ACTIVITIES LINKING SCIENCE WITH MATH K-4

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John Eichinger

Lovingly dedicated to Danube, Wolfe, and Björn

Introduction

"The solution which I am urging, is to eradicate the fatal disconnection of subjects which kills the vitality of our modern curriculum. There is only one subject matter for education, and that is Life in all its manifestations."

Alfred North Whitehead
(The Aims of Education 1929)

Overview

Activities Linking Science With Mathematics, Grades K–4 (*ALSM*) rejects traditional, discipline-bound methods of instruction and instead opens the door to hands-on, discovery-based, and academically rigorous activities that link various scientific disciplines to mathematics in particular, but also to visual arts, social sciences, and language arts. These 20 activities, intended for inservice and preservice K–4 teachers, align with the National Science Education Standards (NSES) and the National Council of Teachers of Mathematics (NCTM) standards, both of which encourage an increase in interdisciplinary instruction. The lessons balance integrated content with the processes of personally relevant inquiry and are designed to promote creative, critical thinking on the part of all students. The lessons are also teacher friendly, requiring no advanced expertise in any particular subject area and using inexpensive and easy-to-find materials.

ALSM is an engaging supplement to core classroom curriculum that allows all teachers to maintain high expectations with effective, authentic, and student-centered instruction. Preservice teachers in particular benefit from the early introduction to these sorts of strategies, helping them develop effective interdisciplinary classroom instruction. Indeed, as McComas and Wang noted, teachers must "experience effective blended science instruction models firsthand" for true interdisciplanry models ever to flourish in our education system (1998, p. 345). To that end, *ALSM* models alternative, yet proven, teaching practices that can be applied in any classroom. The activities are particularly well suited to urban schools, where access to natural study sites such as lakes, streams, and forest trails, or even small plots of grass are limited. What's more, the focus on individual student observations and cooperative group work (rather than teacher-centered lectures, traditional textbooks, or pencil-and-paper tests) as the basis for conceptual understanding levels the playing field among students of different genders, cultures, and native languages.

As you acquaint yourself with the *ALSM* approach, keep in mind that though classroom ready, these 20 activities are intended to be neither rigid nor overly prescriptive. Think of them as models, jumping off points, and let the active, constructivist approach to teaching inspire you to develop and implement your own academically integrated lessons that stimulate the natural curiosity and problem-solving skills of your students.

Theoretical Foundation

Educational constructivists believe meaningful learning depends on prior experience (Piaget 1970). Understanding is mediated by personal and social background; knowledge is constructed, negotiated, and tested via experience. The only adequate test of knowledge, then, is its viability when applied to current problems (Tobin 1993). Constructivism does not outline a particular methodology but generally suggests that you consider students' prior experience (and even misconceptions), create situations in which students have opportunities to reconceptualize naive ideas, and remain flexible and alert to the growth and viability of student knowledge. As von Glasersfeld noted, "successful thinking is more important than 'correct' answers," and to foster motivation, the constructivist teacher will "create situations where the students have an opportunity to experience the pleasure inherent in solving a problem" (1993, p. 33). *ALSM* combines this attention to students' experience and successful thinking with classroom lessons and pedagogic strategies you'll quickly recognize: hands-on and minds-on instruction, guided discovery, experimentation, the learning cycle, open-ended challenges, projects, metacognition, attention to the affective domain, and authentic assessment. (A matrix clarifying the various instructional strategies used in each of the activities appears on page 12.) The activities described in the following pages push you to apply these well-known teaching techniques in novel, more student-centered ways.

Four overarching principles—each clearly recognized and encouraged by the national standards in science and mathematics—guide *ALSM* lessons (AAAS 1989, 1993; NCTM 2000, 2006; NRC 1996).

1. *Student relevance* refers to a focus on student interests, prior knowledge, questions, and ideas, as well as student-initiated projects and

solutions. In short, lessons should reflect the lives of the students involved. In the words of the National Science Education Standards: "Teachers[should] plan to meet the particular interests, knowledge, and skills of their students and build on their questions and ideas" (NRC 1996, p. 31). Relying only on teacher-directed memorization of facts is insufficient and ineffective according to a number of influential sources, including the national standards in science and mathematics (AAAS 1989, 1993; NCTM 2000; NRC 1996). If a deeper and more viable understanding is to be reached, you must help students bridge the familiar with the unfamiliar. That is, meaningful teaching begins with what students already know and connects, through active learning methods, to new, expansive concepts and understandings. *Principles and Standards for School Mathematics* states, "Mathematics makes more sense and is easier to remember and to apply when students connect new knowledge to existing knowledge in meaningful ways" (NCTM 2000, p. 20).

