concepts and/or general topic that the story attempts to address. In short, it tells you where this story fits into the general scheme of science concepts. It may also place the concepts within a conceptual scheme of a larger idea. For example, in "The Slippery Glass," the story is shown to be part of a larger concept or conceptual schemes, which may involve the water cycle and changes of state and energy transfer.

Related Concepts

A concept is a word or combination of words that form a mental construct of an idea. Examples are *motion, reflection, rotation, heat transfer, acceleration.* Each story is designed to address a single concept but often the stories open the door to several concepts. You will find a list of possible related concepts in the teacher background material. You should also check the matrices of stories and related concepts.

Don't Be Surprised

In most cases, this section will include projections of what your students will most likely do and how they may respond to the story. The projections relate to the content but focus more on the development of their current understanding of the concept. The explanation will be related to the content but will focus more on the development of the understanding of the concept. There will be references made to the current alternative conceptions your students might be expected to bring to class. It may even challenge you to prepare for teaching by doing some of the projected activities yourself, so that you are prepared for what your students will bring to class. For example, with "Plunk, Plunk" you may want to try various types of beans yourself, before asking your students to do so. In that way you will be prepared for the data they will bring to class and be aware of possible problems.

Content Background

This material will be a very succinct "short course" on the conceptual material that the story targets. It will not, of course, be a complete coverage but should give you enough information to feel comfortable in using the story and planning and carrying out the lessons. In most instances, references to books, articles, and internet connections will also help you in preparing yourself to teach the topic. It is important that you have a reasonable knowledge of the topic for you to lead the students through their inquiry. It is not necessary, however, for you to be an expert on the topic. Learning along with your students can help you understand how their learning takes place and make you a member of the class team striving for understanding of natural phenomena. You may find an explanation of the content related to the story helpful if you are not completely familiar with the content the story addresses.

Related Ideas From the National Science Education Standards (NRC) and Benchmarks for Science Literacy (AAAS)

These two documents are considered to be the National Standards upon which most of the local and state standards documents are based. For this reason, the concepts listed for the stories are almost certainly the ones listed to be taught in your local curriculum. It is possible that some of the stories are not mentioned specifically in the Standards but are clearly related. When the relationship is strong, a star symbol will be placed adjacent to the statement. I suggest that you obtain a copy of *Science Curriculum Topic Study* by Page Keeley, which will help you immensely with finding information about content, children's preconceptions, standards, and more resources. It is available through NSTA press. Even though it may not be mentioned specifically in each of the stories, you can assume that all of the stories will have connections to the Standards and Benchmarks in the area of Inquiry, Standard A.

Using the Story With Grades K–4 and 5–8

These stories have been used with children of all ages. We have found that the concepts apply to all grade levels but at different levels of sophistication. Some of the characters in the stories have themes and characters that resonate better with one age group than another. However, very simply changing the characters to a more appropriate age or using a slightly different age-appropriate dialog can change the stories enough to appeal to an older or younger group. The theme should be the same; just modify the characters and setting. Please read the suggestions for both grade levels.

As you may remember from the case study in the introduction, grade level is of little consequence in determining which stories are appropriate at which grade level. Both classes developed hypotheses and experiments appropriate to their developmental abilities. Second graders were satisfied to find out what happens to the length of a tree's shadow over a school year while the fifth-grade class developed more sophisticated experiments involving length of day, direction of shadows over time, and the daily length of shadows over an entire year. The main point here is that by necessity some stories are written with characters more appealing to certain age groups than others. Once again, I encourage you to read both the K–4 and 5–8 sections in the "How to use these stories," sections because the ideas presented for either grade level may be suited to your particular students.

