Introduction to Place-Based Science Teaching and Learning

INTRODUCTION

Science education in elementary and middle schools was not widely taught in the United States until the beginning of the 20th century. At that time, science began to be integrated into instruction as part of the Progressive Education Movement. Individuals such as John Dewey included science instruction as a central feature of his curriculum. As explained in his 1922 book, *Democracy and Education*, "The chief opportunity for science is the discovery of the relations of a man to his work—including his relations to others who take part—which will enlist his intelligent interest in what he is doing." (Dewey, 1922, n.p.) In other words, science in the schools connects the child to the real world of work and others. As a result, science not only serves to teach students practical skills, but group and social skills as well.

Students at the University of Chicago Laboratory School creating a garden, 1904

Dewey included science activities, such as raising animals, gardening, cooking, and examining the workings of everyday machines, at the Laboratory School he started in 1892 at the University of Chicago. This represented perhaps the earliest inclusion of placed-based science in primary schooling in the United States, the integration of locally relevant scientific knowledge with the experience of the child. This differed significantly from the standard practice of the day, which, according to Dewey, isolated "science from significant experience." Dewey felt strongly that most students learned a type of science that was not connected in meaningful ways to their world. As a result, the child "acquires a technical body of information without ability to trace its connections with the objects and operations with which he is familiar—often he acquires simply a peculiar vocabulary" (Dewey, 1922, n.p.).

Dewey's criticisms resonate strongly with the condition of contemporary science education in the United States with its overemphasis on generic standards and teaching to a single high-stakes assessment. While the reforms of the last few decades in science education have emphasized the importance of laboratory experiences and hands-on inquiry science, they have not adequately connected scientific curricular content to the lived experience of students beyond the classroom. Indeed, many students still complete their education in science having primarily learned that science is little more than a "peculiar vocabulary." Once again, Dewey's ideas about science in *Democracy and Education* become extremely relevant. Arguing that while laboratory experimentation was "a great improvement" on exclusive textbook instruction, it was not sufficient to promote scientific learning that would become part of the student's larger experience and worldview. As he explained: "Physical materials may be manipulated with scientific apparatus, but the materials may be disassociated in themselves and in the ways in which they are handled, from the materials and processes used out of school" (Dewey, 1922, n.p.).

This is the key to the importance of place-based education in science. For elementary and middle school students, science will be more likely to take on significant meaning when it is related to the communities in which those students live and to other aspects of their day-to-day life. That students rarely see this meaning in their school science education is reflected in the current academic performance of American students in science.

TRENDS IN CURRENT SCIENCE ACHIEVEMENT IN THE UNITED STATES

Overall, U.S. students have not performed well in recent decades on international measures of science achievement. In the largest study of its kind, results from the 1995 Third International Mathematics and Science Study (TIMSS) indicated that U.S. students did not perform competitively with students in other developed nations (Schmidt, McKnight, & Raizen, 1997). While 4th-grade U.S. students scored within the cluster of top-performing nations, 8th-grade students scored only slightly above the international average, and 12th-grade students scored among the lowest-performing nations. In other words, the longer students studied science in U.S. schools, the farther they dropped in international comparisons.

