Chapter 4

STORIES

In this chapter, seven teachers will tell the stories of how they implemented activities and units on packaging and structures at levels ranging from pre-kindergarten/kindergarten to sixth grade. Five of the teachers focused on analysis and design of packaging technologies. The other two engaged their students in designing and making useful classroom structures from discarded packaging materials. All of the activities in this chapter are summarized in Table 4-1.

Table 4-1
Approaches to the study of packaging and structures

Getting Started

Brianstorming about what constitutes a package, including natural and artificial packages

Collecting and sorting examples of packaging

Brainstorming problems at school and home that could be solved by creating new structures

Analysis

Exploring some of the relationships between a package and its contents

Testing bags, boxes, cushioning materials, and pump dispensers to find out their mechanical properties

Determining how the following variables affect the strength of a cardboard shelf: type of glue, lamination method, shape, support method

Design

Repairing and redesigning bags

Designing cushioning systems for a fragile product

Creating portable storage units for transporting shoebox dioramas

Designing and making cardboard shelves for the classroom

Analyzing and Designing Packaging

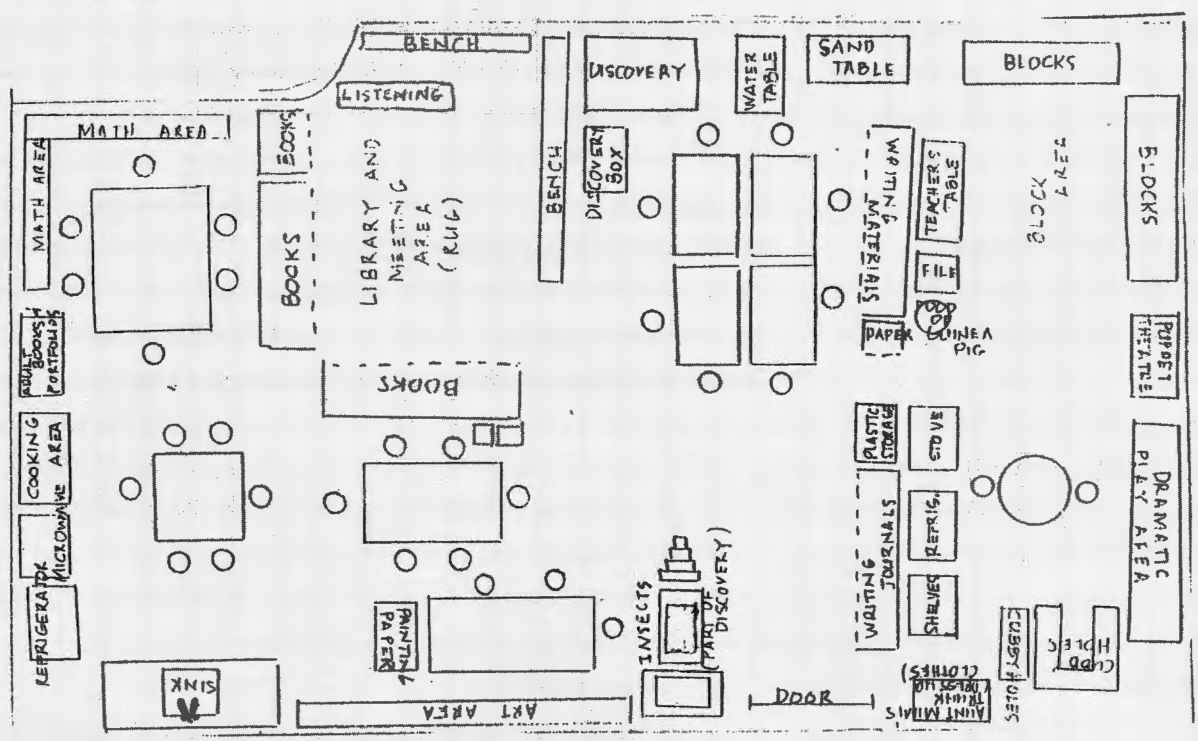
Technology in the Early Childhood Classroom *by Theresa Luongo*

Theresa Luongo is a pre-K/K teacher at Central Park East 2, a small alternative school in East Harlem. Packaging became an ongoing activity in her classroom as her children became intrigued with the properties of boxes, bags, and pump dispensers. Many of the activities were initiated by the children, who found new uses for the pump dispensers and discovered how to modify and repair bags. Theresa came away from these activities with a new appreciation for the potential of technology in the early childhood classroom.

Most children are in my class for two full school years. They enter at approximately four years of age in pre-kindergarten, and stay with me until the end of kindergarten, when they are approximately six years old. This school year (1998-99) my class is made up of two-thirds kindergarten students and only one-third pre-kindergarten, due to budget cuts for pre-K. I have 23 students in my class and a full-time paraprofessional.

My classroom is spacious. The room is divided into work areas where small groups of children engage in a wide range of activities. There is a large rug area where we come together to meet and share work and read. The various areas of the room reflect the choices available to the children during work time: Sand, Water, Math, Discover, Blocks, Dramatic Play, Construction, Painting, Cooking, Clay, Writing, Library and Listening. (See Figure 4-1.) Each day, the classroom transforms into a workshop atmosphere where children work together on projects.

4-1: **Theresa's map of her classroom**



There are certain universals shared among most early childhood teachers. One is that learning is a social process. Another is that learning is active, not passive. If we want our students to be active learners and use language for real purposes, we need to create classroom environments that encourage this. The classroom itself should be viewed as a workshop or studio where experimentation and dialogue take place among the students. Each day a certain amount of time should be devoted to student projects and experimentation. In my school we call it "Work Time." By setting aside a time each day for students to make choices about where they will work, we are helping them pursue their interests and make choices about their learning.

Initially, Theresa was reluctant to integrate technology into this already rich environment. Her overriding goals are in the areas of language arts, and she was not sure how technology would contribute to those objectives. She writes:

One goal of most early childhood teachers is to promote language and literacy development. As a kindergarten teacher, I didn't see how technology could help me achieve that goal and I was skeptical about the role it would play in my classroom. One of my reservations centered around my feelings of inadequacy about technology in general. I was equally concerned about trying to do something new, in addition to everything that was happening in my classroom already.

As I read more and talked with participants who had been part of *Stuff That Works!* the previous year, I started to broaden my understanding of what technology is. I began to see how technology could fit into what happens naturally in the kindergarten classroom and how important it is to expose young children to technology and their part in it. Technology promotes language development naturally. When children come together to repair something or understand the way a mechanical device works, they are forced to use language for real reasons.

It isn't necessary to set up a Technology Corner or a Technology Center for technology activities to take place in the classroom. I want to stress the importance of using technology as an integral part of what already exists in the classroom.

Theresa sought an aspect of technology that would fit neatly into one of the work areas in her classroom. She wanted her students to explore technology in the context of the things they were already doing. In addition, she was hoping that they would pursue these investigations over the long term, revisiting their own questions as new ideas arose. Theresa decided to introduce pump dispensers—the kind found on lotion and cleanser bottles—into the water table in her classroom.

How Do We Get the Smelly Water Out of the Water Table?

This was something I knew I could fit into an area already established in my classroom, the water table. Our water table has a large basket underneath where various objects are kept. Among those objects was one large plastic pump. During a meeting at the rug area I brought over a pump dispenser (filled with water) and a clear plastic cup. I explained that the children going to the water table would have a chance to use these kinds of pumps. I then passed the pump dispenser and cup around to give the students a chance to use it.

Up to three students at a time may go to the water table. In addition to water toys, several pump dispensers were available. Each day I encouraged different students to choose Water as a Work Time activity. The students began experimenting with the pumps. Initially, the children didn't all know that the tube needed to be in the water. They tried to fill the tube with buckets of water, basters, large spoons, etc., only to turn the pump over and have the water spill out. (See Figure 4-2.)

4-2: Maira tries filling the pump upside down.

4-3: The pump collection

Here is a sample of the talk at the water table:

DIONISIO:
It's bubbling, the water is bubbling. We made it bubble.

JUSTIN (holding a meat baster):
How does this thing work?

THERESA (the teacher):
How do you think it works?

JUSTIN:
I know. You have to push it ≑the tip≑ real hard.

DIONISIO:
You have to squeeze it.

THERESA (holding up the pump):
How does this work?

DIONISIO (turning the pump upside down):
You have to fill it up. Hey, we need some help here. I can't put water in this thing.

JUSTIN:
You should fill it in the sink.

Both students worked on filling the tube upside down, only to have the water spill out when it was turned over. Finally, they decided to submerge the pump's tube in the water.

I asked the students to start looking for pumps at home. The one deal I've made with the class is, "If you bring in a pump, you will definitely get a chance to go to the water table during Work Time that day." Now we have a rather extensive pump collection that keeps growing. (See Figure 4-3.)

Once I felt the students had had enough time to play with and explore the pumps, I began our experiment.

The students selected three pumps of various sizes and labeled them #1, #2, and #3, and also numbered three cups. Then, taking turns, each child operated a pump just once, with the flow directed into the cup with the same number. (See Figure 4-4.) The question was "Which pump will pump the most water?"

Theresa continues:

With each test, we would record the results of our experiment and the date on a chart. (See Figure 4-5.) After several trials, we started testing three different pumps labeled #4, #5, and #6. These pumps are closer in size to one another than the pumps used in the first trials.

4-5: **Pump data chart**

4-4: **Maira tests a pump dispenser**

As we continue to test our pumps, the students are asking and answering their own questions about how the pumps work. Some are convinced the bigger the pump, the more water it will be able to pump. Others aren't sure if that's true.

In the course of these investigations, some children came to see the pumps as useful tools, as well as interesting objects to experiment with. There was a real problem that the pumps could solve: "How do we get the smelly water out of the water table?" They recognized not only that the pumps could do the job, but also that the large pumps could do it faster.

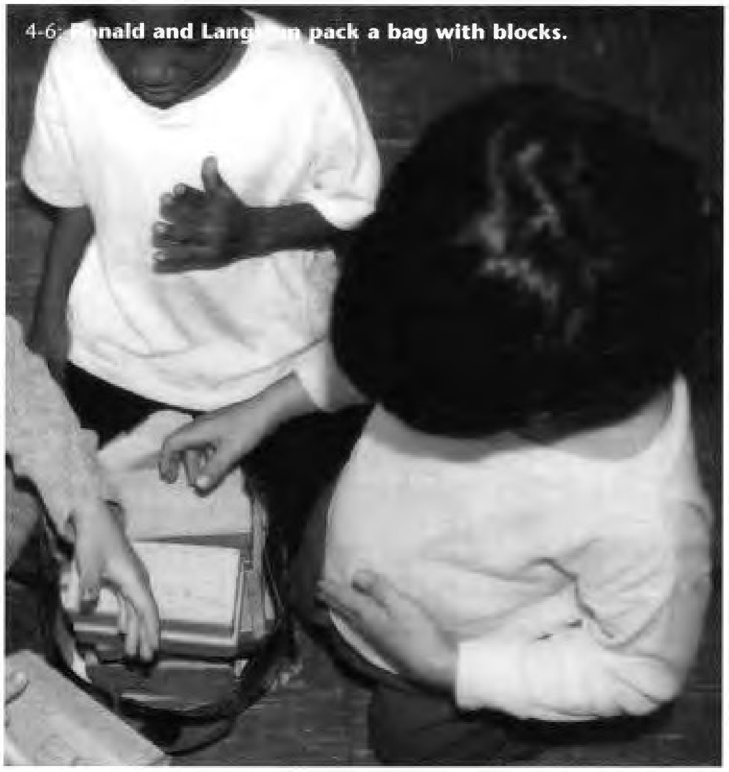
One student actually tried using a spray pump to empty the water table. Now, when it's time to clean the water table, the students are using the large pumps and taking turns doing the pumping. The study of pumps and they way they work is now part of our classroom environment.

Theresa was very pleased with this sequence of events. The study of pumps seemed to fulfill her goal of stimulating language development. As an added and unexpected bonus, her students had discovered for themselves that they could solve real problems using their newly developed knowledge of these devices.

The study of bags proved to be even more fruitful. As with the pump dispensers, Theresa integrated this activity into an existing work area—this time the block area.

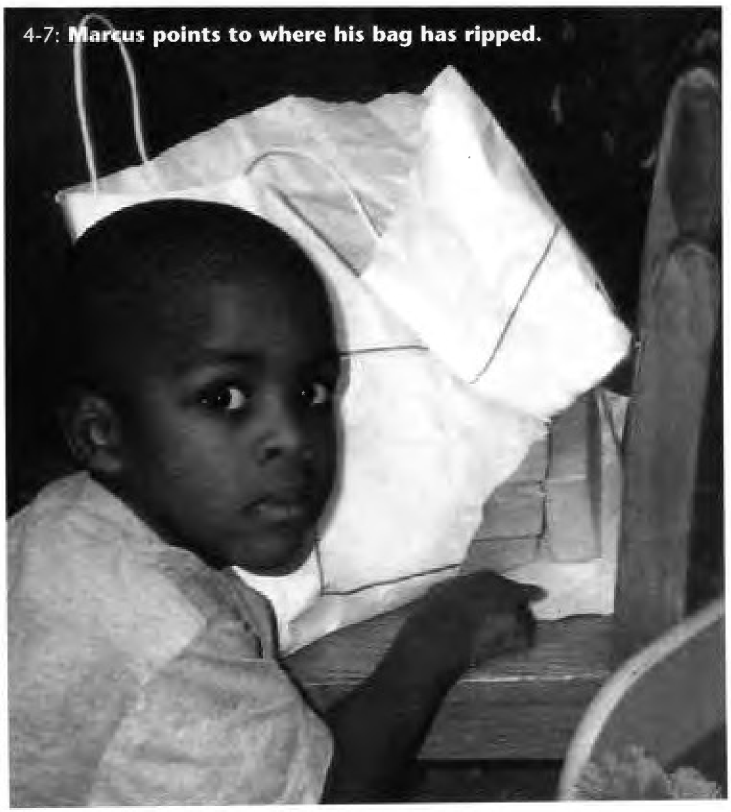
From Bag Testing to Bag Repair and Redesign

We began in the block area with an activity designed to test the strength of two small shopping bags. During a group meeting before Work Time, I asked the students who chose Blocks to see how many blocks they could fit into the two bags and to find out which bag could hold more. I asked the students to work as a group to fill each of the bags. (See Figure 4-6.)



4-6: Ronald and Langston pack a bag with blocks.

Once one of the bags broke, I talked about it first with the small group and then with the class. I wanted them to investigate which part of the bag broke. (See Figure 4-7.)



4-7: Marcus points to where his bag has ripped.

This too has taken on its own life in the classroom. It's interesting seeing the rules they make up for packing and unpacking the bag, as the following dialogue illustrates:

RONALD:
We got to do it this way.

LANGSTON:
I know what I'm gonna do...

RONALD:
You gotta share the blocks.

LANGSTON:
I am sharing.

DANIELLE:
First we fill this bag. Who's helping me? Bria, get the blocks down. Bria, I'm getting the blocks down.

LANGSTON:
Look. Hey look! I'm almost finished with my bag.

RONALD:
You can't put them in like that. They won't fit like that.

LANGSTON:
I'm finished. Want to see?

When both bags were filled up, the children tried carrying them around the classroom to show the other students. I asked them to find out how many blocks each bag had. We never really found out. Instead, the objective became just taking the blocks out carefully.