There is no highly technical apparatus to be bought. Readily available materials found in the kitchen, bathroom, or garage will usually suffice. We provide you with background information about the principles and concepts involved and a list of materials you might want to have available. These suggestions of ideas and materials are based upon our experience while testing these stories with children. While we know that classrooms, schools, and children differ, we feel that most childhood experiences and development result in similar reactions to explaining and developing questions about the tales. Whether they belong to Joyce and her slippery glass or to Maya and Leo trying to weigh their gigantic puppy, the problems beg for solutions and, most important, create new questions to be explored by your young scientists.

Here you will find suggestions to help you teach the lessons that will allow your students to become active inquirers—develop their hypotheses and finally finish the story, which you may remember was left open for just this purpose. I have not listed a step-by-step approach or set of lesson plans to accomplish this end. Obviously, you know your students, their abilities, their developmental levels, and their learning abilities and disabilities better than anyone. You will find, however, some suggestions and some techniques that we have found work well in teaching inquiry. You may use them as written or modify them to fit your particular situation. The main point is that you try to involve your students as deeply as possible in trying to solve the mysteries posed by the stories.

Related NSTA Press Books and NSTA Journal Articles

Here, we will list specific books and articles from the constantly growing treasure trove of National Science Teachers Association (NSTA) resources for teachers. While our listings are not completely inclusive, you may access the entire scope of resources on the internet at *www.nsta.org/store*. Membership in NSTA will allow you to read all articles online.

References

References will be provided for the articles and research findings cited in the background section for each story.

Concept Matrices

At the beginning of each section—Earth systems science and technology–related stories, biological-related stories, and physical science–related stories—you will find a concept matrix, which indicates the concepts most related to each story. It can be used to select a story that matches your instructional needs.

Final Words

I was pleased to find that Michael Padilla, past president of the National Science Teachers Association asked the same questions as I did when I decided to write a book that focused on inquiry. In the May 2006 edition of *NSTA Reports*, Mr. Padilla, in his "President's Message" commented, "To be competitive in the future, students must be able to think creatively, solve problems, reason and learn new, complex ideas.… Inquiry is the ability to think like a scientist, to identify critical questions to study; to carry out complicated procedures, to eliminate all possibilities except the one under study; to discuss, share and argue with colleagues; and to adjust what you know based on that social interaction." Further, he asks, "Who asks the question? Who designs the procedures? Who decides which data to collect? Who formulates explanations based upon the data? Who communicates and justifies the results? What kind of classroom climate allows students to wrestle with the difficult questions posed during a good inquiry?"

I believe that this book speaks to these questions and that the techniques proposed here will allow you to answer the above questions with, "The students do," in the kind of science classroom this book envisions.