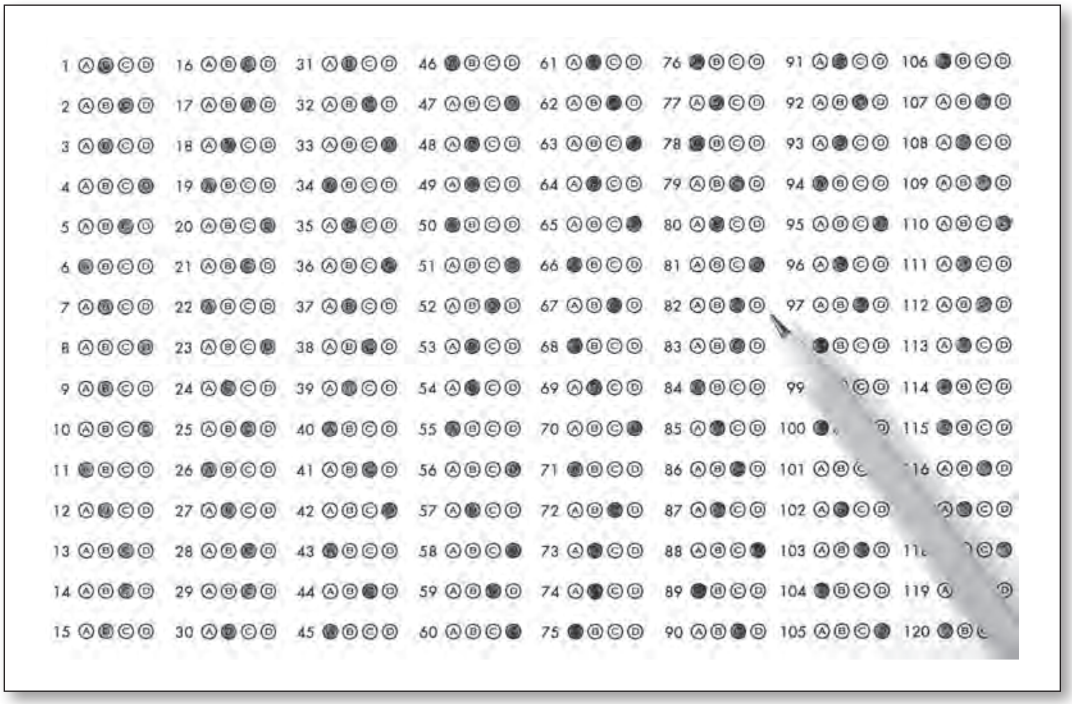
The 1999 TIMSS-Repeat (TIMSS-R) was meant to provide a more detailed comparison of science performance, but it involved only 8th-grade students. As was the case with the 1995 administration of the TIMSS, 8th-grade U.S. students ranked slightly above the international average, placing 18th out of 34 nations (National Center for Education Statistics, 2000). Dishearteningly, American students showed no significant change in science performance between 1995 and 1999, despite the emphasis on implementing systemic science education reforms in U.S. schools during this time period. Additionally, when the TIMSS-R data were disaggregated to show the 14 U.S. school districts that participated in the study individually, striking differences were seen. Several of the more affluent suburban districts scored on par with the highest-achieving nations such as Singapore and Japan, whereas the lower-SES urban school districts performed significantly below the international average, on par with less-developed countries such as Bulgaria and Tunisia.

The most recent administration of the TIMSS was conducted in 2007 and again showed no significant changes for 4th- and 8th-grade U.S. students in international comparisons. Thus, despite major investments in science reform efforts over the past 15 years, science achievement, as measured by the TIMSS, has remained stagnant.

The other major international assessment of science learning is the Program for International Student Assessment (PISA), which tests 15-year-olds. PISA was administered to students in 43 countries in 2000, 2003, 2006, and 2009. PISA assesses students in reading and mathematical and scientific literacy and, unlike TIMSS, strives to assess problem solving and relevant life skills related to the disciplines in addition to basic content knowledge. When it comes to applying science in meaningful ways, such as using scientific evidence, identifying scientific issues, and explaining phenomena scientifically, U.S. 15-year-old students performed in the bottom half of the international PISA comparisons during each of its four administrations (2000, 2003, 2006, and 2009; National Center for Education Statistics, 2009).

At the national level, the National Assessment of Educational Progress (NAEP) provides assessment of U.S. students' academic performance over time for 9-year-olds, 13-year-olds, and 17-year-olds. NAEP science data from the assessments in 1996, 2000, and 2005 show similar trends to those seen in the TIMSS data for U.S. students. Fourth-grade students continued to make steady progress in science. Scores for 8th-grade students remained flat across the three tests, and scores for 12th-grade students in 2005 decreased slightly when compared to both the 1996 and 2000 achievement levels (National Center for Education Statistics, 2005). Again, the pattern emerges that, despite an increased focus on science education in recent years, the longer our children study science in U.S. schools, the less growth is seen in their test performance. One interpretation of these test results that is sometimes given by science educators is that the increased efforts to promote hands-on inquiry science may be improving student learning, but not in ways that are reflected in the assessment items used on large-scale comparative tests such as TIMSS and NAEP. The results of the PISA assessment, however, which goes to great lengths to assess problem solving and real-world application, would seem to refute this interpretation.

In fact, the evidence is that the strongest force currently influencing science teaching in U.S. classrooms is not the push for inquiry-based practices supported by the national professional organizations or the results of national or international comparisons such as TIMSS, PISA, or NAEP, but rather the state-level tests that have resulted from No Child Left Behind (NCLB) and Race To The Top (RTTT) legislation. With the release in 2010 of the Common Core State Standards for mathematics and language arts and their immediate adoption by more than half the states in the nation, the promise of even more curricular and assessment uniformity is on the horizon. While the type of accountability for meeting academic standards emphasized in NCLB and RTTT has a place in education, the reduction of this goal to the simple desire to achieve higher test scores, without sufficient attention to what those scores actually mean in terms of student learning, has become the primary focus in far too many schools and districts. In such a learning environment, the value of local knowledge becomes increasingly marginalized, as it is unlikely to be tested on a statewide assessment.



