

Science BEYOND THE CLASSROOM

Science BEYOND THE CLASSROOM

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Introduction

Extending Science Learning for Elementary Children

This book is for those who are interested in providing students with science-learning experiences that go beyond the learning that takes place within the usual school day and within the school building. Establishing science clubs, designing family science events, creating opportunities for students to share what they have learned through an exhibition, field trips to local sites, or overnight experiences—all of these and more are explored through looking at possible extensions. This book is designed not only for teachers in the formal setting of a school but also for scout leaders, club sponsors, people teaching their children at home, and any parents who want to take advantage of additional opportunities for their children—anyone interested in extending student science learning will find valuable information within this collection of articles and resources.

The impetus for this compendium came from an understanding of the value of experiences that go beyond what can be offered to students during the school day. The National Science Education Standards stress the importance of incorporating informal learning opportunities such as field trips and special programs into the curriculum, because they provide access to the world beyond the classroom and tap into student interests (NRC 1996). The Standards emphasize that this applies to the entire science program and all students in all grades.

Specific groups of students may be of particular interest in your work. This book will help in seeking out opportunities for these special groups. One of those groups is girls: Gender issues are important when considering science for all. Opportunities for girls to be with other girls in communities and activities in which they can do what they want to do—whether they're "good at it" or not should be provided. "Girls need opportunities to explore things that might lead to strong interests and careers, without the pressure to 'win,'" Gina Shaw says (2003). "Make sure she knows people can be good at any doggone thing." Encourage girls to try nontraditional as well as traditional pursuits—take them fishing, work on the car with them, help them build a soapbox derby car. Girls Inc. and the Girl Scouts of America too offer a wealth of ideas.

Although not the only goal of a quality science education, increasing the number of students who select science, technology, engineering, or mathematics (STEM) as a career is one of the aims of providing engaging science experiences. Definitive research is lacking, but, according to the Carnegie Foundation report (1992), the research that has been done, along with retrospective observations by practicing scientists, suggests that the following elements are important in encouraging students to aim for mathematical and scientific careers. Many talent initiatives try to address these needs:

- Solid preparation from an early age in math and science content
- Experience with hands-on content
- Awareness of the utility of school-based learning in the workplace
- Exposure to role models and mentors who work in these fields
- Access to peers who share these interests
- Learning of content. At some level, knowledge of scientific principles, enhancement of technical or problem solving skills, or other preparation to go on to more advanced work should be expected.
- Enhanced positive attitudes—even excitement—toward the discipline
- Increased self-confidence in one’s ability to excel in this field
- Increased knowledge of the value of math and science in the workplace and increased awareness of math and science careers
- Removal of any barriers to possible advancement in math and science that existed prior to the intervention

In addition, researchers have found variables within the family—such as education of parents, careers of parents, support for student interests—and certain affective and personality traits—investigative and theoretical interests, assertiveness, and motivation among them—to be important components of success in these fields. The articles in this collection encourage all of these elements.

This compendium consists of carefully selected articles from the NSTA middle school and elementary school journals *Science Scope* and *Science and Children*. The articles are just a beginning point. You can adapt them to your needs and let them inspire related activities. They provide an overview of information and ideas that can be modified to fit many needs. Many of them provide step-by-step, teacher-tested instructions and guidelines.

The articles are organized into five sections:

- Beyond the Curriculum: Projects and Challenges
- Beyond the School Building Walls: Using Local Sites
- Beyond the School Day: Clubs and Expositions
- The Family: Take-Home Projects and Family Science Events
- Informal Institution: Museums, Zoos, and Other Field Trips

Each begins with an introduction that gives background on using the strategies in the articles and discusses why the strategies are important. In many cases, information on specific research concerning the strategies is also provided. The introductions also describe each article in the section and provide a list of additional useful NSTA journal articles that can be accessed on the NSTA website (www.nsta.org). For a broader view of the general areas discussed, URLs to additional sources are identified. As with all URLs, take care in using them with students because they may change over time.

Linda Froschauer
NSTA Past President, 2006–2007

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Section 1

Beyond the Curriculum: Projects and Challenges

Beyond the Curriculum

Projects and Challenges

If we want to consider science for all, then we must seek ways to engage students in interests that go beyond the curriculum. Solving problems, meeting challenges, and working with others on projects can all provide for conceptual understanding by enthusiastic students. But, problem solving and projects take additional time.

The National Science Education Standards and Benchmarks for Science Literacy stress the importance of creating science experiences that are linked to the real world, something that is familiar to students. Projects and challenges hold the potential for fostering curiosity and motivating students.

Most curricula developed for use in public schools take into consideration the time limitations felt by many elementary teachers. We know that challenges and projects take additional time and are frequently omitted from the choices provided to teachers. These are the types of activities, however, that encourage students and engage them in learning: They should not be considered tangential to developing conceptual understanding.