DANIELLE:
We need to make a big pile. Theresa likes it when it's in a pile.

RONALD:
I'll help hold them.

BRIA (counting each block as it's taken out of the bag):
One, two three, four... Put them on top of each other.

RONALD:
We need to take turns. We all need only one block at a time.

LANGSTON:
Yeah, like I'm doing.

Once the bag was empty, they lost count, and proceeded to fill the bag again until the handle broke off one of the bags.

As with the pump explorations, the students took the bag testing in a direction Theresa hadn't anticipated. They decided to repair the broken bags!

After the handle ripped off one of our shopping bags, Langston, a pre-K student, informed me that he knew how to fix it. I suggested that he go to the Construction area and repair it. Langston took out tape and began mending the bag. Mariah (who's also in pre-K) came over to find out what was going on. She stayed and helped Langston fix the shopping bag. (See Figure 4-8.) Soon, another bag ripped in the Blocks area. This one tore on the side seam. Langston and Mariah carefully worked to repair the shopping bag. (See Figure 4-9.)


4-8: **Mariah and Langston repair a bag.**


4-9: **Langston shows the repaired bag.**

I asked them how I could turn my small brown paper lunch bag into a shopping bag. Here's the advice they gave me:

MARIAH:
You need string, you know.

LANGSTON:
Yeah!

I took their advice and took out string and scissors. Langston began folding down the edge of the shopping bag, which was something he had observed on the larger shopping bags.

MARIAH:
We need glue.

I suggested putting holes in the bag and asked if they thought that might work. Both Langston and Mariah thought it was a good idea. After I punched the holes, Mariah worked with the string to make knots and handles. (See Figure 4-10.) When they were finished, they brought it over to the Block area.

MARIAH:
We're not putting blocks in this bag. Do you know why?

THERESA:
Why?

MARIAH:
This bag will break.

As a result of what Langston and Mariah did, bag testing and especially bag repair caught on. They became among the most popular Work Time activities in Theresa's class.

4-10: **Mariah creates a shopping bag out of a small brown lunch bag.**

Now the students are figuring out how to repair the bags and discovering where the bags tear most frequently. The children have the opportunity to continue to test the bags over and over again and repair the bags over and over again. Only by trial-and-error will the students discover which tape works best or what will help strengthen the various bags. Each day more children seem to want to go to the Block area and test the bags so they can get a chance to repair them.

Recently a child in the class gave out party bags, which were small shopping bags, to each student in the class. Following the party, students started bringing the bags back to school to put in the Block area.

They also feel empowered by being able to fix something. Bag repair has led to children repairing other things in the room. They must think, "Well, we can fix those paper bags. Why not fix these torn book covers?"

After Taylor, another pre-K student, witnessed Langston and Mariah taping a shopping bag, she informed me that she wants to go to the Construction area so she can repair the torn cover on one of our big books. This will lead to numerous technology opportunities in the classroom. What if our Construction area also became a repair station for broken objects and materials in the classroom? I can't help but feel excited for the child who breaks or tears something, only to learn it can probably be fixed. And even if it can't be repaired, it's worth trying. Think of the message it sends! We live in a throw-away society. Suddenly we find children starting to repair things rather than just asking for new ones.

In her concluding reflections, Theresa discusses the potential for technology in the early childhood classroom:

Technology becomes real for early childhood students and teachers when it's used for real purposes. When children in my class go to the Construction area and figure out how to repair a bag they used in the Block area, they are doing many things:

1. **They must work together to figure out what the problem is. Where did the bag tear?**
2. **They must negotiate how they will fix it.**
3. **They must test the materials they will use to repair the bag.**
4. **Most important, it was their choice to repair the bag, so they feel vested in what they are doing.**

My goal is to provide a classroom environment that allows children to make choices about the activities they will participate in. Some children wish to experiment with things until they know the materials inside-out and feel they have mastered them. Others like to try new things all the time. The classroom needs to allow for the individual learning style of each student.

My role as the teacher is to find a point of entry for each child, one that supports his or her needs and allows for differences. Now I see technology as an integral part of my classroom and curriculum. The children have given technology it's own life in the classroom and I support it. I began by feeling cautious with a single pump, but now I can't imagine my classroom without technology.

Packaging as Raw Material for Language Arts, Science Process, and Math *by Verona Williams*

Verona Williams is a third-grade teacher in the South Bronx, New York City. Her goals for her unit on packaging were to develop her students' abilities in language arts and quantitative reasoning. She began by having students define "package" and classify bags and packages and explain their uses. The children's own questions and suggestions eventually led to some systematic testing of bags. Verona's story features her assessment of individual children's strengths and weaknesses, based on their writings about packaging. Verona used packaging as a theme for teaching a variety of subjects, including language arts, science, and math. She began by having her students try to explain the word "packaging." Here is her account:

What Is Packaging?

I asked the students to brainstorm in cooperative groups and answer the following:

- **List all different types of packaging things you know.**
- **What is packaging?**

The class was divided into seven groups. I gave each group three packages to study. I asked them to define "packaging" and to list everything they thought had anything to do with packaging. They listed things found in packages as well as things that are considered packages. (See Figure 4-11.)

Some of their definitions of packaging were:

I think it is when you pack things and boots, toys.

Packaging is when you put something in a bag.

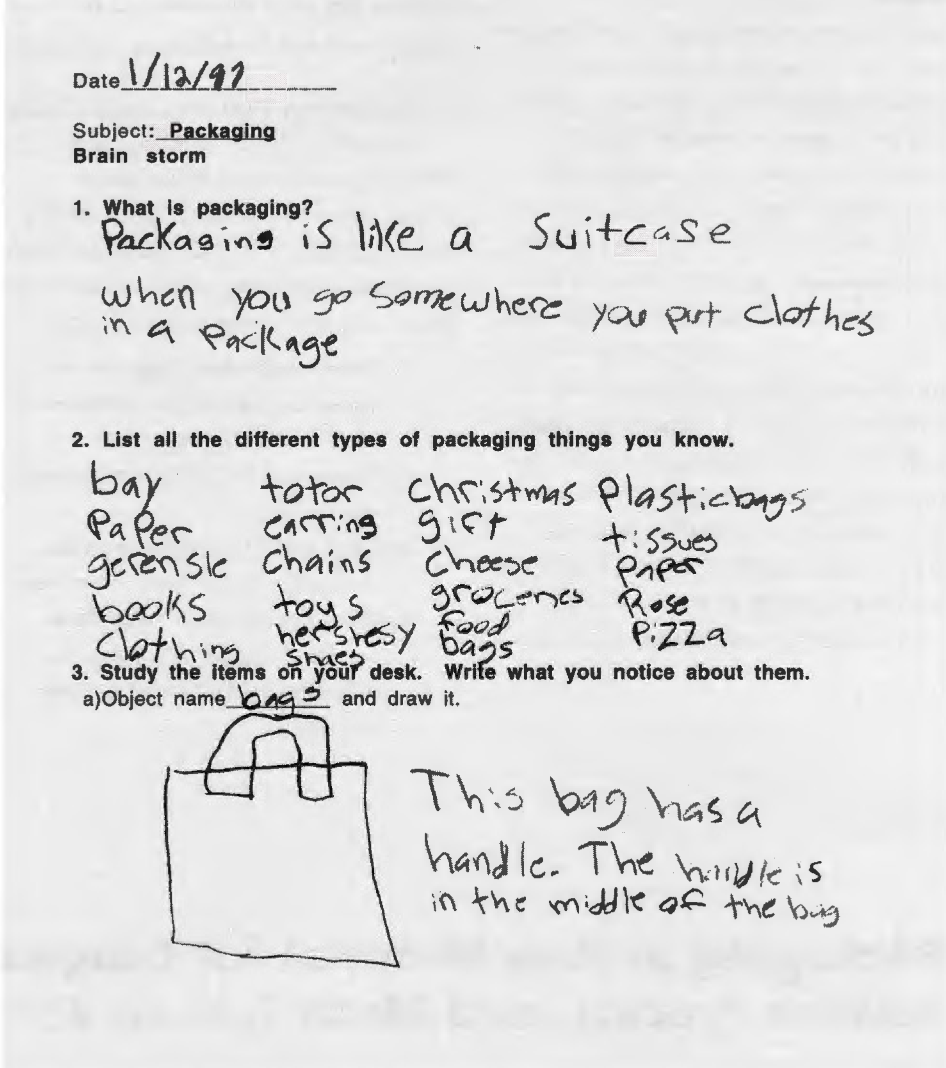
I think that packaging is when you shop for shoes, hats, lunch.

Packaging is when you put stuff in a plastic bag.

Each group shared their list of different types of packages. Below is a summary of their lists:

- different foods that come in packages (15 instances)
- toys (6)
- gifts (3)
- plastic bags (3)
- bags (2)
- clothes (since they cover the body)
- book bags

4-11: **What is packaging?**



Date 1/12/97

Subject: Packaging
Brain storm

1. What is packaging?

Packaging is like a Suitcase when you go Somewhere you put clothes in a Package

2. List all the different types of packaging things you know.

bay, Paper, gerensle, books, Clothing, totor, carring, Chains, toys, hershesy, Shoes, Christmas, gift, Cheese, groceries, food bags, Plastic bags, tissues, Paper, Rose, Pizza

3. Study the items on your desk. Write what you notice about them.
a) Object name bags and draw it.

This bag has a handle. The handle is in the middle of the bag

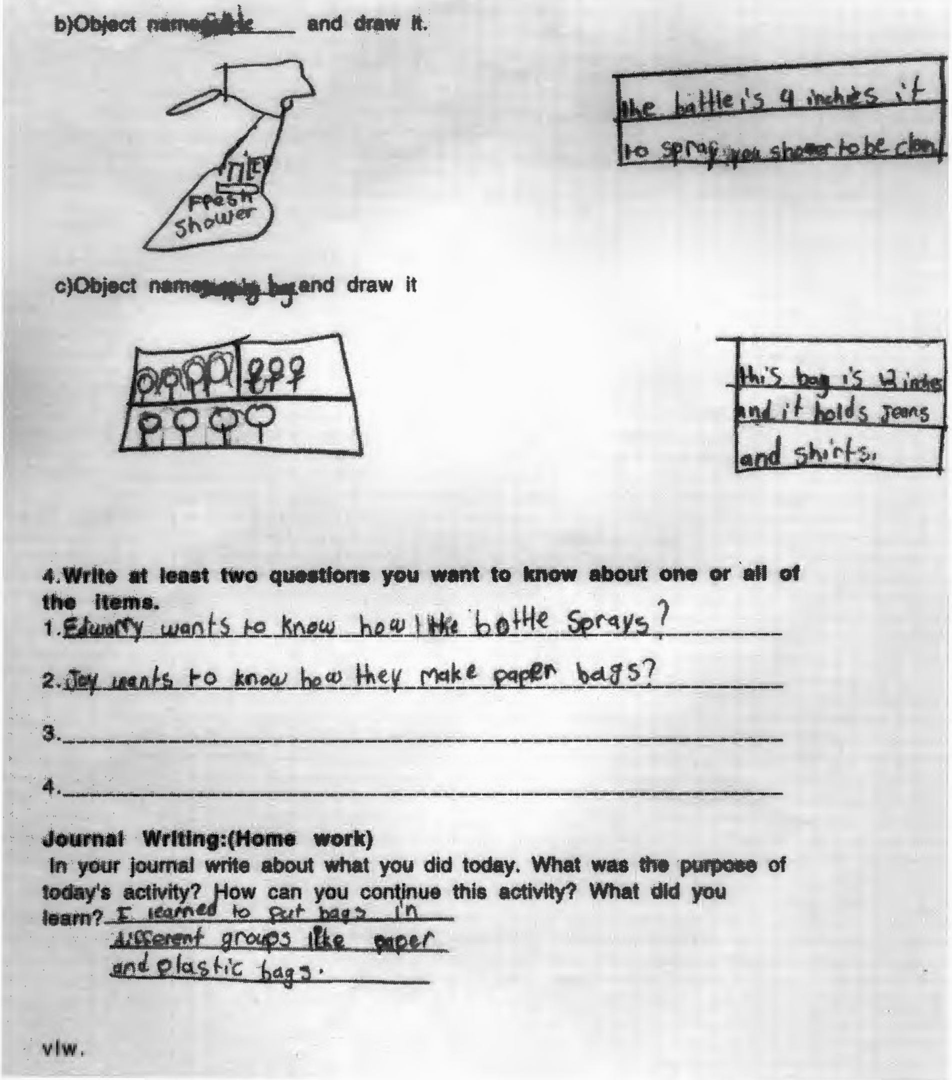
When asked why "food" was given as a package type, several students said that it belongs because food is bought in different wrappings. Even though they listed many items found in cans and boxes, they did not seem to associate these as types of packages.

I then asked the whole class, "From this activity, did we learn what packaging is?" Some of the answers were:

JUAN:
Yes. Packaging is when you put a lot of stuff in a bag, then put it in a carriage.

MARADIS:
Packaging is when you go to the store and you buy things, then put them in a bag.

4-12: **Investigating packaging**


b)Object name______ and draw it.

Fresh Shower

the battle i's 4 inches it to spray you shower to be clen

c)Object name and draw it

this bag i's 12 inches and it holds jeans and shirts.

4. Write at least two questions you want to know about one or all of the items.

1. Edwardy wants to know how the bottle Sprays?

2. Joy wants to know how they make paper bags?

3. ______

4. ______

Journal Writing:(Home work)

In your journal write about what you did today. What was the purpose of today's activity? How can you continue this activity? What did you learn? I learned to put bags in different groups like paper and plastic bags.

vlw.

MICHAEL:

Packaging is when you tell us to pack up.

JENNIFER:

Packaging is when you pack for yourself and someone else.

After gathering this information, I realized many of the groups still thought packaging was putting things in a bag. I wanted them to understand packaging as a type of container or holder of things. Some understood this and said packaging was a bag for something from a store, especially groceries or clothes. However, they only saw packaging in terms of bags, although I had distributed other types of packages, such as bottles, cartons, and boxes.

Verona asked her students what additional questions about packaging had come up in the groups. For homework, she asked them to make a journal entry about the activity. (See Figure 4-12.) However, Verona felt that some of the children had missed the point of the activity.

I assigned this activity to assess the students' comprehension of what they had done, and to find out whether or not they understood the concept of packaging. One group wrote the following:

We measured things. We put things in the box and bag... We draw it nice and neat.

They were not clear about the purpose of the activity nor did they seem to have a concrete understanding of packaging.

I had also asked the students to bring in packages, bags, boxes, or anything else they thought was a package. This was another way of informally assessing what their concept of packaging was. The students brought in bags only; no one brought in bottles or boxes. Based on this, I decided to narrow the investigations to paper and plastic bags.