2. *Interaction/collaboration* reflects the fact that elementary students are fundamentally concrete thinkers who require personal and interpersonal experiences to learn effectively (Vygotsky 1978). As the National Science Education Standards explain, "Interactions among individuals and groups in the classroom can be vital in deepening the understanding of scientific concepts and the nature of scientific endeavors" (NRC 1996, p. 32). You should, therefore, actively involve students both personally and socially in science-math explorations. Engaging lessons that encourage involvement and provide opportunities for meaningful understanding are optimally motivating for students, especially in grades K–4. We also know that to be fully effective, interactive studies must be undertaken in a collaborative manner. Learning depends on socialization, and a deep understanding of science and math depends on an awareness of the interpersonal aspects of those disciplines (Vygotsky 1978). Keep in mind that well-managed group work in the classroom closely resembles the collaborative nature of real-world science, mathematics, and technology—thus offering students authentic, interactive experiences, (AAAS 1989; NRC 1996).

3. *Problem-based learning* provides a challenging and motivating context for classroom math and science exploration. An essential feature of the current national standards in math and science education is a call for deeper, more active, and more relevant inquiry. "Well-chosen tasks can pique students' curiosity and draw them into mathematics," says the

National Council of Teachers of Mathematics (NCTM 2000, p. 18). Posing realistic, interesting, open-ended, and challenging problems for students to solve is a mainstay of the reform movement. In particular, Meier, Hovde, and Meier (1996) stress the importance of realistic and interdisciplinary applications of problem solving. Through problem solving in the classroom, students learn to effectively confront real-life demands by applying higher-order thinking skills. Thus, the development of problem-solving skills through active, engaging investigation is fundamental to the national standards in science and mathematics (NCTM 2000; NRC 1996).

4. *Integrated instruction* is the blending of two or more academic disciplines into a particular classroom lesson. Science and mathematics, though traditionally treated in academia as discrete intellectual entities, are not separated in the real world. Integrated instruction not only promotes the presentation of the subjects in a realistic and relevant context but also provides opportunities for imaginative and personal connections between students and subject matter, further enhancing understanding and motivation. Cross-disciplinary connections deepen understanding by allowing students to simultaneously use the language, concepts, and methods of thinking of several subject areas. That is, students have an opportunity to view and comprehend a situation from more than one disciplinary perspective, generating a greater complexity of meaning (Fosnot 1996). Research into the impact of integrated science-math instruction shows a positive effect on student achievement, problem-solving ability, self-worth, motivation, and interest (Meier, Cobbs, and Nicol 1998). Finally, on a practical level, integrated instruction, by connecting subjects and thereby condensing teaching time, provides more time to teach science and math in what has become a very tight daily teaching schedule.

Integrated, unified, blended, interdisciplinary, cross-disciplinary, multidisciplinary, thematic, and *coordinated*—all are words used to describe simultaneous instruction in multiple disciplines. However, because these terms tend to be used inconsistently, there is a great deal of confusion about what they actually mean. Lederman and Neiss (1998) observe that *integration*, for example, tends to be used in one of two ways: First, it may refer to instructional situations where traditional boundaries are blurred or even lost. Or, it may refer to situations that maintain traditional boundaries but stress the interactions among the disciplines during instruction. Lederman and Neiss favor the second definition, explaining that conventions differ between science and mathematics, largely due to the notion that science (and not math) must consider external empirical observations in problem-solving situations. Ways of knowing vary significantly between science and mathematics (as well as between other academic disciplines), enabling us to discriminate one discipline from another. Therefore, if students are to gain understanding of how science, math, or any other intellectual discipline functions, the lines separating the disciplines should not be erased or even significantly blurred. Rather than dissolving disciplines into incongruous hybrids, Lederman and Neiss argue that if you are interested in integrated instruction, you should help students find meaningful interconnections among existing disciplines. Although a certain amount of disciplinary "cloudiness" is bound to exist in any attempt at integrated instruction, the science-math links described in the following activities reflect the position of Lederman and Neiss.

