The SCIENCE and MATHEMATICS of BUILDING STRUCTURES

Preschool students develop inquiry skills as they investigate how high they can build.

By Ingrid Chalufour, Cindy Hoisington, Robin Moriarty, Jeff Winokur, and Karen Worth

Imagine preschool children playing with blocks—nothing unusual about that, right? Well, now imagine these children using blocks to conduct a rich science inquiry that integrates mathematics and science skills—from exploring shape, pattern, measurement, and spatial relationships to developing understandings of stability, balance, and properties of materials. Sound impossible? It's not.

Students in a Head Start program in Boston, Massachusetts, did just that, and the success of their learning experience was inspiring. Their teacher and a group of curriculum developers who worked with her as she conducted this integrated unit wrote this article to share their story and thoughts. Through this classroom's experience, you will see that you can use everyday activities—like building blocks—as a basis for meaningful learning that meets national educational standards in science and mathematics.

Identifying the Standards

The idea for the integrated unit came about as we reflected on the science that normally took place in the teacher's classroom and realized that neither the science table, with its collection of shells, bird nests, and magnets, nor the planned activities, such as mixing cornstarch and water, were engaging students in *rich science inquiries*—inquiries that would give students reasons to measure, count, or look for patterns. The children loved to build, and as we talked together, the potential for integrating science and mathematics in block play became clear. We started by identifying some developmentally appropriate concepts that could be the focus of the children's block play.

In science, we identified stability, balance, and properties of materials as concepts to explore. In mathematics, we identified numbers and operations as concepts students would use as they collected data about their structures.

In addition to these discipline-specific concepts, we identified several concepts and processes that were part of both the science and mathematics standards. For example, standards in both science and mathematics identify shape, pattern, mea-

surement, and spatial relationships as important concepts for study. Similarly, both disciplines identify questioning, problem solving, analyzing, reasoning, communicating, connecting, investigating, and creating and using representations as processes central to engagement with each subject.

Together we created a Venn diagram (Figure 1, page 32) to clarify our thinking and to show the relationships between the content and processes presented in the *National Science Education Standards* (NRC 1996) and the *National Association of Teachers of Mathematics Principles and Standards for School Mathematics* (NCTM 2000). The figure's center area points out the unit's areas of overlap, while the areas on the right- and left-hand sides point out the targeted concepts specific to each discipline.

Readying the Classroom

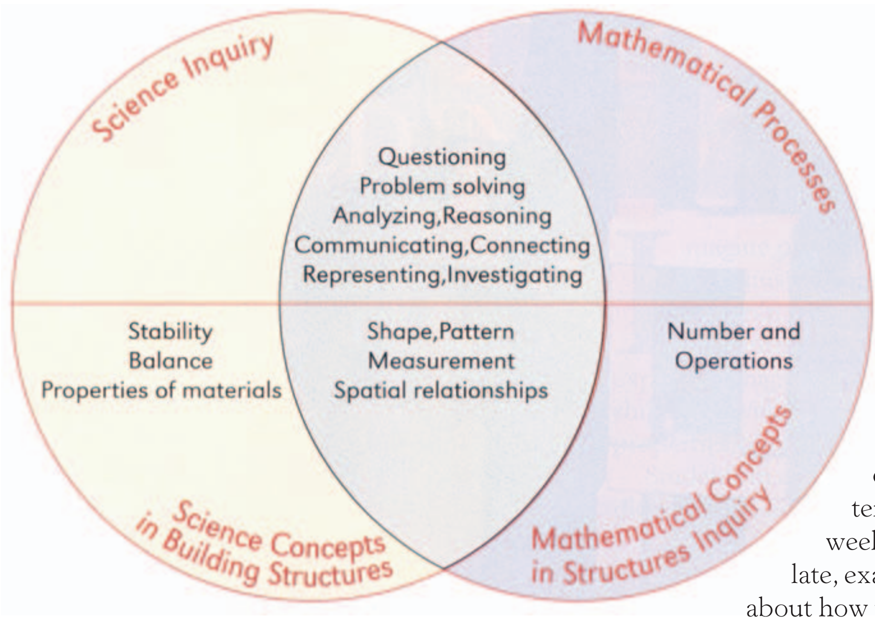
Having identified the standards that would guide the teaching and learning in the block unit over the next several months, the teacher set about transforming the classroom to best meet the unit's learning goals and the needs and interests of her students.