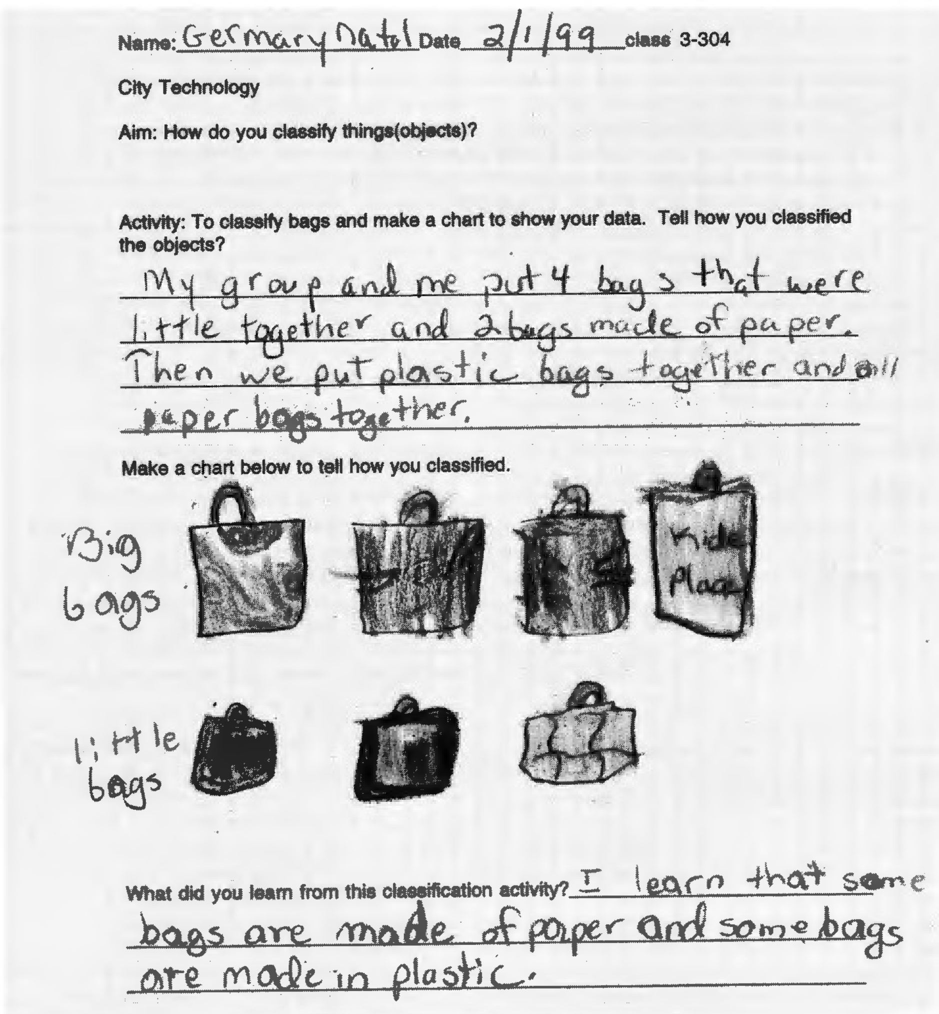
4-13: **Jennifer looks for similarities and differences among the bags.**

Classifying Things

Verona decided to have her students classify bags. She felt that this activity would help them develop the concept of a category, reinforce some math skills, and also help them focus on the aspect of packaging that seemed most familiar to them. First, however, she felt that they needed to learn what it means to classify. To develop this concept, she called to the front of the room a group of students who were all wearing the same colors. The students who were still sitting had to guess what all the students in front had in common. She then repeated this game with some other characteristics, such as students wearing uniforms, female students, and tall students.

Once they were able to see what categories are, Verona went on to the bag activity. She gave each group a variety of bags, and asked them to think about the things about them that make them similar or different. They were to explain the basis for their categories on worksheets, and also construct charts showing how many bags were in each category. For Verona, this activity offered a rich opportunity to assess children's thinking:

4-14: **Germary finds paper and plastic bags as well as big and little bags.**



Name: Germary Natal Date 2/1/99 class 3-304

City Technology

Aim: How do you classify things(objects)?

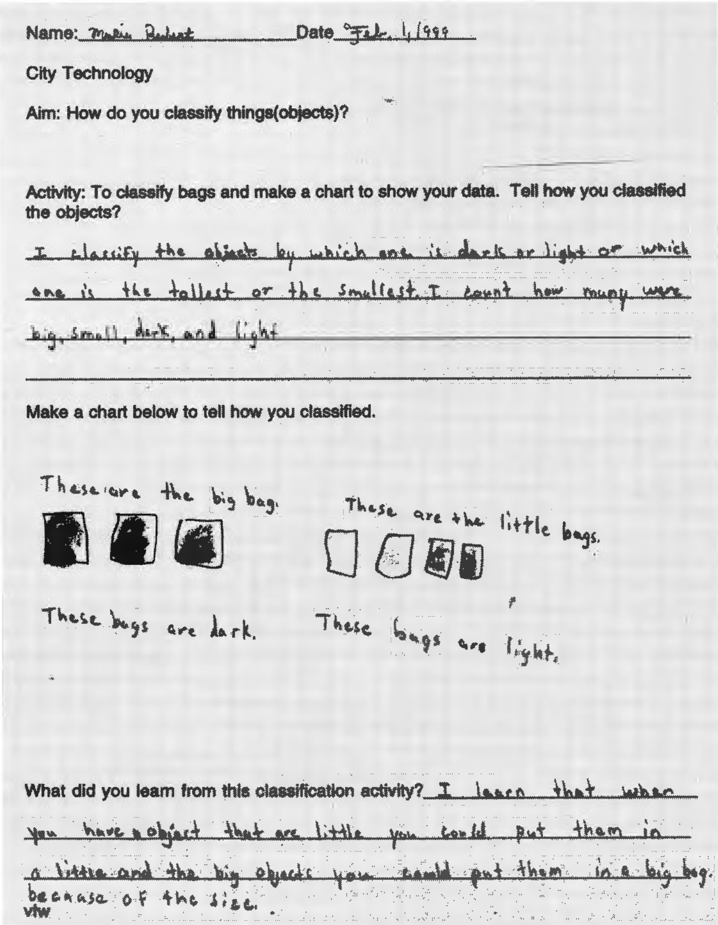
Activity: To classify bags and make a chart to show your data. Tell how you classified the objects?

My group and me put 4 bags that were little together and 2 bags made of paper. Then we put plastic bags together and all paper bags together.

Make a chart below to tell how you classified.

What did you learn from this classification activity? I learn that some bags are made of paper and some bags are made in plastic.

4-15: **Maria's bags are dark and big or light and small.**



Name: [illegible] Date Feb. 1, 1999

City Technology

Aim: How do you classify things(objects)?

Activity: To classify bags and make a chart to show your data. Tell how you classified the objects?

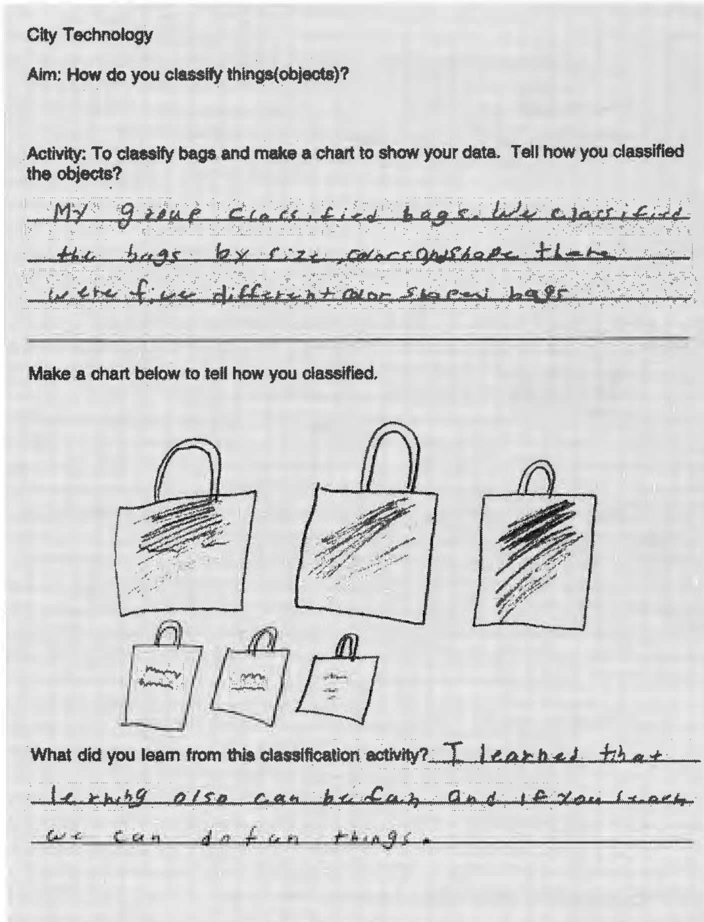
I classify the objects by which one is dark or light or which one is the tallest or the smallest. I count how many were big, small, dark, and light

Make a chart below to tell how you classified.

What did you learn from this classification activity? I learn that when you have a object that are little you could put them in a little and the big objects you could put them in a big bag. because of the size.

vtw

4-16: **Fun with bags**



City Technology

Aim: How do you classify things(objects)?

Activity: To classify bags and make a chart to show your data. Tell how you classified the objects?

My group classified bags. We classified the bags by size, color and shape. there were five different color shaped bags

Make a chart below to tell how you classified.

What did you learn from this classification activity? I learned that learning also can be fun and if you learn we can do fun things.

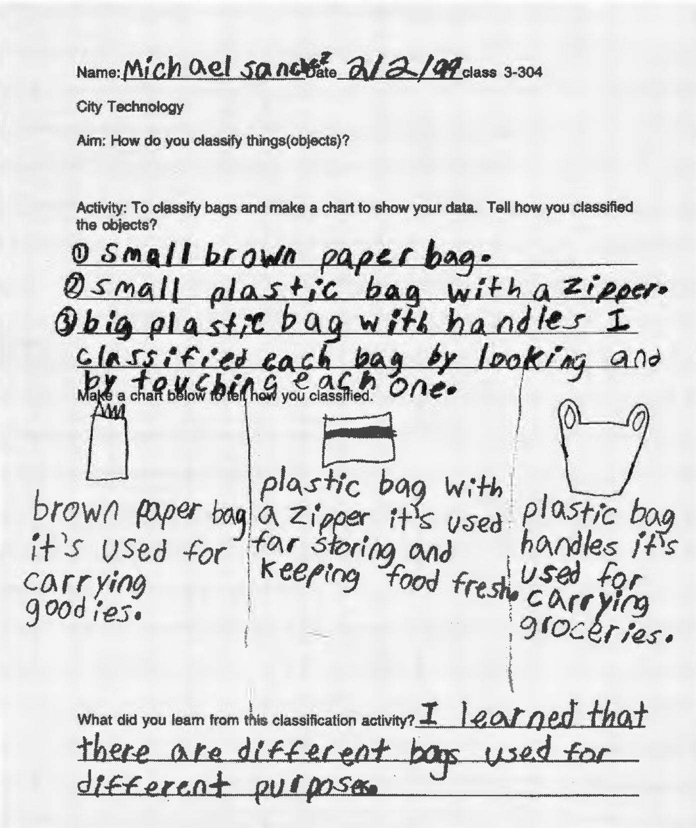
Each student had his or her own handout on which to record the data. Several students simply drew their bags, rather than create a chart, as I had requested. Germary struggles with writing and she has a hard time trying to express herself. She first describes two unrelated classifications: "little" and "paper." Then she says her group had grouped the bags according to whether they were plastic or paper. Her chart shows "big bags" and "little bags." Then at the end of her statement she again referrs to paper and plastic. She was not clear as to how the size categories and the paper-or-plastic categories are related. (See Figure 4-14).

Maria listed the categories of dark or light and big or small, but did not distinguish between these two ways of categorizing. (See Figure 4-15.) One student classified her bags by size, color, and shape. However, the only information she could convey in her chart was the relative sizes of the bags. (See Figure 4-16.)

Michael gave detailed descriptions of the different bags he had, but neglected to sort them into categories. He discussed how different bags are used for different purposes, but did not explain how he had learned these facts. (See Figure 4-17.)

Siara classified by color but gave no details about the process she used. The data on her graph was incorrect. I spoke with her about the numbers and she realized that her group had never had that many bags. At least she was aware that a graph would be an easy way to represent one type of variable, such as color. (See Figure 4-18.)

4-17: **Michael decides what bags are used for.**


Name: Michael Sanchez Date 2/2/99 class 3-304

City Technology

Aim: How do you classify things(objects)?

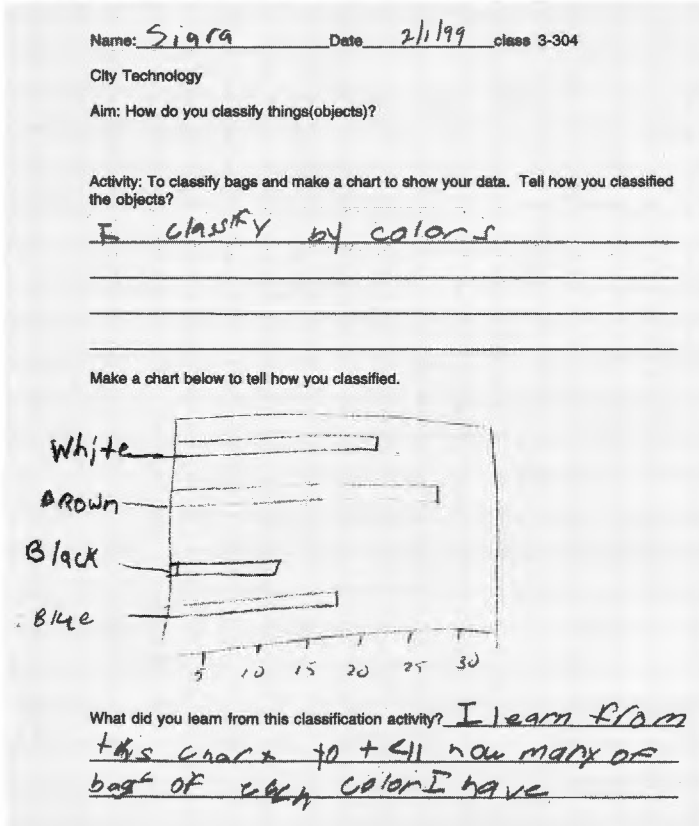
Activity: To classify bags and make a chart to show your data. Tell how you classified the objects?

① small brown paper bag.
② small plastic bag with a zipper.
③ big plastic bag with handles I classified each bag by looking and by touching each one.

Make a chart below to tell how you classified.

What did you learn from this classification activity? I learned that there are different bags used for different purposes.

4-18: **Siara graphs according to color.**


Name: Siara Date 2/1/99 class 3-304

City Technology

Aim: How do you classify things(objects)?