Lillian Katz, professor emerita at the University of Illinois and a specialist in early childhood learning, provides this concerning the place of projects within the curriculum:

Communicative skills develop when there's something meaningful for children to communicate about—when they are taking an active role....

Advocates of the project approach do not suggest that project work should constitute the whole curriculum. Rather, they suggest that it is best seen as complementary to the more formal, systematic parts of the curriculum in the elementary grades, and to the more informal parts of the curriculum for younger children. Project work is not a separate subject, like mathematics; it provides a context for applying mathematical concepts and skills. Nor is project work an “add on” to the basics; it should be treated as integral to all the other work included in the curriculum:

Systematic instruction

1. helps children acquire skills;
2. addresses deficiencies in children's learning;
3. stresses extrinsic motivation; and
4. allows teachers to direct the children's work, use their expertise, and specify the tasks that the children perform.

Project work, in contrast

1. provides children with opportunities to apply skills;

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2. addresses children's proficiencies;
3. stresses intrinsic motivation; and
4. encourages children to determine what to work on and accepts them as experts about their needs. Both systematic instruction and project work have an important place in the curriculum.

[Projects] provide lots of opportunities for children's natural curiosity to manifest itself. With very young children, our role is one of supporter and guide. With preschoolers and older children, we need to be more challenging, involve children in projects. I define "project" as an in-depth investigation of a phenomenon or an event in children's own experience or environment that is worth learning about—something children are interested in, something they can readily observe and interact with. During project work, we help children formulate their own research questions, figure out ways to find the answers, and assist them in representing their findings. Worthwhile projects contribute to children's confidence in their own experiences and help them understand those experiences more fully. (1993)

If you are seeking concrete ideas as to how you might structure a project or in-depth inquiry, the Northwest Regional Educational Laboratory (NWREL) provides an excellent guide on its website. It includes step-by-step instructions as well as exemplars.

In This Section (*articles are in italics*)

This section begins with an article that sets the stage for students to become problem solvers. *Problem Solvers to the Rescue* creates an environment where a simple, realistic problem challenges students to consider a variety of issues and how to overcome them. The model provided through this scenario can be applied to many problems.

There is nothing like being a scientist and sharing real scientific data with other "scientists." In *S'COOL Science* students serve as researchers. Students collect data and share their observations of clouds online with other students conducting the same type of research as well as with NASA researchers. Student observations help NASA scientists calibrate their satellite data.

Design Challenges Are "ELL-ementary" provides insight to the issue of providing quality science experiences for all students, including those with English as a new second language. The design challenges allow students to work in the content area without relying heavily on their English skills. They are allowed to express what they know through their designs rather than language. But, even as language is not the emphasis of the lessons, students develop new vocabulary and use it immediately.

Science and art combine as a way to engage students in subject matter that is high interest in *Every Feather Tells a Story*. Direct observation of the characteristics of feathers comes from a discussion of birds and how their feathers differ from one another. The student's study of form and function lead them to an art lesson in which they create an imaginary bird. This article serves as a model that may be adapted to fulfill the requirements of a curriculum area while extending the conceptual understanding developed by students.

Valuable lessons can be earned through using the local environment while comparing it to the entire country. The Journey North Project inspires students in kindergarten through grade two not only to monitor plants in their own surroundings but also to go online to track the growth and blooming of flowers across the United States. *Tracking Through the Tulips* provides a glimpse into the process from soil analysis and planting tulip bulbs in the fall, inquiring about plants all year, and on to monitoring the growth and blooming progress throughout the spring. It is an example of how the local community can be connected to the entire nation through the World Wide Web.

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Problem Solvers to the Rescue

By Frances V. Figarella-García, Lizzette M. Velázquez-Rivera, and Teresita Santiago-Rivera

Imagine... you must bring water to a hurricane-ravaged area. There is only one bridge and only one truck, and the bridge can only hold so much weight. Your calculations determine if the truck—and its load of water—can make it safely over the bridge.

This is a typical challenge during two-week summer camps for third- through fourth-grade students held in the Construct, Discover, and Learn (CDL) schools across Puerto Rico. The camps—and the CDL schools in which they take place—are part of a systemic professional development program directed by the University of Puerto Rico Resource Center and sponsored by the Puerto Rico Department of Education to support the development of inquiry-based science and mathematics instruction for elementary students.

Our school, University of Puerto Rico Laboratory School in San Juan, is a designated CDL center in which summer camps are held. Through the assistance of university faculty, our center has provided more than 120 teachers guidance and support in implementing inquiry-based instruction. This article describes a typical camp session and some of the things we (a university professor and two classroom teachers) have learned from our experience as camp coordinators.

