BY OLAF JORGENSON

What K–8 Principals Should Know About Hands-On Science

IT CAN BE NOISY AND MESSY, BUT STUDENTS LEARN SCIENCE BEST WHEN THEY DO IT THEMSELVES.

When you think of a science lesson with children in the elementary and middle grades, what comes to mind? If your experience as a school leader, teacher, or parent is typical, you probably imagine a teacher demonstrating an interesting experiment with children hovering a safe distance away; or perhaps you envision children with their noses buried in textbooks, passively skimming for answers on a worksheet while the teacher circulates to offer assistance.

Evidence continues to mount that using student-directed inquiry strategies to teach science has produced remarkable gains not only in science but in literacy and math, particularly among at-risk or disadvantaged students. The author presents the results of two recent major research projects, describes a typical hands-on experiment, and provides a listing of resources for implementing inquiry science.

This is not what I would call active science, but it characterizes instruction in the vast majority of K–8 science classrooms nationwide. It is conceivably even more prevalent in schools with high proportions of at-risk or disadvantaged students, where material costs, extensive classroom preparation, and specialized teacher training—all prerequisite to effective hands-on science instruction—are rarely top priorities for principals or school boards dealing with more pressing issues. And the push for standardized test preparation in many school settings does not leave much room for divergent instructional improvement strategies, especially when "covering the content" through direct instruction, texts, and worksheets seems the most expedient approach.

But in an increasing number of schools and school systems, active, hands-on science is gaining momentum and realizing remarkable gains in students' science, literacy, and mathematics standardized test achievement. Two recent major research projects have documented significant improvements in objective test results, which are supported by extensive anecdotal reports spanning more than 40 years of successful inquiry science implementation, all speaking to the power of hands-on, "minds-on" science to engage and interest children, to help them learn and apply scientific concepts, and to make them better problem solvers in other core academic disciplines as well.

What Is Inquiry Science?

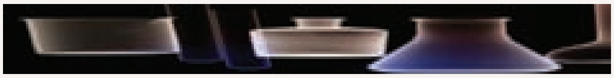
Inquiry-based science instruction is "the creation of a classroom where students are engaged in (essentially) open-ended, student-centered, hands-on activities. This means that students must make at least some decisions about what they are doing and what their work means—thinking along the way" (Colburn 2003). A principal opening the door during an inquiry activity will likely see children working together in groups to complete their own investigations, independently and with considerable excitement, bustle, and noise, with the teacher moving from group to group to monitor and check understanding as the children ask questions, question answers, record data, write observations, ask more questions, and work toward their own conclusions.

The National Science Teachers Association (NSTA) recommends that 60 percent of instructional time in elementary science classrooms, and 80 percent in middle school science courses, be spent in active investigations. This idealized recommendation stands in stark contrast to the reality of K–8 science classrooms nationwide, where it is estimated that on average 80 percent of instruction is dominated by seatwork, textbook and worksheet activities, and occasional teacher demonstrations (NSTA 2001).

While comparatively rare in many K–8 science classrooms, inquiry-based instruction is central to the National Science Education Standards (NSES), which assert that "learning science is something students do, not something that is done to them" (NRC 1996). Active science enables students to acquire valuable skills through their interaction, collaboration, and problem-solving with other students—skills that cannot be learned sitting at desks and listening to a teacher.

Science in a Box

More than 40 years ago, teachers in the Highline Public Schools of Seattle, Washington, discovered, like others before and since, that when children actively engage in science investigations, they are much more enthusiastic and involved in learning, compared to those who passively read about science or watch teachers conduct experiments. They were able to grasp scientific principles and concepts much more readily when they played a part in the actual processes. What's more, they began to see science as "fun" rather than a chore, and looked forward to



"Learning science as a process, rather than a database of facts, is analogous to learning to play a musical instrument; we don't expect students to pick up piano by reading about it or watching the teacher play. These activities might be part of the overall strategy, but the students have to 'do' piano in order to play it."
(Jorgenson *et al.* 2004)

the hands-on lessons—which was exciting for the teachers, too!

Seeking to share their effective and popular "hands-on" student-led science activities, the Highline teachers designed boxed, self-contained science units, including materials and instructions for the teacher. Today, versions of these pioneering science kits are available from a range of vendors who package and ship ready-to-use units that are aligned to the national standards and integrated with reading, writing, and math activities as well.

These kits, which range in cost from a few hundred to several thousand dollars, cover such topics as liquids and solids, force and motion, and habitats and ecosystems. Units within each kit allow teachers to extract individual lessons or activities, or extend a single unit of study across an entire school term. The kits are reusable, with many items, such as cotton balls and rubber bands, readily available at low cost. Some school systems have saved money by developing their own science kits.