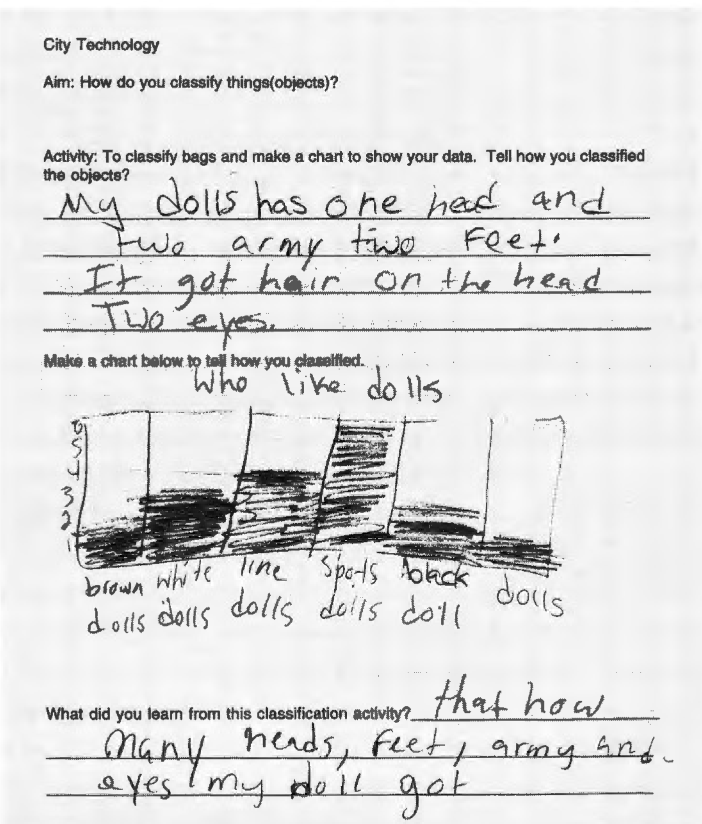
Activity: To classify bags and make a chart to show your data. Tell how you classified the objects?

I classify by colors

Make a chart below to tell how you classified.

What did you learn from this classification activity? I learn from this chart to tell how many of bags of each color I have.

4-19: **Kamina classifies dolls instead of bags**


City Technology

Aim: How do you classify things(objects)?

Activity: To classify bags and make a chart to show your data. Tell how you classified the objects?

My dolls has one head and two army two Feet. It got hair on the head Two eyes.

Make a chart below to tell how you classified.

What did you learn from this classification activity? that how many heads, feet, army and eyes my doll got

Kamina's data had nothing to do with the bag activity. When I asked her where she had gotten her information, she said she had decided to graph the dolls she has at home. (See Figure 4-19.)

In her reflections on this activity, Verona felt that the students had been successful in grasping the concept of categorization, but were not clear about how to represent their data. She felt that this activity could serve as an excellent lead-in to making charts and graphs of data:

> **The students learned the various ways to classify—by color, size, shape, and material. Some of them tried to represent their findings by drawing, charting, or graphing. However, these were first-time efforts. Combining this activity with math lessons about charts, graphs, and quantifying information would provide a frame of reference.**

In reflecting on the design of the activity, Verona felt that the handouts should have been completed by groups rather than by individual students. Individual classifying activities could have followed once students had worked on classifying within groups:

The students realized that discussing their findings as a group, and using one data sheet per group, would have been more productive. They saw how well teamwork had worked in the lesson on defining "packaging." Immediate team feedback and consensus had occurred when each group had only one handout for recording and representing their data. An individual classifying activity would work better afterwards, allowing students to pursue their own interests.

Verona was intrigued by the variety of categories the students used. In retrospect, she felt that she should have focused on the different ways of classifying. Although Verona saw room for improvement in what she had done, it was clear that the study of bags had engaged her students' imaginations.

Several weeks later, the class revisited their investigation of bags. Verona asked her students to study the physical properties of their bags, and come up with some questions they would like to explore further. Maria came up not only with a question, but also with some hypotheses.

Maria was the only student who had written in her journal. She began by asking the question, "How do you test a bag?" She then answered it: "I will test my bag by putting a lot of hard rocks to see if it breaks easily. Also I could say that the bag that has a plastic handle could last longer than the one that has the paper handle."

Maria's question became one for the whole class. They decided that they would test the strengths of their bags. Because no rocks were available, they decided to use books. A question arose about whether the books for testing one bag had to be the same as those used for the others. Verona put this question to the class.

I asked, "Why would you use one type of weight to test the strength of the bags?" Maria said, "... so we could use the same books with all the bags to see which one was the strongest bag. If two bags were the same size and had handles, we should keep the weights the same to really see if one is stronger than the other."

Without using words like "fair test" and "control of variables," Maria had grasped these concepts in the context of a question that was meaningful to her. Her intellectual engagement in this activity continued as they actually tested the bags. In reporting the test results, Maria offered her own explanations of what had happened:

Paper bag: The bag had a handle. We will use big red books. I think we will put 6 books in the paper bag to see if it break. The 6 books that we put broke the bag on the front. The paper bag did not hold 6 big books because the bag was made out of paper and paper is easy to break.

Plastic bag: If you put 5 or 6 or 4 books it will break because when you carry it and there are a lot of books the handles become slippery from your hands because it is too much book. The plastic bag could hold 2, 1 or 3 books. The heavy book strains the bag.

Although Verona felt that this unit had stretched her students' imaginations, she also saw that they needed more help in recording and organizing their data. She added that there should have been more analysis of how the bags had failed.

A closer look at where and why the bags ripped may assist the students in looking at the function of particular bags. Are they doing the job they were designed to do? Are there other ways to test their function? An extended activity would then be to design a more appropriate bag.

Investigating Fruit and Cushioning

by Roslyn Odinga

Roslyn Odinga is a science cluster teacher at Community Elementary School 126, a large school in the South Bronx, New York City. Her schedule requires her to meet with 25 different classes during the week for 45 minutes each. The classes range from second to fifth grade. Sometimes, due to tests or special programs, some of these meetings are missed, and she does not see the same group for two or three weeks in a row. Under these circumstances, Roslyn finds it very difficult to maintain the continuity of a long-term project, or even to complete a meaningful activity in a 45-minute time slot.

Roslyn decided to implement extended packaging units with two of her classes. Her second-graders looked at natural packaging, and her fourth-graders explored cushioning.

Natural Packaging

Roslyn began with a simple idea: explore the "natural packages" that surround most kinds of fruit. When she started this project, she had little idea of the other connections her second-graders would make.

April 14
I asked the children what packages are and when something is a package. I introduced them to different types of packaging, e.g., packaged cereal, rice, ketchup, beverages, and gift-wrapped boxes. (See Figure 4-20.)
I asked: "What happens when you go to the produce area of the supermarket to purchase fruit? Is it packaged or contained in something?"

4-20: **Various types of packaging**

I introduced the idea that some things we purchase are naturally packaged—i.e., the packages are not made by humans. I showed the children examples of fresh fruit. They examined oranges, apples, grapes, bananas, mangoes, kiwi fruits, a cantaloupe, and a coconut. I had them pay special attention to the covering of each of these fruits. The students were very excited about actually working with fruits. I got a lot of positive responses as to what natural packaging is. We talked about our bodies and how they are actually packaged by the skin.

April 21
I decided I had to take them on a field trip to the supermarket. We went to the produce section and saw all the different types of fruits and realized that fruits don't necessarily come in bags. Jiovanni and Jennifer M. were unaware of certain types of fruit. Kiwi and cantaloupe were complete mysteries to them.

I also noticed that the children had no sense of prices. They were amazed that apples were 99 cents a pound. Then we got into a discussion of what a pound is. We used the scale to determine how many pounds of each fruit we had. Another question was, "If they sell five oranges for $1.00, how much would each one be?" The students really enjoyed their trip.

4-21: **Classifying fruit by texture**

HOW DO I FEEL?

Directions: Write the names of different fruits in each box. Put a check in the correct column if the covering of the fruit is Smooth or Rough.

Name of Fruit	Smooth	Rough	Other
mungoe	✓		
strawber		✓	
Banana	✓		
Kiwi		✓	hairy
Apple	✓		
pear	✓		

It is remarkable how much we take for granted about children! One of the striking features of "real-world" activities, such as going to the supermarket and looking at fruit, is how they expose aspects of children's understanding that are rarely touched by traditional instruction. Roslyn's next activity was similar, in that it required her students to come up with their own vocabulary for describing textures.

April 28
Students examined fruit samples, paying special attention to the textures of the skins. I got answers like "smooth," "rough," "bumpy" and "hairy." (See Figure 4-21.)

We discussed how packaging protects fruits. I cut the fruits so that the students could observe the differences between the outsides and the insides. They were noticing colors, and also seeing that under the skin is the actual fruit. We then went further, and classified by whether the skins are edible or inedible.

There also turned out to be a big discussion about coconuts. How do coconut trees grow, since coconuts don't have any seeds? We found out that when a young coconut falls from the tree, it's still green, and is planted. So, my students came to the conclusion that a coconut is actually a seed. I could not dispute them! I was really amazed by their intellect.

May 18
Today is Fruit Salad Day. It's like a party. We talk while I make the fruit salad. Some children taste fruits they've never tasted before. "No coconut!" they shouted in unison. They didn't want to eat that giant seed, plus they were afraid it would get in their teeth. I was also questioned as to why a banana will get brown so fast. This is going to lead us into another type of inquiry...

Which Type of Cushioning Is Best for an Egg?

Roslyn conducted a different kind of packaging unit with a fourth-grade group. Because they were older, she wanted them to do a controlled experiment and collect and present quantitative data. This activity also involved some design, because the cushioning materials and their arrangement were not specified. As with "Natural Packaging," the students took this activity much further than Roslyn had anticipated.

Day 1
I showed the students a dozen eggs and demonstrated how they were packaged in a carton with an individual compartment for each egg. Pretending to do it by accident, I dropped the carton of eggs on the floor and of course several broke. I once again showed the students the carton and asked them how the eggs could be packaged more effectively. I then presented students with the challenge:

"Package an egg so that it won't break when dropped from different heights."

I let them preview the materials that we were going to work with. These included foam rubber, Styrofoam, newspaper, bubble envelopes, egg cartons, Styrofoam peanuts, Enviro-bubble (a brand of bubble wrap), cloth, towels, masking tape, packaging tape, paper, pencils, markers, journals, and small milk containers.

Of course I expected some feedback, because I want them to have a VOICE. They were upset about having to work with the small milk containers, which they said were too small. Theodore pointed out that when you buy a carton of eggs at the supermarket, of course the packaging is larger. They just section off spaces for the eggs! I couldn't dispute that fact, so we changed the size of the packaging. I allowed them to use shoeboxes, which were 8" x 10", and whatever else they could bring in from home.

Roslyn recognized the need to open up the materials list to include anything the students could find. In this way, she encouraged them to be resourceful in solving a technology problem: What would make good cushioning material? She also gave them a greater stake in the project by turning a piece of the problem over to them.

The students also looked closely at conventional cushioning supplies, such as Styrofoam peanuts and bubble wrap, which they referred to by its brand name, "Enviro-bubble." They became involved in figuring out what these materials are made of and how they are made. Focusing on these common artifacts strongly stimulated their curiosity.

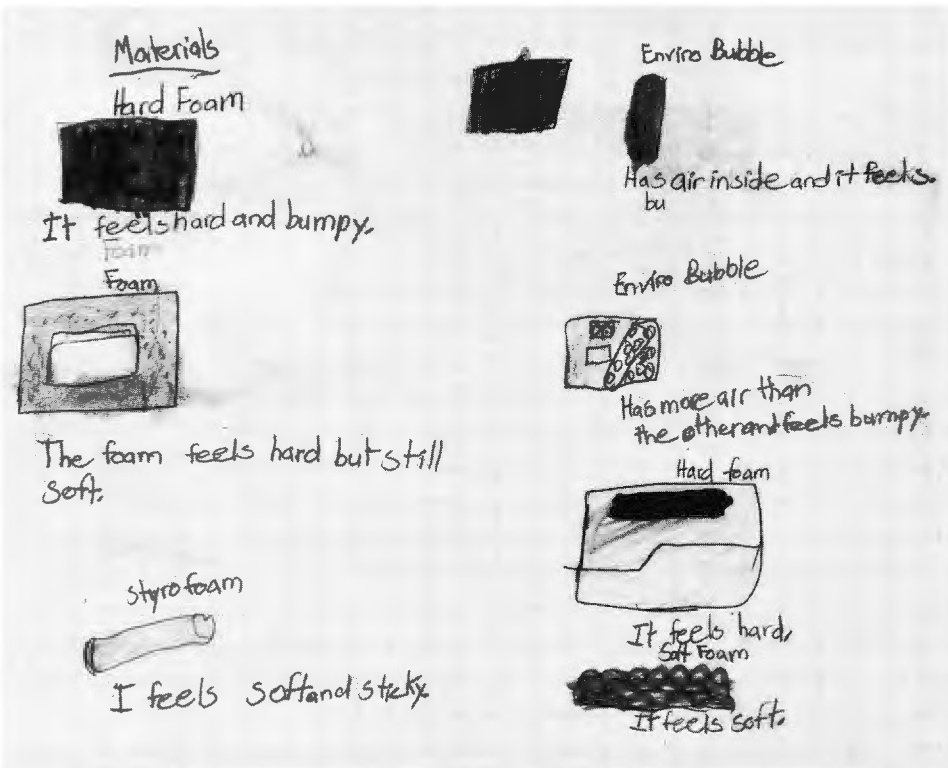
Day 2
I asked them to write down their observations about different kinds of cushioning material. After students examined all the materials, there was a discussion to determine a name for each item. Donald took it upon himself to name the two types of foam (foam rubber and Styrofoam): "soft" and "hard." With the Styrofoam peanuts, he had a little problem. He said that although they looked like foam, they had a different type of feel to them. (See Figure 4-22.)

"Enviro-bubble"—that's the phrase of the day. "Enviro-bubble this! Enviro-bubble that!" There were a lot of questions as to how they get the air inside of the bubbles. Is it processed in a certain type of machine that has allotted spaces for air? Or, is it blown up and then pressed down, which allows the air to stay in specified places? I LOVE THESE TYPES OF QUESTIONS. Now they have research to do!

Day 3
Although the students had worked in groups to do their initial observations, they decided to work individually on the actual packages. The students first tried packaging their eggs individually using shoeboxes and other types of material such as aluminum foil, Pampers, swatches of clothes, cotton balls, Styrofoam, etc.

They then tested their packages by having them dropped from a designated height. We then opened the boxes and talked about the types of packaging that were used.

4-22: **Donald describes the cushioning materials**




4-23: **Theodore with his egg-cushioning box**

Theodore's egg broke, because he failed to tape down the top of his box. (See Figure 4-23.) Grace's egg was wrapped in aluminum foil, with an underlayer consisting of a wad of paper towels. It also broke. The other drops were all successful.

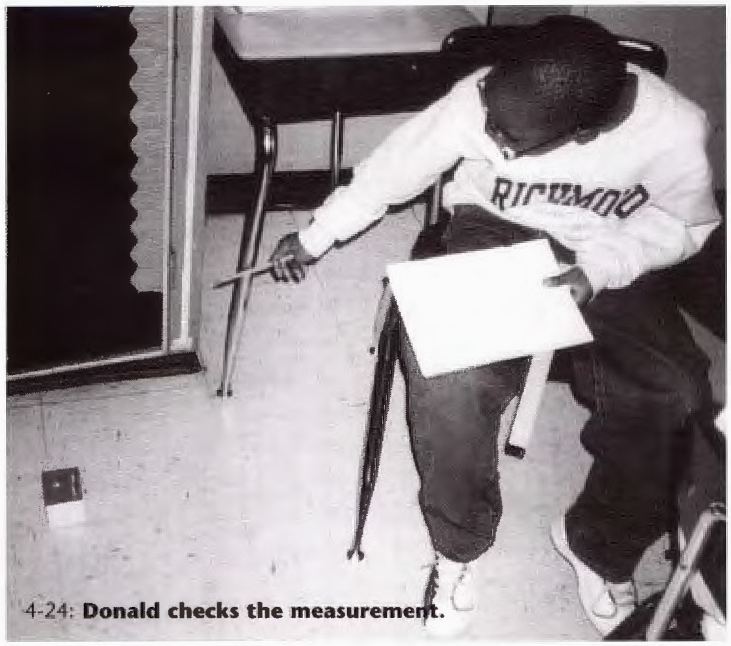
Day 4

After the preliminary work with shoeboxes, I could see they were now ready to go on to the formal challenge. Each child was to package the eggs in three small milk cartons, in any way he or she wanted, and compare the results:

- Carton #1 was used for Styrofoam peanuts;
- Carton #2 had newspaper; and
- Carton #3 contained Enviro-bubble.