A Problem to Solve

Since our program began in 1999, we have focused on the design of science curriculum units using the constructivist methodology of problem-based learning (PBL). We decided to plan lessons specifically related to the concepts of mass and volume because (1) these concepts are not commonly taught at the elementary level in Puerto Rican schools, even though they are fundamental concepts for this level; and (2) even when these concepts are taught, it is often done in a traditional way—through the use of the textbook, without hands-on activities (Gabel 1994).

Delisle (1997) introduced a specific structure that facilitates the use of PBL, which we adapted to suit our instructional objectives. We followed these steps:

1. Present the problem.
2. Generate possible solutions.
3. Explore what is known using a Know-What-How (KWH) table (Fosnot 1996; Brooks and Brooks 1993).
4. Identify the most convenient method to solve the problem.
5. Conduct activities to learn the concepts needed to solve the problem.
6. Apply new concepts to solve the problem.

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7. Present the solution to share and demonstrate the knowledge constructed.

Water Over the Bridge

To present the problem to students, we held a hypothetical public hearing in which two teachers, representing the mayor and a community member of a town in Puerto Rico, dramatized the following scenario:

The community member was seeking help from the mayor because the town was running out of water. A hurricane had damaged a bridge in town that was the only way to get into the community. A provisional yet fragile bridge substituted the original one, but vehicle transportation was restricted.

The mayor was willing to provide a municipal truck to carry the water, but he didn't know if the bridge would support the truck's mass or what volume of water the truck would transport. The mayor needed advice from a scientific team who could determine the mass and water volume the bridge could support. The mayor invited the students to be the scientific team to help solve the community's problem.

The students were excited to accept the challenge. The teachers discussed the situation and asked students to explain the situation in their own words. For the most part students assessed the situation accurately (i.e., "A hurricane passed through Jurutungo. The people have no water and the provisional bridge is falling down. The mayor wants scientists (us) to find the maximum amount of mass that the bridge can hold and the maximum volume of water that the truck can take in just one trip").

However, there were some students who focused on nonessential aspects of the situation, asking such questions as, "How long has the town had the water problem?" and "How do children go to school, if the cars cannot cross the bridge?"

The teachers helped students focus on the part of the situation they could solve and made sure everyone clearly understood all the information provided to them.

We'll Solve It!

Next, students began brainstorming possible solutions. Some of their ideas included carrying water by foot, transporting the water through a very long hose, building a new bridge or a water pipe, and transporting water by helicopter. The teachers asked such questions as, "How far is the bridge from the community?" "How much water can a helicopter transport?" "Does the town's mayor have a helicopter available to transport the water?" "How much would it cost to construct a new bridge?" and "How long would it take to build the bridge?" to help students realize that these were not feasible solutions to the problem.

The teachers reminded students the mayor had already evaluated the municipality situation and the town's available resources and had decided the best (and most immediate) solution was to transport the water by truck in one trip, using the provisional bridge. But to make sure his decision was right, he needed their help as scientists. Their job was only to help him determine the mass and volume that the bridge would support, not to bring water to the community—that was his responsibility.

As students continued brainstorming ideas about how they might measure mass and volume, they realized it would be dangerous to do tests on the provisional bridge. Instead, the teachers suggested testing their ideas using models and showed students a model bridge that had been previously constructed from inexpensive wood, a plastic toy truck, and several small plastic containers of different capacities.

Procedure via Consensus

After brainstorming, students solidified their ideas by completing a KWH table (Figure 1) to consider what they Knew about the situation, What they needed to learn, and How they could learn it. This organizational step helped students clarify their understanding of the problem at hand and anticipate the steps required to solve it.

Students Knew that the provisional bridge was frail, the community was nearly out of water, and the town mayor had offered a truck to transport the water in one trip. Students also knew What they needed to learn—the maximum mass the bridge could support and the maximum volume of water that could be transported in one trip. Students thought about How they could learn this information—by learning how to measure mass and volume.

When they had completed the chart, the teachers divided students into five groups of four students each and asked each group to design a procedure to solve the problem and present it to the whole class. When each group had come up with a procedure, the teacher and students evaluated the procedures presented by each group, and, via consensus, they chose a general procedure for all groups to follow:

1. Gather the necessary materials (truck model, bridge model, graduated cylinder, platform balance, water, small containers of various capacities, two tables, and adhesive tape).
2. Mount the bridge between two desks and tape in position.
3. Using the graduated cylinder, measure a volume of water in the small container.
4. Measure the truck's mass on the platform balance.
5. Measure the mass of the small containers holding the water on the platform balance.
6. Add the mass of the truck and the mass of the small containers when full of water.
7. Repeat the procedure six times (trials), gradually increasing the volume of water carried each time, to find the maximum amount of water to transport across the bridge in one trip.