Standardized test

We are concerned that more and more, students are being trained to become expert test takers rather than engaged learners and creative problem solvers. The world that today's students will live in will require creative problem solving and persuasive communication if we are to overcome the many challenges we will face as a nation and as a planet. Some of those challenges are known, such as climate change and increasing population pressures on natural resources. Other challenges will emerge in the next generation that we cannot conceive of in the present day. In both cases, a large part of the solution to these challenges will reside at the local level. Even global challenges are often most effectively addressed by local action. Climate change, for example, which affects our entire planet, can be ameliorated by small lifestyle changes made by individuals in their communities—changes that can be understood through a focus on place-based science education. Thus, in a very real sense, the current focus on standardized test scores as the only relevant outcome measure of student learning is not only misguided educationally but is also counterproductive to our future well-being. This concern was a primary motivation for us to create a book that promotes placed-based science learning in elementary and middle grade classrooms.

A History of Place-Based Education

Place-Based education is not a new idea. Its roots can be traced back to antiquity and to the Greek philosopher Aristotle's (384–322 BC) notion of *topos*—i.e. (Greek "place"; *pl.* topoi). *Topos* is the root of the English word *topology*, "the study of a given place." Place-Based education was practiced widely during the 19th century. Childhood educators, such as the Swiss Johann Heinrich Pestalozzi (1746–1827) and the German Friedrich Froebel (1782–1852), included models of place-based learning in their early childhood programs. Froebel, the founder of the modern kindergarten, for example, included nature study, gardening, folk tales, and similar types of localized content in his curriculum. In the

United States, John Dewey (1859–1952) included place-based knowledge as an essential part of his Progressive curriculum. According to Dewey:

> From the standpoint of the child, the great waste in the school comes from his inability to utilize the experiences he gets outside the school in any complete and free way within the school itself; while on the other hand, he is unable to apply in daily life what he is learning in school. That is the isolation of the school–its isolation from life. When the child gets into the schoolroom he has to put out of his mind a large part of the ideas, interests and activities that predominate in his home and neighborhood. So the school being unable to utilize this everyday experience, sets painfully to work on another tack and by a variety of [artificial] means, to arouse in the child an interest in school studies. . . . [As a result there is a] gap existing between the everyday experiences of the child and the isolated material supplied in such large measure in the school. (1956, pp. 75–76)

At the Laboratory School of the University of Chicago, Dewey and talented teachers such as Katherine Kamp and Georgia F. Bacon developed models of place-based education for both science and social studies. The first day of the school's operation was chronicled by Dewey as follows:

> The building No. 389 57th Street is a new house; has large windows, sunny rooms and is surrounded by a playground. The work of the first morning began with a song followed by a survey of the premises to test the knowledge of the children regarding the use of garden, kitchen, etc. as well as their powers of observation. At the end of the morning each child had completed a paper box for pencils and other materials. A story was told by one of the children and physical exercise concluded the program. (Dewey, 1896, p. 707)

Children learned about regional geography in their social studies lessons, taking field trips to the mouth of Lake Michigan and studying maps in order to understand why Chicago was built where it was and why it became a major commercial and transportation hub. In the science classes, students tended gardens and raised animals such as rabbits.

Sixth-grade students at the University of Chicago Laboratory School building a tabletop town (1904). Students designed and constructed scale models of a topological map (right), a 3-D neighborhood map (left), and a fully constructed home with interiors (center). Courtesy of University of Chicago Laboratory School

In addition to being place based, Dewey's curriculum was also highly interdisciplinary—another model of instruction that has been deemphasized in contemporary schools. Like the child's life, Dewey felt that the curriculum should not be compartmentalized. As a result, activities in science flowed into social studies and literature and *vice versa*. The educational models that Dewey developed at the Laboratory School made their way into other educational settings—both public and private. One of the most interesting was the development of the Country Day Movement in private education.

In 1911, Dewey, who had moved to Teachers College, Columbia University in New York City, was contacted by a group of parents from Buffalo, New York, about establishing a private school based on his educational theories. In 1912, the Park School of Buffalo was founded under the leadership of Mary H. Lewis, one of Dewey's students at Teachers College, and a former teacher at the Horace Mann School, which was the Laboratory School for Columbia University.