Basically all of the cartons with peanuts were packaged the same way: peanuts on the bottom, egg in the middle, and peanuts on top, with one or two peanuts on the sides. Carton #2 (newspaper) was a little more interesting. One had newspaper on the bottom, egg in the middle, and newspaper on the sides and top. Patrice wrapped her egg first in about one-and-a-half sheets of newspaper. Then she cut newspaper squares and put some in the bottom of the carton. She put her egg in the middle and then squished a little newspaper on top. For Carton #3 (Enviro-bubble), Patrice used the same process as she had used for newspaper. Theodore once again neglected to tape his top, so his packaging wasn't successful. Donald layered his: Enviro-bubble on the bottom, egg in the middle, Enviro-bubble on the top and sides. We were then ready for the actual testing.

Day 5
We started testing by dropping the eggs from 50 cm., first testing Carton #1 to see if there would be any damage. (See Figure 4-24.). At each try we increased the height of the drop by 25 cm. The largest drop was 150 cm. We followed the same process with Cartons #2 and #3. (See Figure 4-25.) The students found the Enviro-bubble to be the best packaging material for the egg. They seemed to feel that the air pockets provided greater protection.



4-24: **Donald checks the measurement.**

4-25: **Data from the egg-drop tests**

Name	Height	Type of material	Condition of Egg
Pat	150cm.	peanuts	
Donald	150cm.	peanuts	
Theodore	150cm	peanuts	
Angeridno	75cm	peanuts	
Pat	150cm	Bubble	
Donald	75cm	Bubble	
Theordore	150cm	Bubble	
Angeritho	150cm	Bubble	
Pat	150cm	Newspaper	
Donald	150cm	Newspaper	
Theordore	75cm	Newspaper	
Angeridno	0cm	Newspaper	Couldn't find

Roslyn was very pleased with this unit, which had engaged her students in both a design activity and a controlled experiment. The chart in Figure 4-25 presents the data in a novel way. However, Roslyn felt that it was unreasonable to try to cut up this type of project into 45-minute periods. She resolved to do something about her schedule.

I decided to speak to the principal about extending the science period for next year. I figured that if the classes had a double period with me, and went in clusters (e.g., rotating through the science room for eight-week stretches), they would learn more. As an alternative, I suggested that I could teach one period alone, allowing the regular teacher his or her prep, and then we could co-teach during the next period.

The only response I got was that either plan would be impossible. Our principal will be leaving in June; maybe the new principal will be amenable to the idea. I will try again.

Fifth-Graders Test Bags

by Minerva Rivera

Minerva Rivera taught the only fifth-grade class at Harbor Academy, a small alternative school in East Harlem, New York City. Minerva was a second-year teacher, without much experience in teaching inquiry science. She wanted her students to develop their own systematic investigations of how different types of bags compare. In her reflections, she discusses how these activities contributed to her own thinking about science teaching.

Many of Minerva's concerns centered around the social development of her students, and their ability to work in groups. At the same time, she wanted them to expand their curiosity about the world around them, and develop ways of answering their own questions. It was in this spirit that she conducted her unit on bags.

Day 1

The students worked in groups of four for approximately 45 minutes. The following materials were provided to each group: lab paper, pencil, plastic and paper bags, rulers, tape measures, construction paper, and markers.

I asked each group to examine their bags for differences as well as similarities in both construction and function. I encouraged them to write down any questions that might come up during the course of their investigation. They were also required to think of some ways to test a few of the qualities they listed on their lab sheets.

Much time was spent in getting the students to discuss what they saw and to describe it in written form. Many students felt that writing their observations was the hardest part. I sat down next to a few students and helped them focus by asking a few questions:

MS. R:
What are some of the similarities that you've noted so far on your paper?

BIANCA:
Well, they all have handles (meaning the plastic bags). And they all made of plastic.

MS. R:
What else do you notice about them?

LATAURA:
The bottom of the bags is the same.

MS. R:
What do you see?

LATAURA:
All the bottoms are sewed the same way. They look like they are sewed straight across.

JONATHAN:
But the handles are different. Some of them are on the sides this way (showing the length of the bag) and the others are this way (showing the width of the bag).

MS. R:
Why do you think that they are made that way?

JANNE:
Maybe it helps the bag be stronger.

MS. R:
What can you do to test this? See if you can find things in this room that will help you do this.

I left that group and went around the room and did the same thing with the other groups. I asked a few questions to get some groups started while other groups were way ahead and had started devising ways of testing the bags. They tried to load as many books as they could into the bags to see if the bags could hold that much weight.

A few of the students did not want to work on the project at all and it took my constant prodding to get them to continue. Since it was difficult to get the whole class motivated to do this project, I decided that it would be better to have three groups working on the packaging project as opposed to the six that I had now.

The other thing I noticed is that the majority of the students had a VERY hard time with the lab sheet I devised. I wound up having to explain the sheet three times to the class and several more times to individual students. This sheet definitely needs to be modified. The students need to get the vocabulary (i.e., "procedure," "materials," etc.), but I need to put the information into simpler terms. Instead of just using the word "Procedure" I could use this instead: "Procedures: the steps you followed in doing the investigation..."; instead of "Materials," "Materials: the items you used in the investigation..." and so on.

Minerva recognized some of the problems with this lesson and corrected them the next day. She was able to divide her class in two. Those children who were interested in the project continued to work with her on packaging, while the other students worked with another teacher. She also provided clearer instructions about how they were to document their work. At the same time, she still left most of the thinking and planning to her students.

She was able to make some of these changes because of the flexibility in scheduling and use of space afforded by a small school. Minerva could allow her students to work in the hallway and use the bathroom as a resource for their investigation.

Day 2

I started out by letting the class know that they were to be split into two groups. I put those who were somewhat enthusiastic the last time into the group that would be working with bags again. Those who had not really been interested stayed in the classroom with Ms. K while I worked out in the hall with the packaging group.

I put up a very simple paper that requested that they look at the similarities and differences among the bags. I asked that they also come up with a way to test the bags that would be slightly different from what they had used the last time. I did not specify what aspect of the bags I wanted them to test because I wanted to leave that to the children. I felt that if I gave them enough time, they would be able to find a variety of things to evaluate.

Sure enough, the first group came up with the idea of testing the strength of paper shopping bags after they get wet. It was so enjoyable to watch these students get all excited about working on this project. These particular students ran to the bathroom with the paper bags. Once they got there, I asked them what they were going to use to measure the amount of water they were to add to the bags.

MS. R:
What kind of measuring tools are you going to use in order to collect your data?

JANNE:
We could use one of those measuring cups in the classroom!

JONATHAN:
Yeah and we could use the baseball to see if the water messes up the bag!

MS. R:
What do you mean by that?

JONATHAN:
I mean that we could use the baseball you have in the classroom to put it inside of the bag to see if it'll make them break.

ALISHA:
Well, I could count to see if the bag lasts long.

JONATHAN:
Okay, then I could pour the water and Janne can hold the bag.

These students found that the bags were not all the same when it came to withstanding the water test. The group spent about thirty minutes gathering their data. They poured a cup of water into the bags and then

saw how long it would take for the bag to start leaking. (See Figure 4-26.) They placed the ball in and waited to see if the bag could hold the weight. All of the bags broke easily except for a gift bag that had a cardboard-like piece on the bottom.

ALISHA:

Ms. Rivera, I think that this bag is better than the rest because of this cardboard. It is the thing that helps it hold the ball longer. That's why it took so long to break.

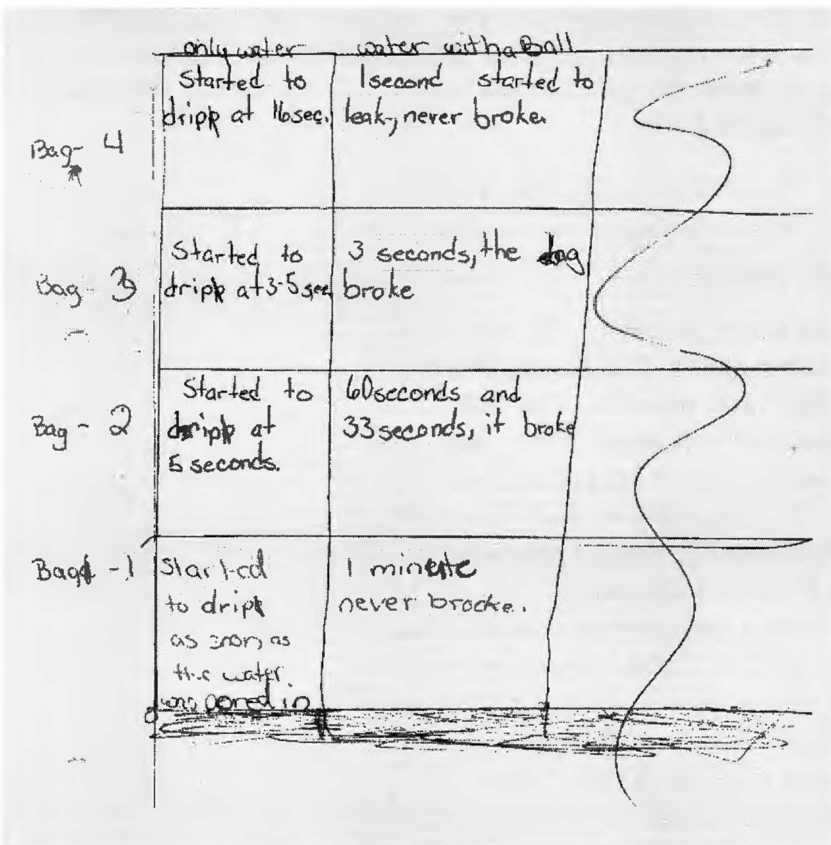
The students were able to work for about an hour and ten minutes without losing momentum. In fact, the groups were so into the work that Ms. K had to remind me that it was time for lunch.

The data from these water tests are shown in Figure 4-27. Another group tested bags using books, in much the same way that Verona's students did. (See page 105.) The third group was hampered by one student who tried to dominate. Minerva felt that the activity had gone well in general, but that she could have provided more direction.

I've learned several things doing this unit. I regret that I did not brainstorm more often. I have to find a better way of documenting the words of my students so that I can have more quotes from them. I am contemplating videotaping them, so that we could analyze the film as a class and have a chance to see what actually happened, as opposed to getting snips and pieces of whatever manages to be recorded. The children truly enjoyed this particular activity and have asked to do it again. I think that next time I would break the class into smaller groups so that the children would have more time to process and investigate without the added pressures of competing with one another.

4-26: **Putting water in a shopping bag**

4-27: **Bag water-test data**



	only water	water with a Ball
Bag-4	Started to dripk at 16sec.	1second started to leak, never broke.
Bag-3	Started to dripk at 3-5 sec.	3 seconds, the bag broke
Bag-2	Started to dripk at 5 seconds.	60seconds and 33seconds, it broke
Bag-1	Started to dripk as soon as the water was pored in	1 minete never brocke.

Which Pump Works Best?

by Christine Smith

Christine Smith was a science teacher in her second year of teaching, at I.S. 164, a middle school in Washington Heights, New York City. Christine came to the job with a very strong science background, but had serious problems with classroom management. She decided to implement a project on systematic testing of pump and spray dispensers. She felt this unit would both be fun for her sixth graders, and also give them experience in designing and carrying out controlled experiments. She met with this group three times a week, for one double period and two single periods.

Christine made a collection of pump and spray dispensers from the tops of cleaning fluid bottles, soap containers, lotion bottles, etc. She began the unit by distributing a spray pump and a lotion pump to each group and asking them to make and record their observations.

October 22 (double period)
I placed the students in groups of 4 or 5. They began the activity by observing the pumps they would later be testing. I gave each group two pumps in a plastic bag, a ruler, paper, and colored pencils. I asked them to observe the pumps and record their data through written notes and drawings. They were to use their five senses to gather data on such topics as size, color, material, and moving parts. Water was also available for them to test with.

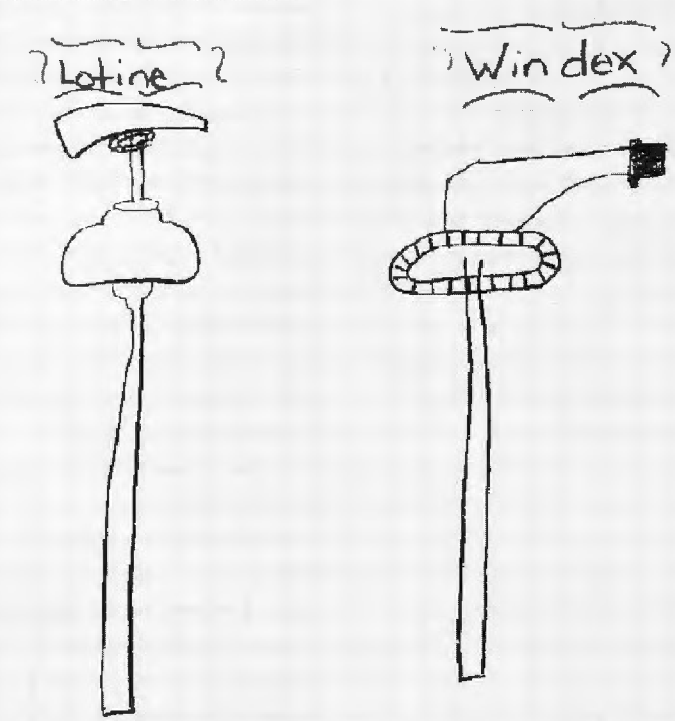
Maritza's drawings of her pumps are shown in Figure 4-28. She wrote the following:

The pump is white. The tube looks like if it's foggy inside. The shape is weird. The top looks like a duck's beak and then the bottom is long and thin. The pump sounds like it is very hard inside and you have to push it real hard. Also it sounds like if it got something inside of it that's stuck. The material is made of plastic. That is my choice because when it falls on the floor it doesn't break.

They are the same because they both throw water out. They are both made out of plastic, both of them have tubes that are clear, and you can see the water through.

They are different because one of them is bigger than the other, one throws water straight and the other throws it crooked, and one of them got yellow and white and the other is all white.

4-28: **Maritza's drawings of her pumps**



October 26

We discussed the results of the previous day's observations. I asked them to focus on several questions:

- **How are the spray pumps different from the "pump" pumps?**
- **How does each pump work?**
- **When do we use each kind of pump?**

These discussions went really well. The students, for the most part, made excellent observations of the pumps and generated some good thoughts on how the pumps worked:

- **Ernie noted that the pumps you push down on are good for thick liquids that you don't want to spray anywhere.**
- **Jennifer made the observation that the spray pump has adjustments for the spray, but the lotion pump cannot be changed in any way.**

The students were intrigued by these common devices, which they had never examined carefully before. They became aware of the resistance that makes the top hard to push down. They also saw the difference in viscosity between the liquids squirted by pump dispensers and those dispersed by spray dispensers. Christine felt that these preliminary observations and discussions served their purpose of preparing the students for designing product tests.