How to Use This Book

Think of *ALSM* not as an activity book but as an instructional framework and a resource that can be easily adapted to any discipline.[1] The *ALSM* lessons can be introduced in any sequence and may be used in a variety of ways: as an active introduction or dynamic closure to a unit of study; as a motivational, guided inquiry that supplements the core curriculum via application; or as an open-ended and independent investigatory project. Choose *ALSM* lessons that reflect and extend your required curriculum, or try one that looks appealing or taps into a particular student interest. Expand or modify the activities to meet your individual class needs and as time permits. Be mindful of opportunities that allow you to draw connections with past or future areas of study.

When implementing the lesson ideas, plan thoroughly but remain open to emergent and spontaneous learning opportunities, paying particular attention to student questions, impressions, and proposals. Student ideas are often the keys to establishing meaningful understanding and lasting motivation. Listen carefully to students as they investigate, think, and grow in confidence and knowledge. Take your cues from them as you brainstorm how to improve your instruction and seek ways to extend lessons into new areas of learning. Remember, successful teachers prepare thoroughly, enjoy the experience, and share their joy of learning with students.

This book is organized according to scientific discipline, as seen in the Table of Contents, to expedite the location of appropriate lesson ideas

1. Francis and Underhill (1996) provide another practical approach for developing interdisciplinary lessons, one that may be applied effectively in most classrooms. Their model relies on collaboration between two teachers (one math, one science), determines the key components of each topic to be taught, and uses a matrix format to plan instructional connections between those key components.

for your curriculum planning. In actuality, the various disciplines overlap substantially and many activities include aspects of several diverse science disciplines. For example, Activity 17: Examining Colors, Color Perception and Sight, which is listed as a life science project, also involves a significant amount of physics. Similarly, most activities have a great deal more math embedded in the procedure than can be conveniently outlined in each lesson's list of processes and skills.

Take advantage of the curricular ambiguity inherent in linking disciplines, as it provides for more malleable lessons. The amount of science, math, art, literature, and so on that you include in your lesson depends on your pedagogic style, curriculum needs, and comfort level with the material. Students' backgrounds, interests, and goals should also come into play. In short, the depth and breadth of interdisciplinary connections is entirely up to you and your class, thus allowing for a customization of experience and meaning.

The *ALSM* lesson structure essentially provides a framework for students to do much of their own exploring and discovering. Start by introducing an idea or concept via a question, demonstration, or simple activity. This technique both engages your class and allows you to check for background knowledge and interest in the topic. Then, together with your class, proceed through the lesson, step-by-step. Students, who are often broken into small cooperative groups, collect, analyze, and discuss data, then share their reactions and insights. You have no particular script to follow, but modeling inquiry and problem-solving strategies in your own approaches to the activities is highly encouraged. The step-by-step directions are specific enough for you to easily work through the activity, yet general enough to allow for adaptations as necessary.

Assessment

Standardized or traditional assessment methods are usually inappropriate for evaluating integrated, problem-based tasks such as those that appear in this book. More suitable means of assessment have therefore been included for each lesson. These methods may be termed *authentic assessment*, or methods of evaluation that are well matched to experiential tasks. These methods include the following:

1. *Embedded assessment*. This technique blends assessment and instruction into a seamless whole, rather than following the traditional teach-test-teach-test format. In embedded assessment, you observe students as they participate in activities, looking for mastery of desired skills, processes, and content understanding. This sort of observation is facilitated by asking students questions about their experiences as they participate, such as "What if …?" or "Explain how you know…."

2. *Performance tasks*. Students apply their knowledge as they solve concrete problems in a procedure separate from the instruction sequence. For example, in Activity 8, students conduct an experiment comparing the jumping abilities of small, medium, and large origami frogs. You may assess their understanding of that experimental procedure by evaluating their performance as they test and analyze the jumping ability of a fourth, different size, frog.
3. *Journal entries*. Journals are an effective means of integrating language arts into the study of science and math. In their journals, students can collect and analyze data, explain what they have learned, and reflect on their experiences. Entries could also include illustrations and sketches, enabling you to assess from a nonverbal angle.

Specific assessment suggestions, and associated evaluation rubrics, are provided at the end of each lesson. To gain a more complete perspective of student progress, use several means of assessment within a given lesson. Whatever means of evaluation you choose, however, the assessment must match the instructional task, meaning that as you evaluate students in these wide-ranging investigations, you should do more than simply assess vocabulary acquisition and concept memorization with conventional techniques.