A first-grade "farm" at the Park School of Buffalo, 1915

Lewis's educational experiment in Buffalo began in a single house in the city, similar to the Chicago lab school, but later moved to the 60-acre farm in suburban Snyder, a suburb of Buffalo. Lewis recounted her work developing the first Park School in her 1928 book *An Adventure with Children*, a book that is still relevant today for prospective teachers. Lewis's teaching model is grounded in place-based education, an idea she traced back to her work with Dewey at the Horace Mann School. For example, one day she requested from her principal a carpet for her classroom on which she could sit and work with her students. This "magic carpet" transformed her classroom by breaking down the artificial barriers between teacher and students created by traditional rows of desks and blackboards. While today this may seem a common thing for an elementary teacher to do, in 1928, such an approach was unheard of. As Lewis described:

> The attitudes of the children changed completely the moment they set foot on that rug. Language lessons became confidential chats about all sorts of experiences. One day the rug became early Manhattan Island; another day it was the boat of Hendrick Hudson. Unconsciously it began to dawn upon me that the thing I wanted to do was to break up as far as possible the formality and artificiality of my classroom. (Lewis, 1928, p. 4)

Lewis also believed in "open-air education," the idea that children should learn as much as possible outdoors. This was partially due to a concern about unhealthy closed classroom environments, which encouraged the spread of illnesses, but also out of a desire to teach children in more natural settings that would promote curiosity. On the farm in Snyder, Lewis implemented an outdoor-based curriculum in which the children took care of farm animals and raised vegetables and flowers, as well as conducting science experiments in the school's marsh and pond.

The Park School led to the founding of other private schools around the country, including the Park School of Cleveland, the Park School of Baltimore, the Harley School in Rochester, the Park School of Boston, and the Shady School in Cambridge. Lewis's innovative work as an educator is widely considered to be the origin of the Country Day School Movement in the United States (Provenzo, 1998). Her approach represented an early example of place-based education. While this model has remained a cornerstone of the teaching philosophy in many private schools, such as among members of the National Association of Independent Schools, the model has rarely found a foothold in American public schooling.

One exception to this was the Life Adjustment Movement, which gained some popularity in public schools following the Second World War. This movement emphasized the need for students to develop personal identity and life skills—many of which were linked to community activities. This place-based movement spread through parts of the country from the late 1940s through the mid-1950s. The launch of the Soviet satellite Sputnik in 1957, however, led to a push for more "rigorous" mathematics and science education and the rejection of the Life Adjustment Movement in Education.

Another attempt at place-based education was reintroduced into American schools a few decades later. In the early 1970s, Eliot Wigginton, a high school teacher at the Rabun Gap-Nacoochee School, a small private school in Northern Georgia, began a program called Foxfire. Named after a local plant, Foxfire engaged students in producing a series of magazines and books based on their interviews with local community members as a way of preserving local knowledge and folk traditions. The Foxfire model replicated many of Dewey's and Lewis's ideas. Specifically, Wigginton felt that the traditional curriculum failed to engage and motivate students to learn in meaningful ways. He advocated a model rooted in the local community and with a cross-disciplinary focus as a way to generate excitement in his students and provide an authentic purpose for learning.

Students film Joseph and Terry Dickerson in the process of making tar from pine knots at the headquarters of the Foxfire Fund, Inc., c. 1970, Mountain City, Georgia. Courtesy of the Georgia Archives

Even though the Foxfire model was developed specifically in the context of rural Northern Georgia and in a private school setting, the model has been applied in other settings as well—rural and urban, public and private. The Foxfire model promotes "core practices" that are fundamentally place based in nature. These practices include the ideas that learning must be active, that there must be an audience for student work and projects beyond the classroom, that what is learned in the classroom or school must be connected to the surrounding community and ultimately to the broader global environment, and that imagination and creativity must be a central part of students' learning process (Foxfire Fund, 2009).

During the 1990s, groups such as the National Science Foundation and the Annenberg Foundation funded initiatives to support the revitalization of rural education, including a number of projects that built upon place-based models of instruction. More recently, the need for place-based education, especially in science, has been supported by the pressing need for more ecological education in the face of global ecological crises. Individuals such as C. A. Bowers have argued that students need to access the wisdom and knowledge systems of elder generations (such as through the Foxfire model) as well as embracing new ideas and technologies in order to promote "ecojustice." Ecojustice is the idea that social justice is inseparable from questions regarding ecological well-being (Bowers, 2005). Bowers describes ecojustice as including five elements that are particularly relevant to educators:

1. Eliminating the causes of eco-racism;
2. Ending the ecological exploitation of developing nations by the developed nations;
3. Revitalizing public spaces (the "commons") to enhance community life;
4. Ensuring that resources and opportunities are available for future generations based on the ecological choices we make today; and

5. Promoting “Earth democracy”—that is, the right of natural systems to reproduce themselves rather than to have their existence contingent upon the demands of humans. (Bowers, 2005)

Place-Based education clearly resonates with many of Bowers’s ideas. While place-based education has sometimes focused more explicitly on social studies education (oral history interviews and local geography) and at other times has focused more explicitly on science education (animal husbandry or gardening), a framework centered on eco-justice tends to be more integrative, emphasizing the connections between culture and nature and therefore between social studies and science. Global ecological challenges are likely to produce major sociopolitical crises in the coming years, and our educational system should be proactive rather than reactive in preparing today’s students to be able to respond to these challenges.