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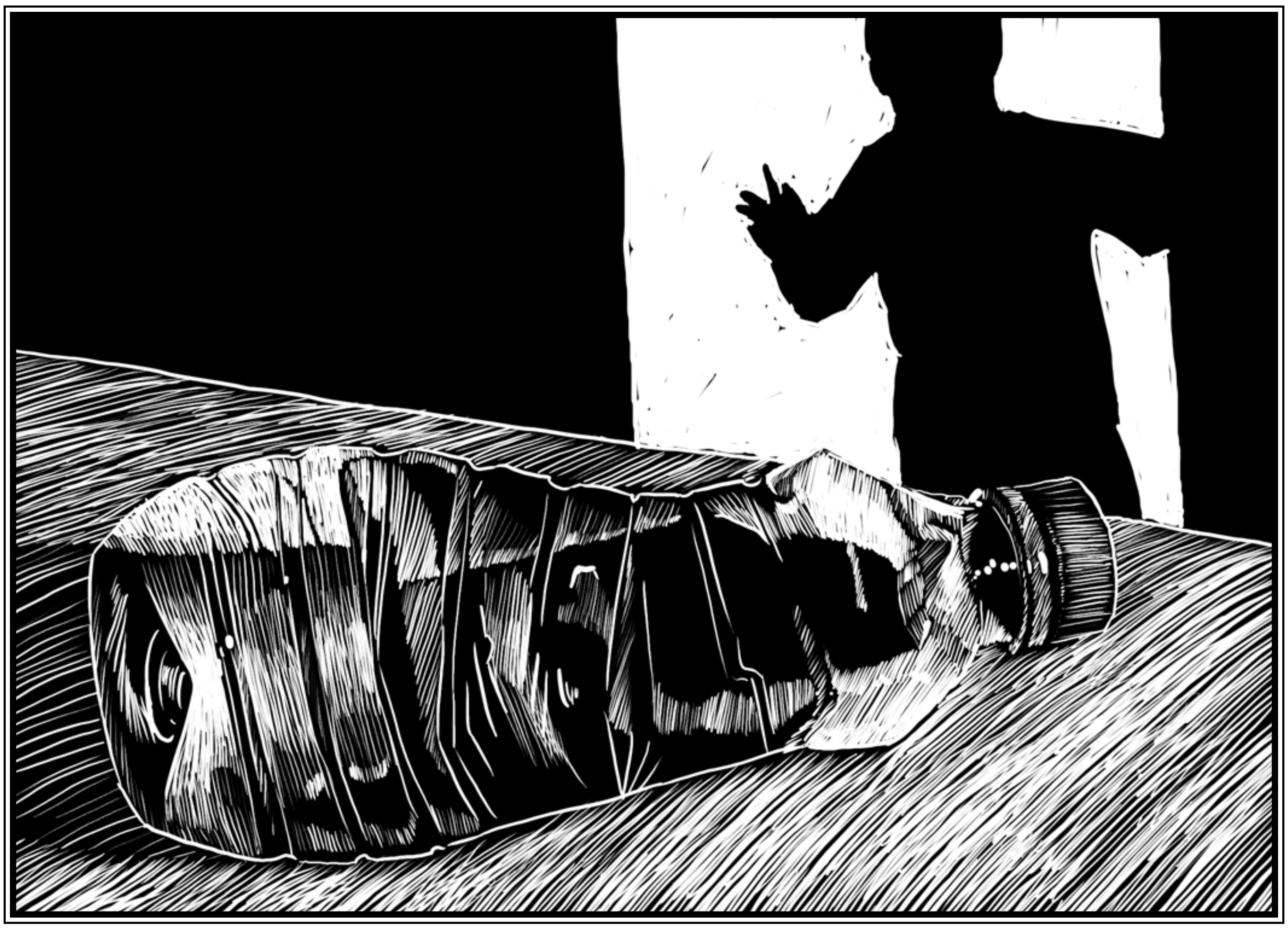
Chapter 7

Here's the Crusher



"Chores! My turn to do dishes again tonight," thought Eric. "Maybe if I have a second piece of pie, they'll forget."

"May I please have another piece of that super delicious pie?" Eric asked. "I think it's the best you've ever made," he said, hoping that flattering his sister would make her forget it was his turn at the dishes.

"Oh certainly, little brother, and since you are doing dishes tonight, I suppose you want to use the same plate you're using now." Janny smiled knowingly at him.

"Rats, she remembered!" Eric decided that he'd eat the pie anyway and then tackle the darn dishes.

He finished the pie, downed a glass of milk, and headed for the sink and the dinner dishes, cleared from the table and ready for his tender loving care. He filled the tub with soapy water, began to wipe and rinse the dishes, and put them into the drainer. When he had finished, he spotted a plastic soda bottle left on the kitchen counter waiting to go into the recycle bin.

"Guess I might as well rinse it out too, even though it isn't a dinner dish," he thought. Eric thoroughly rinsed the bottle out with very hot water, poured out the water and screwed the cap back on. He placed it back on the counter and started to leave the kitchen. Suddenly, he heard a crackle behind him and turned around just in time to see and hear the soda bottle as it began to collapse into itself. It crackled and crushed as though someone were squeezing it.

Eric opened the cap and the bottle returned to its original shape. He repeated the rinsing and capping process again and again and marveled over the result each time.