Safety Issues

During the implementation of the *ALSM* lessons, safety issues are of utmost importance. Use appropriate laboratory procedures while undertaking the activities, not only for the students' immediate safety, but also for the development of their lifelong safety habits. Specific safety considerations have been included for each lesson, and *The NSTA Ready-Reference Guide to Safer Science* (Roy 2007) is an excellent resource for further reading. Essential safety recommendations include the following:

1. Keep the work area clean. Clean up all spills immediately. Clean and store equipment and materials after use.
2. Never taste unknown chemicals. Always sniff gases cautiously. Store materials appropriately and safely.
3. Wear protective eyewear when working with hazardous substances or in any hazardous situations.
4. Be especially careful with electricity.
5. Provide constant supervision during individual or group work.
6. Allow sufficient time to complete tasks without rushing.

7. Provide sufficient lighting and ventilation.
8. Keep safety in mind when undertaking any ALSM or other investigatory activities.

It is vital to remember that "the best piece of safety equipment in your classroom is you—the informed adult shaping and controlling the learning environment" (Roy 2007, p. xiii).

Breaking Down Each Activity

The *ALSM* activity format is broken into a number of sections, each providing important information at a glance. Before trying the activity in class, read the entire lesson to facilitate choices of questioning strategies, modifications, assessment, and overall implementation. Practicing the activity ahead of time also minimizes mistakes and confusion during the classroom presentation. What follows is an explanation of each section of the activity format, as well as suggestions for use.

- **Overview:** A concise description of the activity that helps you determine where it may fit into your curriculum.
- **Processes/Skills:** A list of the processes and skills that students can be expected to employ as they participate in the lesson.
- **Recommended For:** A recommended grade range is provided for each lesson, but the lessons can be easily adapted for either younger or older students. In general, for younger students, simplify the use of terminology, eliminate or adapt procedures requiring fine motor skills, break the duration of the inquiry into shorter segments, and be sure that the lesson proceeds in a clear, orderly, and sequential manner. For older students, expand on the terminology and concepts, provide deeper connections to other disciplines, and offer opportunities for individual exploration, perhaps extending to investigations that can be undertaken outside the classroom (e.g., home, neighborhood, museums). A recommendation for individual, small group, or whole class instruction is also given.
- **Time Required:** An approximate time range for completion of the lesson that will, of course, vary from class to class and that should be considered only a rough estimate. Longer activities, or portions of activities, can be carried out over several days rather than all in one session.
- **Materials Required for Main Activity:** A list of just what materials are needed for the Main Activity as well as for any follow-up activities. Gather and, when necessary, assemble all materials prior to teaching the lesson—nothing ruins a well-organized plan as quickly as a missing item.

- **Connecting to the Standards:** A list of the standards related to the activity. The standards are also noted in the margins of the Step-by-Step Procedures at their main points of use, though they may well apply in several locations within a given activity. Complete discussions of each standard can be found in *National Science Education Standards* (NRC 1996) and *Principles and Standards for School Mathematics* (NCTM 2000).
- **Safety Considerations:** A warning of potential safety issues associated with the lesson. Familiarize yourself with classroom safety procedures and policies.
- **Activity Objectives:** A statement of performance objectives that students can be expected to reach during the lesson.
- **Background Information:** Conceptual information and explanations of terminology, when needed. In some cases, background information is included within the Step-by-Step Procedures.
- **Main Activity, Step-by-Step Procedures:** Sequential and ready-to-implement steps, which are adaptable to fit the needs of each classroom.
- **Discussion Questions:** A crucial aspect of the *ALSM* lessons is attention to your questioning strategy. Thought-provoking discussion questions are provided within the procedure and in this separate section following the procedure to promote the development of higher-order thinking skills, synthesis of disciplinary interconnections, and a deeper overall understanding. You should also develop your own queries, using a range of open- and closed-ended questions to stimulate students' critical thinking. Be careful not to dwell too much on or give away "the right answers," however, because an essential aspect of these lessons is that students have a chance to participate in the process of inquiry.
- **Assessment:** Several specific means of evaluating student progress and, in parentheses, suggestions for using the general method(s) of evaluation. Rubrics are provided for each lesson. In informal assessments, also include aspects of the affective domain, such as whether students are having fun and acting interested.
- **Going Further:** For some lessons, a connecting activity to expand the basic lesson into another subject area, particularly the visual arts.
- **Other Options and Extensions:** Additional ideas for extending the basic lesson. These can be pursued with the class as time allows, or they can be made available to individual students as homework, independent investigation, or a foundation for further study.
- **Resources:** Citations for articles, books, and other supplementary resources.