October 26

The focus of our discussion was: "What makes a good pump?" If you are given different liquids like milk, ketchup, laundry soap, water, and oil, how could you test the pumps to see which pump works best for which liquid? I wanted them to come up with different ways to measure the effectiveness of the pumps.

I was impressed with how quickly they were able to come up with different methods of testing the pumps, and with the validity of their ideas. The first idea came from Shirley, who thought the best way to measure a pump was by "how much the liquid came out." When I asked her how she would measure that, she said to put the pump in the liquid and measure how far away the liquid went when pumped or sprayed. The class decided to call this the "How Far?" Method.

We had just done an exercise on reading graduated cylinders, so it was no surprise when Suleyka came up with the idea of using a graduated cylinder to measure how much came out when the pump was pumped. This method got the name "How Much?"

After some more brainstorming, Kathy came up with the idea of measuring how fast the liquid came out. She suggested timing to see how long it took to get the liquid out of the pump.

I asked for any other suggestions, and Giancarlo suggested doing five strokes of the pump, and seeing if any came out. I let him test his idea, but the liquid just went up and down the tube, so then he revised his method: count how many strokes are needed until any liquid comes out. We called this method "How Fast?"

In the groups, the students were sharing their ideas with their peers as they tried to come up with experiment designs. This worked really well, and they produced high quality work. I think that giving each student their own sheet helped in the sharing process because they were all being held accountable for the work. How to make the tests "fair for each pump" was a frequent question and stumbling block.

The students had a surprising understanding of the pumps, and came up with these ideas relatively quickly with little help. Their methods were still missing a few key ideas that were needed to make them valid. However, I decided not to ask them about validity until they had written the procedures down.

Obviously, the students were very engaged in this activity and had a lot of their own questions about the pumps. Christine recognized their enthusiasm, and wanted them to come up with their own experimental designs. She hoped they would look at these designs critically and improve them, so that each would constitute a fair test. She also wanted them to develop their own strategies for organizing and presenting the data. Otherwise, they would simply be following someone else's instructions rather than learning these skills and concepts for themselves.

October 28
I asked each group to decide the method they wanted to use to test their pumps. Three groups picked "How Far?", two chose "How Much?", and the remaining group selected "How Fast?" Each student had to complete the preliminary work on a lab sheet, which asked them to state the problem, form hypotheses, submit a list of materials, write a step-by-step procedure and create a chart for recording their data. (See Figure 4-29.)

The "How Much?" group forgot to set a standard number of pump strokes for each trial. When I asked them how many times they were going to press each pump, Suleyka spoke up and said they needed to pick the same number for each one. Most of their data charts were really good. For the few that were a little confusing, I asked the students to put in a fake set of numbers. They were then able to come up with a better way of organizing data, once they had a "pretend" data set to work with.

October 29 (double period)
This was the initial test day. It was productive, but extremely chaotic. I underestimated the behavior problems in my class. The main problem was that I thought the other groups would be interested in watching the group that was testing, but I was wrong! In spite of this, the testing went really well. It was extremely messy, but that was to be expected, given the fact that we were spraying stuff around.

4-29: **Testing the pumps**

Pump Lab Sheet

State the Problem:
(What is it you are trying to find out)
how far each liquid goes

Hypothesis:
Which pump do you predict will be best for soap? Pump 1

for milk? Pump 1

for oil? Pump 1

for ketchup? Pump 2

for water? Pump 1

Materials:
What materials will you need?
Ruler, milk, oil, Ketchup, Water, two Pumps
News paper, Soap

Procedure:
How will you test the pumps? What steps will you follow for your test?
Put a straight line of numbers with the newspaper by centimeter test all the liquids with one Pump at a time. then do the same for the second pump. write all the information and put it in a Chart.

Observations:
Create a chart or table to record the data you collect during your experiment. (Please use the back if you need more space.)

	how far each liquid goes?	
	Pump 1	Pump 2
Soap	200 cm	40 cm
Oil	205 cm	38 cm
Ketchup	175 cm	21 cm
Water	91 cm	25 cm
Milk	110 cm	40 cm

I also underestimated how far those pumps could disperse liquids. Kids were fooling around a little with the pumps, but for the most part, they LOVED testing. By the end, however, the other groups became bored and rowdy waiting for their turns.

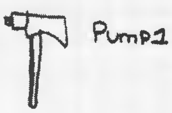
Rumaldo came up to me at the end of class and told me that the effectiveness of a pump depends on the width of the tube. He said that ketchup and laundry soap need a fat tube, but the width doesn't matter for water or milk.

Another interesting discovery had to do with ketchup, which is really hard to spray. The kids discovered that if you use the same pump to spray water first, and then put it right into the ketchup, it will work! When I asked them why this happens, one student thought the water makes the tube more slippery and the others thought the tube just needed to be cleaned out.

I did not see the "How Fast?" group's work, but their results were reasonable, and they had no difficulty doing the test. We ran out of time before the "How Much?" groups could test.

4-30: **Some conclusions from the "How Far?" tests**

Conclusion
Which pump was best for water? Draw a picture of the pump.



Why do you think so? What about that pump made it better for pumping water?

how the liquid got inside the plastic part and came out very far it came the distance of 91 centimeters and that the pump doesn't throw out big drops it throws out small amounts and it goes out very far.

What pump was best for pumping ketchup? Draw a picture of the pump.

Why do you think so? What about that pump made it better for pumping ketchup?

When you added some water it went very far it when 175 centimeters if we didn't put a little bit of water it would come out the pump when we squeeze it for the liquid.

What are some other things you learned from your experiment?

I learned that ketchup is part liquid and part Gel because ketchup is made of tomatoes and a tomatoe is made out of a plant and the plant needs water to grow. And I learned that pump1 is the best for all the liquids we did.

Christine was concerned about the classroom management issues. She hadn't provided enough to do for the groups that weren't testing at the moment, and the two "How Much?" groups hadn't tested yet. Also, she wanted the students who had already tested to summarize what they had done and draw conclusions. She made up a reflective assignment for them to do while the "How Much?" groups tested.

November 2
I came up with a "Conclusion" assignment for the groups who were done with the tests. (See Figure 4-30.) This also allowed me to work with the last two groups. I seated both "How Much?" groups together in a big rectangle with the test materials in the middle. I let them take turns testing while everyone recorded the common results. This worked much better and it was 100% calmer than it had been the day before.

November 5 (double period)
Next, I wanted the students to graph their data. I was surprised to learn that they had just finished graphing in their math class, so they already knew how to use a bar graph to organize their data. We went over a few different ways to set up the axes, and how to define the categories for the graph, but this was really the simplest part of the project. They broke into groups and created their graphs on chart paper. They were excited to have big paper and scented markers. I had a few students who did not work well in groups, so eventually I just gave them paper and let them create their own graphs.

November 6

I wanted the groups to present their results to the class using their graphs. I felt that they should be able to explain which pump worked best for each liquid, using supporting evidence from their test data. I hoped that the class as a whole would discuss why a given pump might have worked better. I also expected them to raise some further questions that had come up during the activity.

Unfortunately, there was a lot of talking while kids were trying to present. No one really offered any valuable comments until I took over at the end and started asking questions about the different graphs. One student did have a question.

RACHEL:

How could we decide which pump was best, since we got different results for each test?

The class decided that the spray pump was the best pump, but according to Ernie, sometimes we don't want the "best" pump—for example, in the case of ketchup. Some further questions that came up were:

- **Does the size of the tube make it work better?**
- **Would the lotion pumps work better for thick liquids if they had a bigger tube?**
- **Why did we have to put water through the spray pumps first to get the ketchup to go through?**
- **Are there other gadgets for liquids that we could compare with these pumps?**

The students reached some very insightful conclusions from this project. They recognized that a technology that is best for one application, such as spraying water, might not be best for another, such as dispensing ketchup. "Which is the best pump?" is a question that cannot be answered directly, because it depends on what the pump is to be used for. Their questions suggest that they were also beginning to grapple with the concept of viscosity ("thickness" of a liquid), and its relationship to the diameter of the tube.

November 9

I made up an evaluation sheet for the students to fill out. (See Figure 4-31.) The evaluations went well. Kids were able to find their group weaknesses and also the most positive parts of their work. In general, everyone gave themselves and their peers high grades. I was happy to see that most everyone enjoyed the project.

Christine also offered her own evaluation of the project. She felt that it had succeeded in its primary goal of giving her students an opportunity to design and conduct their own controlled experiments:

As crazy as this activity was at times, I would do it again because the students really walked away having learned a lot. It was an excellent way to reinforce scientific methods, because they were allowed to design their own experiments. It was a great way to introduce the idea of product testing to the class, and get them thinking about creating fair or valid experiments. They were also able to practice metric measurement skills, which we had been working on in class.

Even though I provided a great deal of guidance, the students had a definite sense of ownership of their work during this project. They took an idea, created an experiment, and collected a data set on their own. They used the skills they had been working on in math and science, but this time with their own data.

4-31: **Maritza's evaluation form**

Pump Lab Evaluation

A. On a scale of 1 to 10, What is your score? 10
Give two reasons why you deserve your score.

1. Because I coooperated with my group and behaved good with them

2. I did almost all the work.

B. List each group member and give them a score between 1 and 10.

1. Norman Reason for score: 5 because he was talking alot.

2. Cladutte Reason for score: 3 She didn't do alot of work and talked to much instead of paying attention

3. Manuel Reason for score: 10 because he helped alot with the group and always was paying attention

C. What did you enjoy about this project? That we got to do alot of things I liked it cause we played with water and ketchup, oil, milk, and soap I really liked this project cause it's alot of fun I hope we get to do it again

D. What could you have done differently on this project? I could of present it to the class we could of done different things with the group if they didn't talk so much with each other

Designing and Making Structures to Solve Classroom Problems

Both of the teachers featured in this section work in the upper elementary grades. These stories begin with a familiar classroom problem: lack of adequate storage space. In both cases, the students designed and built their own structures to solve this problem. Their primary material was cardboard from discarded packaging.

The Portable Storage System

by Sandra Skea

Sandra Skea teaches math at Mott Hall, a middle school for high-performing students in Washington Heights, New York City. Sandra wanted to involve her sixth-grade class in a structures project that would both solve a real problem, and also require them to use geometry and measurement in a practical context. A real problem had already presented itself. The class had created shoebox dioramas, as part of an extended math project. However, they had nowhere to store them. Worse yet, due to a shortage of space in the school, the same class met with Sandra in several different rooms during the course of a week, and they needed access to these dioramas at each location. How could they both store them and also transport them reliably? Sandra explains what they did.

Getting Started

Students of Class 604 were creating dioramas based on scenes from the play "The Phantom Tollbooth." Clean-up time was especially difficult, for classroom storage space was severely limited and student lockers were already packed to capacity. The problem was complicated by the fact that we use several different rooms during the week.

Together, the class and I decided that if we were to continue a project-based exploration of mathematics, we would need to find an effective solution for our storage problem. We also realized that our solution must be a portable one in order to satisfy the constraints of moving from room to room.

Our goal became exploring how to build portable storage systems that would meet our requirements. We explored the problem and brainstormed options. We discussed storage units in general, and the classroom and school constraints in particular. We also used this time to conduct a scavenger hunt to search for materials for use in the construction of these systems.

After experimenting with the materials and with design possibilities the students developed criteria for the system. The criteria included the following:

- The system must be free standing and portable.
- The system must hold and support 8-10 shoeboxes.
- Each compartment must be uniform in size, and be able to support a live load of one pound.
- Accurate measurements are to be taken and recorded, including length, height, width, girth (measured two ways), face diagonals and volume.
- Recyclable materials are to be used.

Sandra's class worked on this project for almost two months, devoting one-hour periods to it once or twice a week. Within the criteria listed above, most of the design decisions were up to the students. They were free to choose the recycled materials, design the geometry of the unit, add handles and/or doors, choose their own methods for attaching the parts, and develop their own methods for testing the design. Sandra also encouraged them to think about storage problems at home, and think about how similar storage units might solve them.

The students divided themselves up into groups of four or five to work on this project. Sandra required them to assign a specific job to each member of the group. Here is Sandra's description of the activities of the groups:

Design and Construction

Students talked freely during this activity. They engaged in sharing ideas, in questioning group decisions and in offering comments and suggestions. Students were allowed to circulate during the designing and building stages to ask other groups for tools and materials. Some questions and statements I overheard were:

Should we use inches or centimeters?

Which is better to use: masking tape or packing tape?

How can we make the shelves stronger?

Why are the shelves buckling? What can we do to fix it?

Where should we place the handles?

Are all shoeboxes the same size?

To make the box stronger, should we put tape on the edges?

Let's add a little space around each compartment so it will be easier for someone to pull out the dioramas.

Many of the design decisions and discoveries were interesting. Stephanie, Rosa, and Flor decided not to make a back for their box. Rosa said this would make the unit lighter and easier to carry. Flor added that it would also make it possible to see in from either the front or the back. (See Figure 4-32.)

Melida, Clarissa, Erica, and Alyssa recognized that students might use different-sized shoeboxes for their dioramas. How could they plan for that? (See Figure 4-33.)

4-32: **Stephanie, Rosa, and Flor decide their unit doesn't need a back.**

4-33: **Melida, Clarissa, Erica, and Alyssa examine shoeboxes of different sizes.**

I was very surprised to see how closely students monitored each other's contributions. The atmosphere was one of dedication to task. Fooling around or time off-task simply were not allowed.

Sandra believes very strongly in ongoing assessment of her students' work. She used an impressive array of assessment tools and techniques, so that she and her students could monitor the progress of the project on a very frequent basis. Her methods included daily sharing sessions at the end of each class, regular homework assignments related to the project, final group presentations to the class, peer assessment of the presentations, individual written reports, and a self-assessment of each student's work. Sandra's reflections on assessment can be found in Chapter 5.

The students were given time to share their work at the close of each session. Each group assessed their progress and made plans for the next day. Questions and comments that arose during these sessions included:

What will happen if we double the cardboard?

What is the best placement for the handle(s)?

Should flaps be added so things don't fall out?

We all took turns and accomplished a lot. We cooperated with each other nicely.

My group calculated the area of the shoebox to see how much cardboard we will need.

Today I was the timekeeper for my group. We took measurements and got a plan ready for tomorrow.

Some of the homework assignments given in relation to this project included:

- **Describe the plan you and your group developed to solve the storage problem of Class 604. Include the roles assigned to each member and how you decided the roles would be assigned.**
- **Describe ways in which your group could change the design of your portable storage unit to make it stronger.**
- **Describe and evaluate how well your group works as a whole.**
- **Describe how you might modify the design of your classroom portable storage system to create a structure that could be used to solve a storage problem unique to your household.**
- **Create a drawing of your portable storage system with all the dimensions labeled. Include length, height, width, girths, and face diagonals.**

In addition to the regular homework assignments, every student had to prepare a written report about the portable storage system. It had to include how the structure was built, the dimensions of the system, how it might be improved upon, and other possible uses for it. Here are some of the ideas they had about applications for similar storage units at home:

MELIDA:
I would use this box to sort out papers that I will need later in the year. It would be like a little file cabinet, only homemade. In certain spaces I will put my laptop, papers, coupons, and receipts. My schoolwork will be a lot neater. I will find everything quickly. My mother will not scream her wits out because I decided to be irresponsible.