"Hey, guys," he shouted. "Come look at this."

Everyone had an opinion about it.

Big sister Janny said Eric had caused a vacuum when he poured the water out because the air in the bottle went out with the water, but couldn't explain why the crushing didn't happen immediately. Mom thought it was a matter of the kind of plastic from which the bottle was made and that it shrunk when heated by the hot water. Dad agreed.

Other members of the family thought it happened because of the water being poured out in the rinsing, while others wondered if the container had to be plastic.

There were a lot of thoughts and lots of wonderings. Meanwhile Eric began thinking in terms of "what ifs…" and began to try a lot of his ideas right there at the kitchen sink. The idea of spending time at the sink was no longer a chore but fun!

Purpose

Anyone who has rinsed out a plastic soda bottle may have had this experience. But I wonder how many have noticed it and had some of their own "what ifs…." That is the purpose of this story. Let's explore air pressure and its importance in our lives as an everyday science mystery.

Related Concepts

- Air pressure
- Vacuum
- Expansion and contraction
- Heat energy
- Temperature

Don't Be Surprised

Even though every weather reporter talks about high- and low-pressure areas, most of these comments go over our heads, or as the saying goes, "in one ear and out the other." Many of your younger students do not believe that air around us has mass or weight, let alone exerts pressure on us and on everything around us.

Many students believe that air, or any gas, is in the same category as abstractions such as thoughts. If you have viewed any of the *Private Universe* films, you may remember Jon, the middle-school student who absolutely refused to believe that air (or any gas) took up space unless it was moving and was called "wind" or was in the form of dry ice. Most children are not aware that "flat" soda weighs less than fresh soda.

One major preconception that can be expected is that children think of air and oxygen as synonymous. Air is of course made up of many gases of which oxygen is only one. Oxygen amounts to about 21% of the total chemical makeup of air.

So, the idea that the atmosphere in which we walk actually has mass and can exert pressure on our world may seem completely ridiculous to many of your students. Of course they won't tell you that if asked directly. The story itself, however, is a type of formative assessment, and a discussion about the various opinions given will give you valuable information on what the students believe about the air that surrounds them.

Content Background

Above us, below us, inside us, and all around us lies a mixture of gases we call our atmosphere. This atmosphere, our *air*, is made up of molecules of gases that take up space and therefore have mass. We take it in and release it from our bodies, as do all animals. It is vital to the life of plants because it provides the carbon dioxide from which they take the carbon to build their cells using photosynthesis. Air contains water vapor and myriad minerals and particles that float around in it, including pollutants. When it moves, we feel it as wind. When it is absent, we cannot breathe.

Air exerts pressure on everything that exists on this Earth. At sea level the pressure is about 14.7 pounds per square inch (psi). The amount of pressure decreases as we rise above the Earth's surface. Technically the atmosphere ends at about 120 km (75 mi) away from the Earth. Five different levels have been delineated in the atmosphere, each indicating a decrease in pressure with altitude.

At the top of Mount Everest at 8,850 m (29,000 ft.), the pressure is about 50% of that at sea level. Commercial airplanes fly at around that altitude, at an average of 33,000 ft. When you fly in a commercial airplane, the cabin in which you sit is pressurized to what the atmosphere would be at somewhere between 6,000 to 8,000 ft. (1,830 to 2,440 m). Although this is not sea level, the difference does not usually cause problems for most people. Airplanes must be pressurized for two reasons. First, the shape of the plane would change at higher levels and possibly cause structural damage. Second, passengers might become ill at the very low pressures found at high altitudes. The oxygen in the airplane cabins is also reduced at higher altitudes, but not usually to the point where you notice it unless you have a medical problem that requires oxygen to be at a sea level standard.