Final Thoughts

It is, indeed, possible to maintain high academic standards while "loosening up" your curriculum to include the natural connections among disciplines. Interdisciplinary connections are not simply interesting side trips; rather, they represent the foundation for lifelong understanding, curiosity, and problem solving. Science and mathematics reinforce each other, each discipline drawing upon the techniques and tools of the other and offering students experiences and awareness that are greater than the sum of the parts. By linking science with math we enhance comprehension and appreciation of both. Help students appreciate science and mathematics not just as topics to be studied in school, but as vital, interrelated elements of their everyday lives.

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KEY INSTRUCTIONAL STRATEGIES USED IN EACH ACTIVITY

Activity	Hands-On	Minds-On	Guided Discovery	Experiment	Learning Cycle	Open-Ended Challenge	Project	Metacognition (Reflective Thinking)
1 Textures	X		X					
2 Visual Observation	X		X					X
3 TV		X						X
4 Möbius Band	X		X					
5 Alphabet Taxonomy	X		X					
6 Museum	X						X	X
7 Art Projects	X						X	X
8 Force and Motion	X			X				
9 Boats	X			X				
10 Magnets	X			X	X			
11 Chromatography	X		X			X		
12 Surface Tension	X		X	X				
13 Acids and Bases	X		X					
14 Soil	X		X					
15 Rocks	X		X			X		
16 Evaporation	X		X	X				
17 Colors	X		X		X			
18 Fingerprints	X		X			X		
19 Vegetable Prints	X		X				X	
20 Apple	X		X				X	

+Physical Science

Activity 9
What Makes a Boat Float?

Overview
Whether or not a boat floats is determined by its shape and density. In this activity, students discover how and why boats float by designing different hull shapes and finding which design holds the most weight. Students record, calculate, and interpret data as they learn about buoyancy in this hands-on activity.

Processes/Skills
- Observing
- Problem solving
- Predicting
- Describing
- Analyzing
- Concluding
- Measuring
- Calculating
- Inquiring
- Communicating
- Recognizing shapes and patterns
- Developing spatial sense
- Cooperating

Recommended For
Grades 3–4: Small group instruction
The lesson can be simplified for students in grades K–2 by using only one or two pieces of foil, offering more boat shape ideas, simplifying the vocabulary

appropriately, and minimizing the math involved. Younger students can still make predictions and design and test boats, and with your help they can create a bar graph of shape versus pennies held. Another option would be to conduct the activity for younger students as a teacher-led demonstration.

Time Required

1–3 hours

Materials Required for Main Activity

- Modeling clay
- Aluminum foil
- Small tubs of water
- Small weights (pennies, metric weights, metal washers, or any small, standardized objects)
- Metric rulers
- Calculators
- Graph paper

Connecting to the Standards

NSES

Grades K–4 Content Standards:

Standard B: Physical Science

- Properties of objects and materials (especially noticing the observable properties of objects and materials, and measuring those properties)

Standard E: Science and Technology

- Abilities of technological design (especially proposing, implementing, and evaluating a solution to a technological problem)
- Understanding about science and technology (especially that investigators can work together to solve problems)

NCTM

Standards for Grades PreK–2, 3–5:

- Numbers and Operations (especially understanding and using numbers, operations, and estimation)

- Geometry (especially identifying, naming, and/or comparing two- and three-dimensional shapes)
- Problem Solving (especially constructing new math knowledge through problem solving)
- Connections (especially noting the valuable interconnections between mathematics and science)
- Representation (especially using representation to record and communicate mathematical ideas and to solve problems)

Safety Considerations

Basic classroom safety practices apply.

Activity Objectives

In the following activity, students

- design and build boats to carry loads and explain why some designs worked better than others; and
- explain why a boat floats, using their own data and the concepts of displacement, density, mass, and volume.