JENNIFER:
I would use it to keep my CDs in order.

ERIKA:
Instead of making a shoebox holder, I would make a towel holder. The unit can be mounted on the wall in the bathroom.

ALYSSA:
Our storage unit would also be useful in my apartment. I would use it to hold my personal belongings, such as my lip balm, camera, diary, Walkman, and portable CD player. I would make a couple (of) changes though. I would add more shelves, make it bigger and paint it light blue.

CLARISSA:
At home, I would use it as a bookshelf, because my desk is a mess, it makes my room look dirty. It would be great to keep all my books in one place.

ROSA:
Using a box design like this in my house would definitely be a helpful and handy way for me to keep my things organized. I can put my toys neatly into each compartment. I can also use it to store my nicely folded clothes.

Each group also had to make an oral presentation, in which they explained and demonstrated their design and answered questions about it.

These final presentations included the showing of their storage system, a description of how the group designed and built it, a demonstration of the mathematics involved, an analysis of the strengths and weakness of the system, and proposals for how the structure could be modified for use at home. During the presentation and the discussion periods that followed, students shared ideas and asked questions, and offered comments. (See Figure 4-34.)

Questions included:

What are the handles made of?

How else can you use your system?

How strong is it really?

How many shoeboxes can it hold?

Show me how you measured the girth.

LUIS:
Why did you put the handle on the top instead of the sides?

JULIAN:
That way, things will not fall out, because when we carry it, the back will be the bottom.

Comments and suggestions included:

You need to reinforce the handle. It will not stand up to wear and tear.

The compartments are of different sizes; perhaps they should be uniform.

You need to strengthen the support system for the shelves.

You used too much tape.

4-34: **Storage unit with handles on top**

Omar described some of the changes he and his group made to their structure. The top of the unit was originally a trapezoid, but this design wasted space and caused the compartments to shift. (See Figure 4-35.)

4-35: **Omar explains how they changed their design.**

Rachel, Precious, and Daniella used two modules to build their unit. They said that if they made another structure, they would use less tape. They also discussed using other joining methods, noting that nails would not work. Rachel noted, "I tried them and they fell out." (See Figure 4-36.)

Sandra prepared a peer evaluation form for students to fill out during the group presentations. (See Figure 4-37.) These forms, which were anonymous, provided each group with their fellow students' assessments of how well they had presented.

Each student also had to evaluate his or her own participation in the project, including both group and individual work, on a self-evaluation form. (See Figure 4-38.)

Candice was very self-critical:

If my group and I had planned more carefully, and worked more diligently, our box could have been much better. We should have recorded our measurements so we would have known how many shoeboxes could have fit into the storage unit. My group didn't plan time carefully, so we ran out of it.

Perhaps the most authentic form of assessment of a design project asks about the design itself. Did it really solve the problem it was intended for? What do the users think of it? A few months after the conclusion of the project, Sandra wrote:

4-36: **Rachel, Daniella, and Precious present their storage unit.**

4-37: **Rating Guide for Group Presentations**

CITY COLEGE CURRICULUM GUIDES
98 Portfolios

The Portable Storage System

Rating Guide for Group Presentation

Directions:
Listen carefully as each group presents. Please do not interrupt the speakers. You will have time at the end of the presentation to ask questions or to make comments. Rate your classmates fairly by circling a number from 1 to5. A rating of I is low; the highest rating possible is 5. Please be sure to read the criteria carefully. Use the back of the rating sheet to record any additional comments or suggestions you have.

CRITERIA	RATING				
1. Students spoke clearly, and used complete sentences.	1	2	3	4	5
2. Measurements were taken and recorded accurately.	1	2	3	4	5
3. Students described how they built their structure.	1	2	3	4	5
4. Students explain how they could change the structure to make it stronger	1	2	3	4	5
5. Students suggested a way they could use the structure at home.	1	2	3	4	5
6. Every member of the group participated in the presentation.	1	2	3	4	5
7. The storage unit is free standing and portable.	1	2	3	4	5
8. The unit has 8-10 compartments capable of holding a shoebox	1	2	3	4	5
9. The storage unit is attractive.	1	2	3	4	5
10. The unit uses space efficiently	1	2	3	4	5

I was also delighted to discover that the storage system created by the students actually did solve our classroom storage problem. As a matter of fact these systems are still in use. At present, they house the materials for our next project.

Overall, Sandra was very pleased with the educational outcomes of this project. It served to develop some mathematics concepts in ways that traditional instruction does not.

I discovered the only real way to assist students in understanding some concepts is through a hands-on experience. Examples are the relationship between length, height, and width to volume, the relationship between girth and perimeter, and the process for measuring and calculating face diagonals

The study of geometry, rectangular prisms in particular, became accessible and real. Students who previously had difficulty calculating girth, volume, and face diagonals from two-dimensional drawings gained the confidence and the skill to do so with ease and accuracy. The understanding of girth, the two ways to measure it, and its relationship to perimeter, became clear as students used their own three-dimensional rectangular prisms for exploration of mathematics.

Building a rectangular prism also served to improve and extend the students' understanding of dimensions and of measurement. Growth also occurred in their ability to use and compare measurement tools. And it must be noted that attention to homework increased and test scores improved.

4-38: **Clarissa's self-evaluation**

CITY TECHNOLOGY CURRICULUM GUIDES

Student Self Evaluation

1. **The part of the project I enjoyed the most was** the finishing touches **because** the group really connected at that moment we worked together
2. **The hardest part of the project was** all the measuring parts **because** sometimes we would fight about who was right.
3. **I helped the project succeed by** cutting the cardboard almost at an exact length and bringing in materials.
4. **The math that helped me to enjoy and to understand this project was** Geometry, measurements of face diagnols and corners
5. **The written work I did related to this project was** a report about how to make it better, how would you use this at home. also note copying.
6. **The part I like writing about best was** the report and the drawings
7. **I can use what I learned from this lesson when I or if I** build a structure at home or other subject areas.
8. **On a scale from 1 to ten I rate this project a (an)** 9+.

Use this space to record any additional comments you would like to make.

I like doing this project. I think it help understand geometry and measurements.

I enjoyed working with my class who encourged me to do better.

I would'nt give this a 10 because it deserve a 9 1/2 because at some points they were tough decisions to make. And sometime it became very boring.. If it were not because of this I'd give it a 10 plus

Two students in particular became very excited about attending math class. Previously, they had contributed little to classroom discussion, rarely completed assignments and class work, and in general saw no reason for studying mathematics. Grades went up for both students.

Although Sandra's primary goals are in the area of mathematics, she saw some other benefits from this project as well. Her students had learned about the value of recycled materials, and had gained some experience in designing and constructing useful structures from them. They discovered that a group is greater than the sum of its parts, because they saw how group members could stimulate and reinforce one another's ideas. They also gained experience in both written and oral presentation. Perhaps most important, Sandra felt they had discovered that they had the power to improve their own environment.

Students explored how purpose affects the design of a structure. They learned how to locate and use recyclable materials in class projects.

They learned the advantage of staying on task and of sharing job responsibilities. Students discovered there are many ways to solve a problem and that brainstorming and the sharing of ideas can simplify the process.

Students also learned how to write clear, concise, and complete reports. The presentation component gave them the opportunity to develop and enhance their listening, speaking and questioning skills.

Students were also involved in an experience where they were in control. The activity was a project for investigation and exploration, not just another routine assignment. Mathematics and technology can be used creatively to solve problems. The students learned that they can have power over their surroundings.

Learning About Structures, Preparing for the Science Fair, and Solving a Storage Problem *by Michael Gatton*

Michael Gatton taught science to sixth- through eighth-grade students at I.S. 143 in Washington Heights, New York City. He was an experienced science teacher who was required to use some materials from Insights, a science curriculum package. He was also responsible for preparing his students for the district Science Fair.

Michael developed and implemented this unit after doing the "Structures" module from *Insights.* He involved his students in designing and building a badly needed storage unit for their book bags. In preparing for the design of this storage unit, each of his six groups did a controlled experiment that served as the basis for a Science Fair project. The results of three of these experiments provided data that the students used in their storage unit designs. As a whole, this project offers a model for integrating scientific analysis with technological design. Michael's story begins with the logistics of his sixth-grade class, his selection of material, and the requirements of the sixth-grade science curriculum.

The Problem

The sixth grade in my school doesn't fit neatly in either the "elementary" school or the "middle" school category. The students have an official classroom where most of their subjects are taught, which is the elementary school model. On the other hand, each subject is taught by a different content area teacher, which follows the middle or junior high school model. They do travel to different rooms for certain subjects, but this is due more to the overcrowded conditions in our school than to some logical scheme. Other teachers and other students use our room throughout the day, and my students must periodically pack up and move to another room.

Some major problems result from the multiple use of the room. If my students leave their materials in the classroom, they could be stolen or "borrowed" by other students who use our room. There is sometimes an adversarial relationship between my students as they put things away before leaving the classroom and the students and/or teachers who are trying to get into our room for the next lesson. Complicating matters is the school policy that closets are to be locked in the morning and not opened

until dismissal. These closets are supposed to be used exclusively for jackets and caps. Of course, students frequently leave books or papers in the closet, and have to interrupt another class to retrieve them.

Clearly, what is needed is a storage system that offers both easy access to the students as they exit or have to retrieve something, and security so that their things will not be taken. With these two goals in mind we set out to design a structure that would fulfill those needs.

Material

What material should we use to make our storage structure? We decided to use cardboard, because it is easily available and free of cost.

However, there are a number of characteristics of corrugated cardboard that make this material difficult to use. It is not easy to cut straight without a box cutter or similar sharp blade. It warps when wet with glue. It has to be recycled in the school, which creates a lot of extra work for the custodian in terms of stacking and tying the odd-shaped scraps. It can be quite strong when folded into the box configuration but individual pieces bend quite easily. It is not so easy to find large pieces for a full-sized unit such as we designed. These were problems we would have to address together.

Sixth Grade Science

Our sixth-grade science curriculum consists of three kits designed by *Insights* and covering three different areas: earth science, physical science, and life science. Our module for physical science is called "Structures." The unit focuses on some key concepts in structural design such as structural components, loads, materials, and shapes. In preparation for this project we did extensive work in the *Insights* curriculum on the concepts mentioned above. A weakness of this unit, however, is its reliance on models of big structures such as buildings and bridges. Students do not have an opportunity to design a real-world structure for their own use. I decided to add this element to the structures curriculum.

An additional key feature of our science program is the annual I.S. 143 Science Fair, which is fairly traditional. Students are expected to conduct and present a controlled experiment that is related to some part of their science curriculum. The design challenge of building a strong cardboard structure presented a wealth of possibilities for Science Fair projects. Here are the kinds of questions we could try to answer through controlled experiments:

- Which cardboard should we use?
- How could we laminate the cardboard to make it stronger?
- Which type of glue would work best?
- How should we attach the shelves?
- What shapes should we use for the columns and beams?

The Design Challenge

To motivate the students I began by discussing their frustrations in moving from room to room. On average, this movement occurs three times per day, including lunchtime. Typically, my students would travel to another room for computer lab, for reading lab, for gym or for social studies. At the end of the day there is usually an after-school program that uses our room and makes it impossible for students to leave materials in their desks.

I asked if they were getting tired of carrying their books around all day, and of coming in every day to find paper or pens missing from their desks. I informed them that if they were interested, we could design and build some storage units to hold their belongings and make life a little easier for them. They definitely liked the idea.

The challenge, then, was to design a system of storage units out of cardboard that would be strong enough to support the load of some full book bags and a few other items, provide a certain amount of security, be easily accessed and not be an eyesore.

Establishing Criteria

We held a brainstorming session about criteria. The most important criteria that we came up with were as follows:

- Each compartment should hold the size and weight of a full book bag. A book bag could weigh as much as 20 lbs., and be as big as 60 cm. x 45 cm. x 30 cm.

- There should be six compartments per unit.
- Doors of some kind should be provided for security.
- They should permit easy access.
- Their locations in the room should allow traffic flow.
- They should look nice and neat.

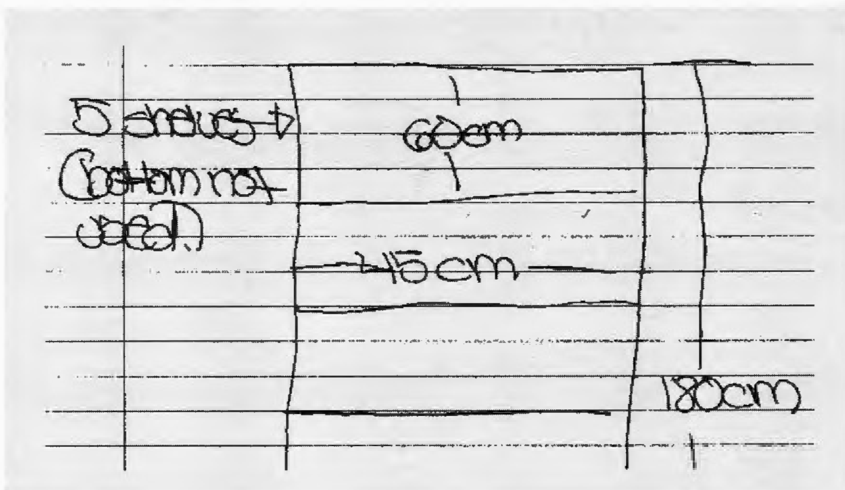
We decided to keep the bottom compartment empty so that no one would have to get down on the floor to get his or her stuff. The size of each compartment was dictated by the size of a large book bag.

In deciding on security, we all realized that cardboard would be fairly easy to break into if anyone really wanted to. On the other hand, two of the storage units used to hold my personal materials were never locked and nobody had bothered them all year long. It seemed that theft would not be an issue unless the items were out in the open and easy to get to. So we thought that a simple door with some kind of latch would work fine for our needs.

Designing the Storage Units

After we came up with the criteria and the material, our design options were fairly limited. If you want a structure of certain dimensions built of cardboard and having a certain number of storage spaces and offering a certain amount of security, you are pretty much locked into a basic shelf unit design. Nonetheless, I didn't tell students this. I simply asked them to design a structure on paper, which would fit our criteria. They all looked pretty much the same: a basic enclosed rectangular shelf unit. (See Figure 4-39.)

4-39: **Design of shelf unit**



The next step would be to make the drawings to scale. The goal was to create a scale model so that the students would see some of the problems we would face. Then we could come up with some strategies for creating the real thing. I had to make the decision, in the interest of time, to simply give students the scaled down measurements. I have taught scaling to another class, in the context of scale maps, and it is a difficult concept for them. Teaching students how to scale might have taken another week or two in itself. Instead, I demonstrated for them what we were doing when we scaled down, but I did not expect them to be able to reproduce what I had done.