Pressure changes can be uncomfortable. You may have experienced discomfort when an airplane you are riding in ascends or descends, and your ears feel the pressure change. Air has been trapped in your ear canal, and as the plane changes altitude, you notice the difference between air inside your ear and out. The eardrum can retract to the point where some people actually feel pain. Others are merely inconvenienced until the pressure equalizes and their ears "pop." You may also feel this when descending quickly from a high mountain in your car or traveling in a fast elevator.

The envelope of air that is the atmosphere serves a very important function for life on Earth. It filters out a great deal of ultraviolet light and provides a shield for escaping radiation, therefore keeping the planet warm and reducing temperature extremes between day and night. This retention of heat energy that modifies the temperature of the Earth is known as the greenhouse effect. Scientists have ascribed the recent rapid increase in global warming to gases from burning fuel that have formed another layer in the atmosphere that prevents heat energy from escaping in a normal way.

Atmospheric pressure is measured as the downward pressure of the weight of air above the place where it is measured. As we mentioned before, it is greatest at sea level and less at higher altitudes. Air pressure is also affected by temperature and the amount of water vapor in the air. High-pressure air is usually more dense and dry, while low-pressure air is usually less dense and moist. This may seem counterintuitive, but the water vapor molecule is lighter than the average molecules that make up the air. Therefore, the average density (which is the mass divided by the volume) of the air is less and less pressure is exerted. This is called a "low." Conversely, a mass of dry air is denser and therefore exerts more pressure and is called a "high."

Dry air is usually cooler than moist air. So when cool air moves into your area, you can usually expect the cooler, dryer, and clearer conditions that go with high pressure weather. The opposite is true of the masses of warm, moist air.

Most of us in our years of schooling have seen the demonstration of the can of water heated so that the water boils and the vapor clouds are seen emerging from the can. The teacher placed the lid on the can, and as we watched in amazement, the can seemed to be crushed by an invisible hand. We were told that it was the air pressure that crushed the can and that the boiling of the water took the air out of the can so that it had no resistance to the air pressure around us. Did we believe it? I remember seeing it at least a half dozen times over my years in school, and by the time I was in high school physics I think I finally believed it and perhaps really began to understand it. I never got to touch the apparatus nor did I have the opportunity or equipment to try it at home.

Now with the advent of plastic bottles, our students can play safely with this activity as long as they want. Homework? Why not—as long as parents know what is going on and will supervise so that kids don't try boiling water. The warm water expands the air inside the bottle, which causes a lot of that air to leave through the open top. When you screw the cap back on after the bottle is empty, there is less air inside and it is warm. As it cools, it takes up even less space so the room

Related Ideas From National Science Education Standards (NRC 1996)

K–4: Changes in Environments

- Changes in environments can be natural or influenced by humans. Some changes are good, some are bad and some are neither good nor bad.

5–8: Structure of the Earth System

- The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.
- The Sun is the major source of energy for phenomena on the Earth's surface.

Related Ideas From Benchmarks for Science Literacy (AAAS 1993)

K–2: Energy Transformations

- The Sun warms the land, air, and sky.

3–5: The Earth

- Air is a substance that surrounds us and takes up space. It is also a substance whose movements we feel as wind.

6–8: Processes That Shape the Earth

- Human activities such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming have changed the Earth's land, oceans and atmosphere.

temperature air pressure pushes on the outside of the bottle and crushes it. You can make it happen even faster if you pour cold water over the bottle after it is sealed. The air inside will cool faster and the reaction will be accelerated.

From personal experience, I can vouch for the tremendous pressure of the atmosphere. I was sold a new gas cap for my car that turned out to be nonvented. As I drove, gasoline was taken from the gas tank but no air was allowed to replace it due to the nonvented cap. The gas tank of the car collapsed from the pressure of the atmosphere! Fortunately, I was awarded a new tank and a new gas cap. The important thing here is that the gas tank was not a flimsy piece of metal but a substantial structure. However, with air pressure at 14.7 pounds per square inch, it was no match for the atmosphere after its contents were emptied, causing it to become a virtual vacuum. Like the plastic bottle, it was crushed from the outside!