Background Information

Two factors, density and shape, determine whether an object floats or sinks. Density is the relative weight of an object, defined mathematically as the object's mass divided by volume. A more dense object or material has more tightly packed internal particles. A brick, for instance, is more dense (that is, it has more tightly packed particles within it) than a piece of wood (which has more loosely packed particles). A brick is more dense than water, and it will sink. Most wood, however, is less dense than water, allowing it to float. Therefore, it is not an object's weight alone that determines whether it will sink or float: It is the object's weight (really its mass) divided by its volume. A really large piece of Styrofoam (say, 500 kg) will float in water despite its large mass because it is less dense than the water. That is, it has less mass per unit of volume than water. Put another way, if we have two equal volumes (say, 250 cm^3) of Styrofoam and of water, the Styrofoam is lighter in weight (or contains less mass). The Styrofoam is less dense than the water and therefore it will float. Density is related to buoyancy, which can be thought of as the tendency of an object to float in a liquid, or as the upthrust that the liquid exerts on an object floating within it. Dense materials are not very buoyant, and buoyant materials are not very dense.

STANDARDS

The other factor that determines floating or sinking is shape. The shape of an object, like a boat, allows it to push water out of the way, which is referred to as displacement of the water. If a boat, and the air contained in it, displaces more water than the weight of the boat itself, it floats. Large boats and heavy boats, therefore, must displace a great deal of water. If the boat displaces less water than the weight of the boat itself, it sinks. The shape of the boat, then, is crucial in determining how much weight the boat can carry and whether the boat floats (as demonstrated in the following activity). You could say that a boat's shape strongly influences its buoyancy or that a boat's buoyancy is determined by that boat's density and shape.

Main Activity, Step-by-Step Procedures

SCIENCE
Properties of objects and materials
Abilities of technological design
Understanding about science and technology

MATH
Geometry
Problem solving

1. Begin by showing students a small, flattened piece of modeling clay. Bend it into a very roughly shaped boat. Ask students, "Will it float?" Then place the clay into a small tub of water (5–10 cm deep). The clay floats. Next, mold the clay into a tight ball. Ask students, "Will the ball float (after all, it's the same clay)?" Once again, place the clay in the water. This time, the clay sinks. Ask students to conclude what they can about floating and sinking in this situation. Give them a moment in groups to discuss and then listen to their ideas. Obviously the shape matters. Ask students, "Does the boat's size matter?" Demonstrate that the clay can be doubled or tripled in size but will still float if shaped like a boat and will sink if shaped like a ball. The boat's shape matters more than its size.

MATH
Numbers and operations
Communication
Representation

2. Now try an exercise to challenge your students. Provide each student group with three 15 cm × 15 cm pieces of aluminum foil, a pile of pennies, and a small tub of water (you can substitute metric weights, metal washers, or any small, standardized objects for the pennies). Challenge students to design a boat that can float as many pennies as possible (they can shape their boats any way they choose). Each boat has to float with its load of pennies for at least 5 seconds for the trial to count. Encourage students to brainstorm before beginning the activity: What boat shapes are possible? Students must try at least three different boat shapes, predicting how many pennies each will hold before loading the boat with pennies. Then each group runs three trials with each of the three boats and records data in a table (see Activity Sheet 9.1, p. 86). In the table students briefly describe each of three boat shapes that they tried (younger students could draw a picture of the boats rather than describe them in words), list how many pennies each shape held in each trial, and average the

trials for each boat. Finally, groups record and discuss their conclusions. Younger students can generate a bar graph, with teacher help, of the number of pennies held for each basic boat shape.

3. In the next exercise, older and more advanced student groups discover whether the area of the base of the boat is related to the number of pennies that it can hold. Using three more 15 cm × 15 cm sheets of foil, groups perform three trials with each of the three boat designs again (designs should include low, flat boats and tall, slim boats), this time recording the approximate area of boat base (i.e., the bottom of the hull) versus the maximum number of pennies held in each trial. Hull area can be determined using metric rulers, calculators, and area formulas (remind students that the surface area is πr^2 for generally circular hulls, and length times width for generally rectangular hulls). Predictions and data can be recorded on Activity Sheet 9.1. Students can then graph the area of the base of each boat (*x* axis) versus the average number of pennies that it held (*y* axis). Students should look for patterns in the data and the graph, and document their conclusions. (Generally, the wider the hull, the more weight the boat can handle without sinking because the load is spread over a wider area.)
4. Finally, host an open competition for the boat design that can hold the greatest number of pennies. Student groups design and construct their best boat, using what they've learned in the lesson so far. Test all boats in a classwide demonstration to determine the winner. Students can then write their observations, thoughts, reactions, conclusions, and questions in their science journals.