In school after school that has used kits to implement inquiry-based science programs, student and teacher enthusiasm for science instruction skyrockets. In the Mesa, Arizona, public schools, where inquiry-based science was implemented into the elementary grades over a period of 35 years, there are no science textbooks in grades K–6. Kit-based instruction engages young students so effectively that several years ago, when science was inadvertently listed as "optional" on a seventh-grade pre-registration form at one junior high school, only 4 percent of students from a feeder elementary school that was then using traditional text-based instruction enrolled—compared with 96 percent of sixth graders from a feeder school with an inquiry-based program.

What the Research Shows

While there has been little research to determine the quantitative benefits of inquiry science, there is a growing body of anecdotal evidence supporting its positive impact on academic performance as measured objectively on standardized tests. Research comparing schools with hands-on, student-centered science instruction versus more traditional teacher-directed, textbook-based science instruction demonstrates considerable student achievement gains for those in hands-on programs. For instance, data from a study in Wisconsin show that after three years of inquiry science instruction, K–8 student test scores on the state's standardized science achievement tests improved from 55 percent of students scoring "proficient" or "advanced" to 80 percent.

In the Cornerstone Study conducted by The Einstein Project, a nonprofit science education cooperative, results at five schools showed that 81 percent of the students who regularly engaged in inquiry activities attained mastery of science terminology, compared to only 20 percent of students at five control schools who did not use inquiry methods.

In a study of schools in El Centro, California, a high-poverty, high-ethnicity, traditionally low-performing district near the Mexican border, four years of data collection on inquiry science instruction had an amazing impact on K–8 student achievement in math, reading, and writing, as well as science. El Centro sixth graders (overwhelmingly English language learners from high-poverty family backgrounds) who were engaged in inquiry science for four years scored approximately 35 percent higher in math and 28 percent higher in reading, on average,

A Hands-on Experiment

A fifth-grade inquiry-based lesson begins with a question from the teacher: "How many drops of water will fit on the head of a penny?"

The students then cluster in small groups around separate table stations, with each assigned a particular task, such as "researcher," "observer," or "recorder." Using droppers in various shapes and sizes, water at different temperatures, and pennies in varying conditions, they begin by first predicting how many drops they think will fit on the penny. They then conduct multiple trials, recording the results of each on a graph provided by the teacher, who moves from group to group, asking questions and redirecting rather than correcting or providing answers.

When they have finished experimenting and discussed their findings, the students take some quiet time to write their findings in their lab notebooks, answering questions like, "Was the outcome what you expected, and if not, why not?"

In the next class session, the teacher sets up the graphs and leads the students through a comparison of each group's results. The goal is to have students begin to notice the role of variables and to identify not only the variables involved in the experiment—the dropper sizes, water temperatures, and coin conditions—but others, such as which side of the coin was used and the coin temperature. The discussion typically becomes lively as the students "get it" about the scientific concept of variables and fire off more questions before applying their newfound knowledge to another hands-on project.

than their classmates who had not been exposed to inquiry-centered science instruction. On their writing proficiency exam, sixth graders who had not received inquiry science instruction scored 23 percent, while those who had been taught using the hands-on methods for the full four years of the program scored 89 percent (Klentschy *et al.* 2001).

As study leader Michael Klentschy explains, "the skills of reading and mathematics are strengthened when taught using engaging, high-interest content" of inquiry science (2001). El Centro's high concentration of English language learners benefited from the inquiry methodology because it afforded a meaningful context for the complex science vocabulary that appears on standardized tests, and because active science in El Centro involves extensive use of lab notebooks.

Evidence from El Centro and other sites demonstrate that while active science instruction benefits all students, it offers particular promise for closing the science achievement gap between underprivileged and more advantaged students. Research data are bolstered by countless teacher testimonials and hundreds of case studies documenting decades of successful inquiry-based science instruction. Inquiry science offers remarkable promise for children in any school setting.

That said, it's important to note that even those who advocate the inquiry approach would not argue for its exclusive use. In fact, the NSTA recommends a blend of direct and inquiry-based strategies in effective science instruction. This is in part because some learners respond better to one approach than the other, and teachers need to differentiate instruction based on their students' needs.

Resources for Implementing Inquiry Science

National Science Teachers Association (**www.nsta.org**)
NSTA is a professional organization for science educators which offers a wide range of benefits and resources.

National Science Education Leadership Association (**www.nsela.org**)
NSELA provides information and resources on a wide variety of topics (student learning, safety, curriculum, technology, professional development, assessment, inquiry, and science education reform).

American Association for the Advancement of Science (**www.aaas.org**)
AAAS developed Project 2061, the nation's first plan for science education reform, which widely impacted American science education. AAAS publishes the highly regarded professional journal, *Science*.

National Science Resources Center (**www.si.edu/nsrc/**)
NSRC, operated by the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and the Smithsonian Institution, disseminates information about exemplary science teaching resources, develops curriculum materials, and provides training (especially leadership and technical assistance) to promote hands-on science. (See LASER)

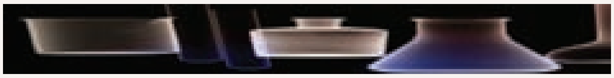
Leadership Assistance for Science Education Reform (LASER) (**www.si.edu/nsrc/about/about.htm**)
The NSRC, the Smithsonian, the National Academies, and several corporate sponsors offer this intensive one-week institute in Washington, D.C. and a number of regional locations. LASER trains teams of educators, community members, and business partners in the five building blocks of science reform: curriculum, assessment, developing community and administrative support, professional development, and materials support.