To begin, she created an environment for inquiry by enlarging the block area, creating additional building centers and adding foam and cardboard blocks to the collection of unit, hollow, and tabletop blocks. She also temporarily removed Legos from the block collection. Though the children loved Legos, they tended to use them to build solid, squat structures, and she wanted them to experiment with materials that did not stick together. She hoped the various other kinds of blocks would entice students to explore the relationship between the kind of materials they used for building and the balance and stability of their structures. The Legos would be reintroduced later in the exploration so students could compare them to the other building materials.

In addition to changes in the block areas, the teacher displayed books and posters of structures around the classroom, such as the Eiffel tower, the Empire State Building, and various other buildings and bridges. For easier access to the blocks and to facilitate cleanup, she labeled shelves with pictures of each kind of block, which provided students the added benefit of practicing their problem-solving skills as they compared shapes and their attributes.

Figure 1.

This Venn diagram highlights the unit's relationships between science and math content and processes.



Before the unit began, we all worked with the blocks to explore how they balanced and how different designs and kinds of materials affected structures' stability. This experimentation was a big help when the classroom teacher later observed students' block play to consider the mathematics and science concepts they were exploring.

Open Exploration

Twenty-four children, speaking eight different languages, arrived in the classroom in mid-September. For the first month of school, the teacher's goal was to engage students in building and provide opportunities for students to wonder, question, and develop initial understandings of properties of materials, stability, and balance.

Every day students explored, via trial and error, what the materials could and could not do. They discovered quite a bit about their triangle-shaped blocks. For example, they determined it's possible but not easy to balance a rectangular-shaped block on the point of a triangular one; they noticed that two triangular blocks together can be used instead of one square block, but only if the triangular blocks are laid on their flat sides. They agreed that triangular blocks are not strong when you try to stand them up as a square: the two triangles slip away from each other.

Every day at the class's morning meeting, the teacher got students excited about using the building materials. She talked about the children's buildings or drawings from the previous day's block play and then shared a picture of an interesting building (the Taj Mahal, for example) or introduced a new kind of building material.

During the daily choice time or activity time (about an hour each day), the children worked in three block centers. During this time, she walked around the classroom, observing the different ways children built and expressing interest in students' block play. She asked children to tell her about their buildings, described interesting features of their structures aloud, and sketched and photographed children's buildings.

Toward the end of each week, she engaged children in talking about the patterns and designs they were using. These weekly "science talks" helped children articulate, examine, and defend their developing ideas about how to build strong buildings: what materials were best, and which blocks were good at the bottom.

To stimulate these conversations, the teacher referred to the drawings and photographs and to excerpts from conversations she'd had with children about their structures' stability (for example, "You need to use big blocks on the bottom and smaller ones on top if you want to have a strong building" or "If it starts to wiggle, you need to hold it with your hands").

As students became more comfortable with their building experiences, the teacher began to highlight the

Students collected and recorded data about their block structures by measuring, counting, and drawing.

PHOTOGRAPH COURTESY OF THE AUTHORS

science and mathematics in her children's open exploration of building structures.

She used comments like, "The block under your house makes for a strong foundation" and "The block between these walls is balancing on its end!" to focus attention on their structures' designs and stability and relative position in space. In so doing, she addressed a section of the NCTM geometry standard as she modeled vocabulary, such as *under* and *between*, that children need to learn as they talk about location and space.

As she communicated her interest in the various ways children had designed and balanced their structures, the teacher supported each child's development of new science and mathematics language and modeled its use. This enabled the children to communicate better with one another, an element of both the *NSES*'s and the NCTM's communication standards.

PHOTOGRAPHS COURTESY OF THE AUTHORS

The students' preoccupation with building straight up led to the inquiry project, "How tall can we build?"

Questioning and Investigating

A few weeks into the open exploration of building structures, the teacher noticed students' preoccupation with building straight up. She decided to help students focus their inquiry on the question they all seemed to be asking through their building behavior: How tall can we build?

She brought the children together and showed them photographs of the various towers they'd been building out of different kinds of blocks. She articulated their question, "How tall can we build?," and asked for predictions.