STANDARDS

MATH
Problem solving

Discussion Questions

Ask students the following:

1. With your boat, did the height of the sides matter? Why? In a real boat, would the height of the sides matter? Why? What kinds of boats have wide flat bottoms (or hulls)? What are they generally used for? What kinds of boats have small, knifelike hulls? What are they generally used for?
2. Describe the sort of boat you would want if you were hauling heavy loads of ore on a river. Describe the design you would want if you were trying to race other boats.
3. Of the two factors determining floating/sinking (density and shape), which do you think is more important to boat design, and why?

Assessment

Suggestions for specific ways to assess student understanding are provided in parentheses.

1. Were students able to design and build boats that supported loads, and could they explain, based on their own data, why certain hull designs worked better than others? (Use embedded observations during Procedures 3 and 4 as performance assessments, and use Discussion Question 3 as a prompt for a science journal entry.)
2. Could students explain why a wider hull generally holds more weight and how they determined an answer to that question? (Listen carefully to student responses to Discussion Question 2 as an embedded assessment or as a prompt for a science journal entry.)
3. Were students able to explain how a boat floats, using their own data and the concepts of displacement, density, mass, and volume? (Pay attention to their activity and discussion during Procedures 2–4 as performance assessment and embedded evidence.)

RUBRIC 9.1
Sample rubric using these assessment options

	Achievement Level		
	Developing 1	Proficient 2	Exemplary 3
Were students able to design and build boats that supported loads, and could they explain, based on their own data, why certain hull designs worked better than others?	Attempted to build load-carrying boats, and did so with some success, but were unable to explain why some designs worked better than others	Successfully built several load-carrying boats and could explain why some of their boats worked better than others	Successfully built several load-carrying boats and could explain why some of their own boats, as well as the boats of other students, worked better than others
Could students explain why a wider hull generally holds more weight and how they determined an answer to that question?	Attempted to explain but were unable to do so effectively	Successfully explained the effectiveness of a wide hull but did not apply math concepts or terminology to do so	Successfully explained the effectiveness of a wide hull, and did so by using their own data as well as math concepts and terminology
Were students able to explain how a boat floats, using their own data and the concepts of displacement, density, mass, and volume?	Attempted to explain but were unable to do so effectively	Successfully explained flotation using science concepts but did not apply math concepts or terminology	Successfully explained flotation using science concepts, as well as math concepts and terminology

Other Options and Extensions

Tell students to research boat design using the library or the internet. Ask them, "Do any of the boats you found look like boats that you designed? Explain."

Ask students, "What are some things, other than boats, that float? What makes those objects float?"

Resources

Adams, B. 2006. London Bridge is falling down. *Science and Children* 43 (8): 49–51.

Bloom, S. J. 1994. Data buddies: Primary grade mathematicians explore. *Teaching Children Mathematics* 1 (1): 80–86.

Martin, S., J. Sharp, and L. Zachary. 2004. Thinking engineering. *Science and Children* 41 (4): 18–23.

Saltonstall, S. 1986. Ship shape. *Science and Children* 24 (1): 48–49.

Scheckel, L. 1993. How to make density float. *Science and Children* 31 (3): 30–33.

Schomburg, A. 2008. The better boat challenge. *Science and Children* 46 (2): 36–39.

ACTIVITY SHEET 9.1
What Makes a Boat Float?

1. Prediction: Which boat shape will hold the most pennies? Why?

	Boat 1	Boat 2	Boat 3
Describe the boat's shape			
Prediction: number of pennies boat will hold			
Pennies held, Trial 1			
Pennies held, Trial 2			
Pennies held, Trial 3			
Average number of pennies held			

Conclusions:

2. Prediction: Which boat shape will hold the most pennies? Why?

	Boat 1	Boat 2	Boat 3
Approximate area of hull base (cm^2)			
Prediction: number of pennies boat will hold			
Pennies held, Trial 1			
Pennies held, Trial 2			
Pennies held, Trial 3			
Average number of pennies held			

On a separate piece of paper or the back of this sheet, graph the average pennies for each boat versus the approximate area of that boat's hull.

Conclusions:

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