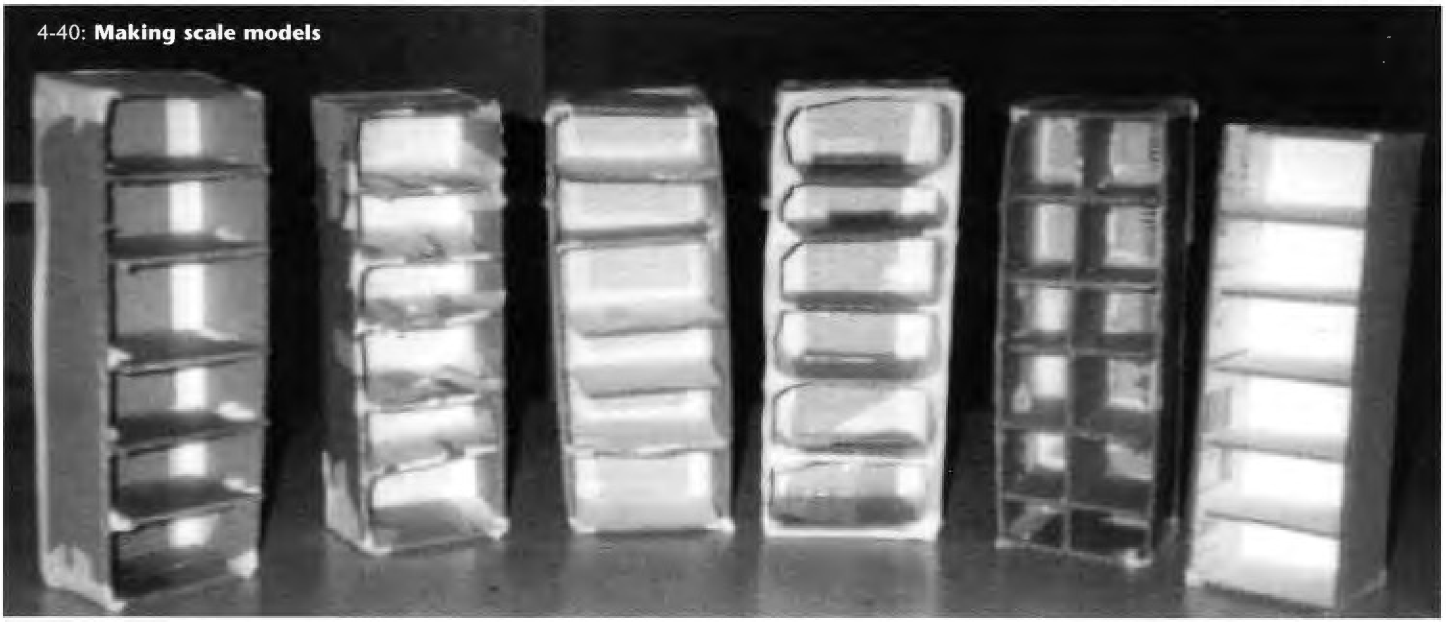
Making Scale Models

From the basic design we discussed the idea of putting together a scale model. That way, we could all see in 3D what our shelf units would look like and get some sense of how to put the units together.

I was surprised that the students had no idea how to go from the scale drawing to a scale model. I had thought that by discussing the sizes of the various parts of the unit, it would be obvious how to measure the pieces and cut them out. To my surprise, some of the groups started randomly measuring pieces of cardboard with no regard for the scale drawings. Others ignored the scale, abandoned all attempts at measuring and seemed to be trying to mold the entire unit out of a single piece of cardboard. I was beginning to realize what a complete lack of experience my students have in building things, or in understanding how things are built.

As teachers often do, Michael had taken it for granted that his students would know some basic procedures that turned out to be entirely new to them. He backtracked and did a bit of "reverse engineering." He had them look at manufactured items around the

4-40: **Making scale models**



classroom, as examples of how structures are put together. In looking for structures to study, one never has to go very far!

I stopped the lesson and went around the room pointing to structures and discussing how they are manufactured from parts that are assembled to make a whole. We discussed each of the parts that were needed to build our model shelf units. We wrote down both the dimensions and the number of parts required. For example, we needed two side pieces that would be 27.7 cm. x 6.9 cm. I then discovered that they didn't know where to begin with creating a rectangle. I had to demonstrate how to measure and draw a rectangle.

After we completed cutting out our pieces, we assembled our scale-model units and discussed some of the problems that we would face when building the real thing. (See Figure 4-40.) For starters, our model units were fairly strong due to the sizes of the pieces. When we were to build a larger unit, however, the cardboard would not maintain the same relative strength. This meant we would need some way of laminating pieces of cardboard together to make stronger, thicker pieces.

We needed some way of supporting the shelves. We also thought about how we might incorporate some supporting columns and how we might change the shape of the shelves to make them stronger. We decided that tape would make for an ugly structure, and decided that we would use only glue and cardboard.

In making and thinking about the scale models, a number of issues came up that could only be resolved by some systematic testing. These tests would also be the basis for Science Fair projects. But first, the students would need to understand the need for controlling variables, and develop the concept of a "fair test." Michael recognizes that students are unlikely to learn these principles just by being told to follow them. They have to see the need for themselves.

Testing Variables

The problems that we identified in building models led us to test some variables in order to discover the best design for our shelves. This is where Science Fair projects naturally fit in. Students were assigned to groups and each group was assigned one of the following research questions:

1. **How do different types of glue affect the strength of a laminated shelf?**
2. **How do different ways of laminating cardboard affect the strength of a shelf? For example, should the ribs of the two pieces of cardboard be oriented the long way, the short way, or some of each? (See Figure 4-41.)**
3. **How do different types of cardboard affect the strength of a shelf?**
4. **How do different shapes affect the strength of a shelf?**
5. **How do different types of triangles affect the strength of a truss?**
6. **How do different types of supports affect the strength of a shelf?**

The concepts of a controlled experiment are not easy to grasp and instruction in this area is an ongoing process. I had already done an experiment connected to the *Insights* module as a neat way of teaching the basic elements of a controlled experiment. (See "How Does the Shape of a Column Affect Its Strength?" in Chapter 3, "Activities.") These concepts include independent and dependent variables, constants, data collection, and so on.

I usually try to give my students a concrete experience first which I hope demonstrates the need for certain vocabulary. So we build vocabulary on top of the experience and I can always refer back to the experience for review. Because I teach most of my students for three years, I planned to spend a great deal of time with them in sixth grade learning how to do a Science Fair experiment. I expect that they will do more and more of their own work in the seventh and eighth grades.

Before students began their Science Fair projects, I again reviewed the requirements for a fair test. In response to my review questions they seemed to get most of the concepts, at least in the abstract. In practice, however, students had a hard time identifying variables in their own tests and needed a lot of prodding to keep all the variables constant except for their independent variable.

Although I repeatedly reminded students about controlling variables, and they kept reassuring me that they had done so, I deliberately allowed them to make mistakes. For example, a group of students con-

4-41: **Testing lamination methods**

ducted an experiment on which type of glue would make the strongest laminated shelf. With my guidance they kept the size of their pieces constant and then glued the pieces together to form laminated beams. They tested the load capacity and declared that Elmer's School Glue was the strongest. "Great," I said. "How much of each type glue did you use?" "Uh-oh. We didn't measure the amount of glue."

So they had to redo the experiment keeping the amount of glue constant. Every group had at least one obvious variable that they initially neglected to control. In each case we discussed the problem as a class in terms of what constitutes a fair test. It is a time-consuming approach, but it's really the only way students will grasp the idea of controlling variables.

When the Science Fair projects were finished, we discussed how to incorporate the findings into the construction of our shelf units. In some cases the results were inconclusive; in others, we simply decided not to use the particular variable. For example, the shape of the shelf couldn't really be changed, and it would have been impractical to use trusses to support the shelves.

While some of the experiments didn't turn out to be so useful to the design project, others were. Here is an excellent example of how science inquiry, using a controlled experiment, can inform a technological design. The results of the experiments on glue, lamination method, and support method really contributed valuable information:

1. A nice outcome of the glue experiment was that the most readily available glue turned out to be the strongest: Elmer's School Glue.
2. The experiment on laminating cardboard pieces was very instructive. The laminate in which all the "ribs" are running the same way (along the length, not the width, of the beam) was the strongest combination for making a shelf or beam.
3. Also very useful was the experiment on which supports work best for holding up a shelf. Here we found that a simple strip of cardboard, glued to the back and sides of the storage unit, provided the most support.

Final Product

With the results of our tests in hand, and with time rapidly slipping away, we decided to create a single shelf unit. Each group produced a laminated shelf. The first groups finished were assigned to laminate the side and back pieces and make the support strips. Then, just as we had done with the model units, we assembled the pieces to make a whole unit.

Of course, with such a large piece, the assembly part proved a bit more involved and required several stages. As this was our first unit, we weren't quite sure what order to follow, and there could easily have been a better way. If we had time to produce a second unit, we would definitely do some things differently. Nonetheless, here's how we did it:

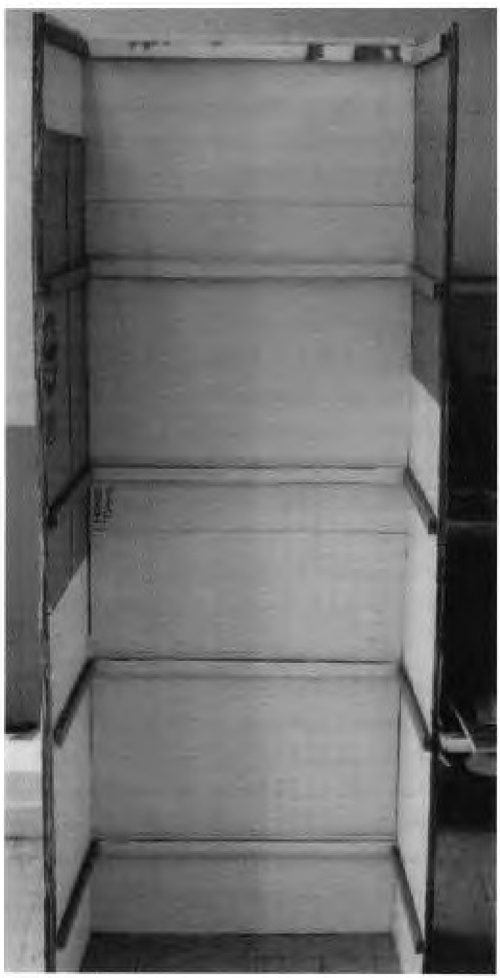
1. Lay the back and side pieces flat on a table.
2. Measure and draw lines where the support strips will be glued.
3. Glue the support strips onto the sides and backs.
4. When the support pieces are dry, glue the edges of the back and the sides where they come together, place the shelves on the support pieces (without glue), and fold the side pieces up and into their places. The shelves are there to keep the sides in place.
5. Use twine to hold the glued sections together.
6. Place the shelf unit on the floor, on its side, and use weights to hold the pieces in place. (See Figure 4-42.) Allow it to dry. (The result is shown in Figure 4-43.)
7. Glue the shelves to the support strips. (See Figure 4-44.)
8. Make cardboard flaps and glue them to the outside corners to stabilize the unit. (See Figure 4-45.)

Ideally we would have attached doors to the unit. We would then have tested the unit for strength and made adjustments to the design. We would then use the experience of building a single unit to construct five more units. Our plan proved overly ambitious and I will suggest ways to avoid this problem.

4-42: **Gluing the sides to the back, using the shelves to keep things in place**

Overall, Michael was pleased with the outcome of the project. Besides producing a useful piece of furniture and six Science Fair projects, it had engaged his students in learning math and science in the context of a real problem and given them a genuine feeling of accomplishment. At the same time, there had been many frustrations along the way, and the project had taken considerably longer than he had expected.

These difficulties were mostly inevitable, because of the way in which a design and construction project draws upon such a wide range of skills and concepts that students may not have. As Michael points out at the end of he following passage, many skills and concepts that are taught in math or science are never really learned until students really have to apply them.



4-43: **Back and sides, showing support strips**

4-44: **Gluing shelf to support strip**

4-45: **Adding cardboard flap to strengthen back-to-side joint**

Frustrations

After we completed the scale drawings, we ran into a bit of a snag that any teacher who wishes to do this project must address. How does one cut the cardboard? Here's the dilemma: Box cutters are neat and efficient, producing nice clean lines rather quickly, but they are dangerous and are not even allowed in many school buildings. As I discovered, you might also get tired of cutting all those pieces of cardboard yourself. On the other hand, any other method that we tried proved slow and produced rough, aesthetically unpleasant lines that might prove difficult to glue.

Another problem came with the actual construction of the scale models. Perhaps I should not have been surprised that students lacked the basic understanding of how things are put together in the real world. Many of them wanted to mold the entire model out of a single piece of cardboard and most of them completely ignored the dimensions that we had agreed on. This was of course a frustrating realization and one of many such construction problems that extended this project beyond the original timeline.

Each task that I wanted students to learn had at least one subtask that they needed to learn before doing it. So in the example above, I wanted students to learn about controlling variables, but I had to help them measure the mass of a liquid in order to do this. It's a frustrating realization that students often do not come to us with the prerequisite knowledge that we expect them to have. Then it becomes difficult not to get caught in an almost infinite regression teaching what should be prior knowledge. How many times have I used science class to review or even teach basic multiplication and division because a science activity requires students to perform averages?

I will provide the following list of the necessary concepts and skills that many of my students simply didn't have, as I often discovered the hard way:

- Measuring: using a ruler, scale, graduated cylinder, triple beam balance
- Right angles: for making good rectangles, shelves, columns, etc.
- Place value: for reading a metric ruler and working with measurements
- Making data charts and graphs
- Multiplication, division, and taking averages
- Making parallel and perpendicular lines

In many cases, I suspect the problem is simply one of applying to a real-world task the skills and concepts that have been taught as abstractions in math or previous science classes. That's what makes these types of projects so important, and why I consider the time spent on this project worthwhile. It brings math, science, and technology together.

Streamlining the Project

How could someone do this project without spending almost half a year on it? I believe that the idea of building single large units does not work well. It requires too much teacher coordination and perhaps too much material. If I were doing this project over again, I would have each student build his or her own individual compartment and make them stackable. This would eliminate the need for large pieces of cardboard and would make lamination a lot simpler. It would also tend to keep everyone engaged and invested in the project.

The potential problems I see for this approach would be getting the units to a standardized size and construction. There will always be some students who are less adept at making things, and this will create problems with lining up the units and stacking them. I would also find a way to let students do their own cutting. There may be other ways of cutting that we didn't consider. There may be a way to make the edges look nice after they have been cut. It might be possible to use papier mache or some other technique to cover the cardboard and hide the rough edges.

Evaluation of the Project

I was impressed with the final product. It was a sturdy piece of furniture with a lot of potential. There were mistakes made in the construction that would have been simple to correct if we had continued. For example, the students didn't always follow the rules for laminating that we had agreed upon. It showed in the strength of some shelves. These shelves would need to be stronger or they would need more support in the front.

I found the experience of building a shelf unit out of cardboard to be both rewarding and frustrating. It's rewarding to see certain students who don't necessarily shine in an ordinary classroom environment really come through and perform enthusiastically in this type of activity.

One of my students, for example, is diagnosed with ADD and normally has trouble staying focused in class. He probably worked harder than anyone else on his part of the project and produced a Science Fair project almost single-handedly (the other members of his group weren't as enthusiastic). I also believe that my students come away with a pretty good idea of how to do a controlled experiment, which I consider an essential part of science education.

I believe that linking the Science Fair projects to a design challenge is an innovation that we will add to the school-wide Science Fair guidelines next year.