Some children used movement, some used numbers, and others described height in terms of other objects ("as tall as the door," for example) to answer how tall they could build. The teacher recorded students' ideas in words, numerals, and sketches, and she helped interested groups and individuals plan their investigation by working with them to figure out who was going to build where during the upcoming choice time. Children could select in which of the three different building centers they were going to work. Some children partnered up, others worked solo.

Now that the children's science investigation focused on a single question, the teacher facilitated this part of the inquiry differently. She used morning meetings for the next few weeks to refer children to the previous day's data, plan their day's work, or make predictions about what they might discover.

During choice times, she encouraged children to represent their towers' heights in two-dimensions and three-dimensions, and she helped children measure their towers, count the blocks, and compare heights. And she used their weekly science talks to help students analyze their data and support their developing theories about building tall towers with evidence from their own experiences.

For example, in one science talk, the teacher shared photos and representations of the children's towers and, together, they compared the numbers of blocks on towers of different sizes. Students were able to easily observe that the taller towers had more blocks.

In another talk, students discussed which kinds of blocks—unit blocks or cardboard blocks—made the tallest towers. The teacher asked students probing questions, such as "Why do you think the cardboard blocks fell down more than these cylinders?," to encourage students to elaborate on their ideas. In this way, the teacher was able to shift the children's focus from the effects of design on their towers' height and stability to the effects of the properties of the building materials themselves on the stability of a tall structure.

As she worked with her class, the teacher deepened students' science and mathematics learning in several ways. For example, she

- Identified questions to focus the inquiry;
- Helped children collect data using photographs, drawings, models, counting, and measuring;
- Used informal conversations and whole-group science talks to help children communicate and analyze their data; and
- Encouraged students to use representations and other data to articulate theories they developed about how design and properties of materials affect a tower's stability.

Of course, by encouraging students to articulate theories and use evidence from their work to support their ideas she also addressed NCTM's process standards: reasoning and proof; data analysis and probability; and communication. Children also measured and counted with a purpose: to collect data that would help them answer their questions, "How tall can we build?" and "Which blocks make the tallest towers?"

Tying It Together

As the children's interest in building tall towers began to wane, the teacher suggested they hold an open house so they could share their investigation of the ways materials and designs affect tall structures' stability.

When the visitors came, students challenged their guests to build tall, stable structures. They passed out clipboards and markers and invited the guests to draw their structures and write about the strategies they'd used to make their structures stable. Photographs, charts, and documentation panels were hung around the classroom, and the teacher encouraged the visitors to ask the children about them.

The teacher also referred to the experience and shared examples of students' work in parent-teacher conferences to discuss how their children's social/emotional, language, and mathematical skills and understandings had developed in concert with their developing understanding of inquiry, stability, balance, and properties of materials.

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards

Grades K–4

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

Standard B: Physical Science

- Properties of objects and materials
- Position and motion of objects

This article relates to the following *Principles and Standards for School Mathematics* (NCTM 2000):

Grades PreK–12

Algebra

- Understand patterns, relations, and functions

Geometry

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships
- Use visualization, spatial reasoning, and geometric modeling to solve problems

Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

Communication

- Organize and consolidate their mathematical thinking through communication

Connections

- Recognize and apply mathematics in contexts outside of mathematics

Representation

- Create and use representations to organize, record, and communicate mathematical ideas

Beyond Blocks

Building with blocks clearly offered this teacher and her students rich opportunities to integrate mathematics and science. Other science topics can also offer similar opportunities.

For example, try adapting the Venn diagram in this article to facilitate a life science inquiry, such as a study of organisms in the environment. Replace the physical science concepts related to building structures, currently listed in the bottom left-hand section of the diagram, with age-appropriate concepts related to life science, such as life cycle, characteristics of living things, and habitat.

Think about a rich classroom environment including many plants representing a good variety, as well as several terrariums representing different local habitats. Think about taking children outdoors each day to observe their natural surroundings. Try to fill out the rest of the Venn diagram.

You might include opportunities for three-, four-, and five-year olds to use patterning, counting, measuring, and spatial relationships to describe what children notice and think about the growth and development of living things. With a little consideration, it is possible to create integrated science and mathematics units that keep the integrity of each subject and also highlight the overlapping processes and concepts central to both subjects. ■

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Resources

National Association of Teachers of Mathematics (NCTM). 2000. *Principles and Standards for School Mathematics*. Reston, Va.: Author.

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