Using the Story With Grades K–4

I like to start by asking the students if they have done dishes and have had the experience described in the story. Surprisingly, some have and are eager to tell you about it. Obviously, those who have not seen this firsthand will want to try it. I suggest that you demonstrate it for them by having them tell you what to do at each step. These steps can be written down on a large sheet so they can be analyzed in an effort to understand what might have happened.

It is also a good idea to have a half dozen identical bottles so when the children suggest different changes in the procedure, the bottles can be compared to one another. For example, if the children ask if warmer water makes a difference in how much the bottle is crushed (and they usually do ask that), you can try this and see.

If you have a sink in your room with hot and cold water, it will be easier for you to demonstrate this phenomenon. If not, you will have to have several containers of different temperature water at your disposal or else a hot plate to warm the water. It is also a good time to introduce your students to a thermometer if you have not already done so. This way, there will be data to record and analyze. Variables may include

- Temperature of the water
- Length of time you leave the water in the bottle
- Size of the bottle
- How much water you put in the bottle
- How the water is emptied from the bottle
- How the bottle is cooled
- Shape of the bottle
- The thickness of the bottle's plastic
- Difference in procedure, such as just heating the bottle from the outside

Children will be aware of procedure. You may put water in and swirl it around, or may pour it out quickly or gradually. Ask your students if it makes a difference if you follow the same procedure exactly each time. They are usually sticklers for following the exact routine.

Even though Eric did not cool the bottle quickly, you may want to add this to your procedure and ask the children to predict if the shrinking of the bottle will change in any way. This way, you introduce the idea of cooling as an important part of the solution to the problem. You probably will have to give hints as to the source of the pressure even though the children may still have trouble with this concept at the early elementary stage. Still, it gives them something to ponder over time and will add one more experience to those that eventually lead them to accept the scientific view of air pressure.

If you are brave, you may set up a center and allow students to try the investigation themselves. Or as an alternative, you may want to involve parents by sending a note home explaining what the students are supposed to do and asking that they supervise so that the children do not use any dangerous procedures. Warm water from the normal hot water tap is usually enough to give a reasonable reaction.

Using the Story With Grades 5–8

Older children have probably had some experience like Eric's and will have opinions on why the bottle was crushed. Starting out with a "Best Thinking" sheet is a good way to begin the thinking process. Rest assured that your students will want to see this phenomenon and you can either proceed as suggested in the section above or, if your facilities allow, let the students test their ideas themselves. If you develop a list of possible variables as suggested previously, you can ask groups of students to try each of the various tests and to report on their findings. Predictions are important here, as always, and having students record their findings in their science notebooks will allow a good discussion after the lab work is completed.

I cannot overstress the importance of class discussion of this topic. Your leadership of the discussion is very important as you listen to what your students are saying and respond to them in as conversational a way as possible. The more you can get them to interact with one another, and not through you, the better the discussion will be. Dialogue among the students will bring out a great many ideas, and the arguments will allow the students to have their say and then have the opportunity to revise their thinking on the basis of what they have heard or said. It is always a good idea to have the materials available for students to demonstrate their points as needed.

Of course, doing it at home is another alternative—with the caution that parental supervision is important, even more so with children of this age because of their fearlessness and frequent lack of judgment about safety.

Lastly, if you have access to the NSTA website, you can download the article "Torricelli, Pascal, and PVC Pipe" in the *Science Scope* archives (Peck 2006). In this article, the author has some great ideas about using straws, tubing, and PVC pipe to measure atmospheric pressure. I recommend it highly. The use of straws is a wonderful way to expound on one of the most popular misconceptions, that of our *sucking* up drinks through a straw. Actually, we lower the pressure in the straw and the atmospheric pressure *pushes* the liquid up into our mouths!

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