Practice Makes Perfect

With the procedure in place, the teachers had students conduct five related activities to help students understand mass and volume. The student groups would

- learn how to use the graduated cylinder,
- measure the volume of water in different containers,
- practice using a platform balance,
- find the mass of water in different containers, and
- estimate (and then measure) the mass of a solid and volume of a liquid.

Figure 1.

A KWH table.

A Know-What-How table helps students synthesize the information at hand before solving a problem.

K	W	H
<ul style="list-style-type: none"> • The bridge is frail. • The community has almost no water. • The town's mayor has a truck available to transport the water in one trip. 	<ul style="list-style-type: none"> • What is the maximum mass of the truck? • What is the maximum volume of water that could be transported? 	<ul style="list-style-type: none"> • How is mass measured? • How is volume measured?

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After each activity, the teachers discussed with students what they observed. By the end of the activities, students had begun to formulate operational definitions for *mass* and *volume* and recognize that mass and volume are physical properties that can be used to describe matter.

Will the Bridge Hold?

Once students were comfortable with their knowledge of how to measure mass and volume, students were ready to apply what they learned to the water problem posed earlier.

So, following the procedure agreed upon earlier in the project, each group was given a plastic toy truck, a bridge, and a selection of different containers with which to conduct their six trials.

Before conducting any trials, students mounted the bridge using the provided instructions; decided the initial volume of water they planned to transport; chose the container in which to transport the water (some containers could transport the same volume of water but had different masses); determined the mass of the water in the container and the truck; and predicted how many containers they could fit on the truck. When all the necessary decisions had been made, students conducted the trial.

Initially, some groups were more conservative than others, transporting only 30 mL or 40 mL of water, while other groups began the trial with larger amounts, such as 120 mL of water. Students recorded the results after each trial, gradually adding more mass and volume until they had completed six trials without breaking the bridge. The bridge bowed under the weight in some of the trials, but never failed.

With each trial, students grew more excited. Some students were fearful the bridge would not hold the mass and volume that was being put on it. Others mentioned the bridge was much stronger than they had expected. The mass and volume of the last trial was the group's maximum support that the bridge could hold.

When each group had completed all six trials, students compared data. Students discovered that each group had determined different "maximum" quantities, so they chose to present the results from the group that transported the greatest volume of water to the mayor.

Making the Case

The teachers documented the whole process with photographs, and students concluded the experience by writing summaries of their camp activities—from the initial public hearing to the problem's solution—and creating a book, which they presented to their parents, the "community member," and "mayor."

The presentation began with a restatement of the problem and a summary of the different activities that led to the solution. Then, students presented the maximum volume of water and maximum mass the bridge could support using the highest amounts achieved by a group in the last trial.

The students also shared their concerns related to the velocity of the truck, the mass of the driver, and the type of containers they recommended using. Students recommended the truck go at low speed, the driver be slim (so that he/she would not add much mass), and the containers be the ones with the lowest mass so they could take more water.

Real-Life Learning

Learning was assessed in several ways throughout the experience. Students completed laboratory journals in which they recorded the data acquired in each activity, wrote answers to analytical questions posed by the teachers, and reflected over the days' events and activities. Other assessment measures included various performance tasks, oral presentations, written reports, and a class-created book describing their experience.

Through these measures, we were able to assess students in several areas: scientific vocabu-

lary; written and oral language skills; cooperative skills; creativity; conceptual understanding of mass and volume; reading numeric scales; measurement skills; mathematics skills, such as addition and subtraction; and science-process skills, such as observation, prediction, inference formulation, hypothesis formulation, and experimental design.

We found students were motivated to learn when they were presented with a “real-life” problem to solve. The hands-on experiences afforded by the PBL methodology enabled students to go beyond learning about technical skills and constructing definitions, and promoted a significant understanding of mass and volume concepts. They played, enjoyed, and learned in a stimulating and challenging environment.

Through the summer camp program, each of us (the teachers) truly experienced being a facilitator for students’ learning processes. We concluded that the most important function of the science teacher is to orchestrate hands-on and minds-on activities to promote the process of inquiry, the construction of knowledge, and the development of a scientific culture.

When the new semester began shortly after the camp concluded, we encountered a new challenge: incorporating the PBL methodology into some of our existing curricular units, this time without external financial resources, extra time to plan collaboratively with peer teachers, and the support of university faculty. Could it be done? Given our successful experience during the summer, we would definitely give it our best shot!

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Connecting to the Standards

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

Content Standards

Grades K–4

Unifying concepts and processes

- Constancy, change, and measurement

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard B: Physical Science

- Properties of objects and materials

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