Association of Science Materials Centers (ASMC) (**www.ces.clemson.edu/aophub/**)
A LASER affiliate, ASMC provides the Next Steps Institute in cooperation with several corporate sponsors to focus on implementation issues surrounding the five areas of reform. The NSI is a valuable and popular follow-up training for those who attended LASER and are dealing with challenges in implementing their science strategic plans.

Planning for Inquiry Science

Because it involves fundamental changes in the way science is supported, structured, and delivered, a shift to inquiry methodology needs to be widely discussed and deliberately planned in a school community. Implementing inquiry science involves a considerable investment of time and resources across a school's constituencies: parents need to understand why textbooks will be used less frequently; site and central office administrators need to budget for the considerable initial expense in purchasing science kits, and the ongoing cost of refurbishing them; teachers need instructional training; and principals need to understand what they can expect to see when they visit classrooms during inquiry investigations. The transition to inquiry should be gradual, with perhaps one or two teachers implementing a unit each at first.

Fortunately, comprehensive training is available covering the five building blocks of inquiry science reform: curriculum; assessment; developing community and administrative support; professional development; and materials support. Each year, the National Science Resources Center, the Smithsonian



Sources for Hands-On Science Materials

Activities Integrating Mathematics and Science (AIMS)
www.aimsedu.org

Biological Sciences Curriculum Study (BSCS)
www.bscs.org

Foundational Approaches to Science Teaching (FAST)
www.hawaii.edu/drdg/FAST.pdf

Full Option Science Systems (FOSS)
www.delta-education.com

Great Explorations in Math and Science (GEMS)
www.lhsgems.org or **www.carolina.com/GEMS/**

Investigating Earth Systems (IES)
www.its-about-time.com

Prime Science Middle School, INSIGHTS, and Science 2000+
www.kendallhunt.com/elhi

Science and Technology Concepts for Middle School (STC/MS)
www.carosci.com/stc.htm

Science Education for Public Understanding Project (SEPUP); Science and Life Issues (SALI)
www.lhs.berkeley.edu/sepup/

Institution, the National Academies and several corporate sponsors offer intensive one-week LASER (Leadership Assistance for Science Education Reform) institutes in Washington, D.C., and a number of regional locations. LASER trains teams of educators, community members, and business partners from individual schools, and brings the teams into a network of more than 1,000 schools and districts around the world that have successfully implemented K–8 inquiry science instruction. During a very full week of training and networking, the LASER teams develop individualized strategic plans under the guidance of educators and consultants who have led successful implementation in other schools, and lay out timelines for the transition to kit-based active instruction,

Where Do We Begin?

As many principals know, a good first step in any instructional change initiative is to bring a small group of interested constituents—teachers, parents, administrators, community leaders—together to examine school needs and priorities, and to gauge interest and commitment levels.

Are you happy with the way science is taught in your K–8 grades? Are teachers and parents aware of what best practices research says about the potential for expanded science engagement and achievement with inquiry methods? Is there an interest in learning more? The next step is to rally support from school and community leaders to pursue training, such as LASER or a comparable workshop provided by a recognized science education organization, such as NSTA.

It's important to note that even with adequate training, networking, and access to resources, not all inquiry implementation efforts succeed. Change is difficult because educators tend to be risk-averse and many are suspicious of the fads that often wash through our profession and leave little of lasting value in their wake. Inquiry science requires a sizeable initial investment of time and resources, and also demands that teachers relinquish some control over the learning process—which for many is a formidable challenge in itself. Add to that the fact that the inquiry science experience for teachers and children is very different from what most of us have been conditioned to expect in K–8 classrooms.

As science educator, author, and consultant Larry Blaine observes, hands-on science is basic, but it takes some getting used to:

- Science smells. It also goes bump, boom, and makes other noises.
- Science is found everywhere, not just in textbooks.
- Science is noisy and may appear out of control.
- Science teachers teach skepticism.
- Science teachers bring science into the other content classes.
- Science teachers introduce students to scientists, both present and past.
- Science teachers keep parents involved.
- Science teachers do not resist trying new things.
- Science teachers shouldn't bite off more than they can chew (Blaine 2001).

Inquiry-centered methodology embodies a powerful instructional initiative with the potential to profoundly impact how well and how eagerly teachers teach and children learn science. How often do school leaders encounter an instructional strategy with four decades of success and a growing body of empirical research to fully support its implementation? The transition to inquiry science is a challenging prospect for many school communities, on a number of levels—fiscal, philosophical, motivational, logistical—but given the extraordinary and widely demonstrated possibilities, it is an investment that promises to pay off endlessly for the schools and communities we serve. ■

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