Other theoretical support for place-based education comes from the research on psychological and anthropological perspectives on learning in context. Cognitive psychologist Ann Brown and cultural anthropologists Jean Lave and Etienne Wenger put forward the idea of “situated learning” in the late 1980s, claiming that learning is inseparable from its physical and cultural setting. They argued that learning can best be promoted through an apprenticeship model where the learner gradually moves from newcomer to expert status within a community of practice. A community of practice could be composed of the students in a classroom, but it could also be a family on a picnic, a Girl Scout troop on a camping trip, or a bunch of kids at a neighborhood swimming pool. In essence, situated learning emphasizes an awareness of authentic contexts, meaningful activities, and worthwhile assessments along with guidance and mentoring by a teacher who serves as a “master learner” and who models learning strategies rather than dispensing knowledge. This view of “situated learning” can be seen as synonymous with place-based education.

Thus, there is a strong historical and theoretical basis for promoting place-based teaching as an important component of modern education. First, such an approach is engaging and motivating for students and teachers. Second, it is relevant to the skills and ways of problem solving that today’s students will need as tomorrow’s citizens. Third, it provides a needed counterbalance to the testing-driven model of instruction that has become dominant in public schools today. Finally, it is more equitable because students in “exclusive” private schools continue to receive this type of engaging education, while students in public schools are increasingly getting an education that focuses on passing an annual series of tests.

While we want students (and teachers) to have fun using a place-based model of science teaching, we also wish to highlight the role that a place-based approach can play in addressing serious educational, social, economic, and scientific challenges. As Thomas “Tip” O’Neill, a longtime Speaker of the House of Representatives in the U.S. Congress, once stated, “All politics is local.” We can help our current students and future leaders get prepared to address the big challenges they will face by helping them explore these challenges today at the local level. This approach has sometimes been referred to as “critical place-based pedagogy” (Buxton, 2010; Gruenewald, 2003) because it combines the traditional local focus of place-based teaching with the attention to social inequities and injustice common in critical pedagogy.

Teachers who take up this model of place-based teaching and learning should be prepared for a change in their classroom and their students. Once we begin to treat our students as the capable thinkers and problem solvers who will be asked to confront tomorrow’s global challenges, it is difficult to go back to traditional fact-driven education. In a sense, if you adopt the approach we are advocating, you are opening up Pandora’s Box and your students are unlikely to let you put the lid back on.

Place-Based Science and Diverse Learners

The school-aged population in the United States continues to grow more racially, ethnically, socioeconomically, and linguistically diverse (U.S. Census Bureau, 2005). For example, the 2007 racial and ethnic makeup of students in U.S. schools was 55% White, 21% Hispanic, 17% Black, 5% Asian/Pacific Islander, and 1% American Indian/Alaska Native (National Center for Education Statistics, 2008). While these figures already represent the lowest percentage of White students and the highest percentage of Hispanic students in U.S. schools to date, this is a demographic shift that is almost certain to continue for the foreseeable future. In terms of socioeconomic status (SES), in 2007, 42% of the nation's K–12 students received free or reduced-price lunch, indicating students coming from homes where the family income was less than $38,200 for a family of four during the 2007–2008 school year (NCES, 2008). Free and reduced lunch data over the past decade indicate an increase in student poverty that is also likely to continue, given both demographic and economic trends.

Today's classroom

Along with the increased growth of minority representation in the U.S. student population is the steady increase in English language learners (ELLs), who can now be found in virtually every school in the nation. Currently, more than 20% of U.S. residents speak a language other than English at home. More than 5.5 million, or 11%, of public school students are categorized as ELL students (NCES, 2008).

There are nearly 9 million Hispanic students in U.S. schools, of which approximately 4.4 million are Spanish-speaking ELL students (U.S. Department of Education, 2007). While Spanish speakers make up approximately 80% of the U.S. ELL student population, there are more than 400 different languages spoken by U.S. students. Increasing concentrations of ELL students have spread into geographic regions of the country that lack a history of educating linguistically diverse populations. Most notably, the 12-state Southeastern region has seen the largest percentage increase of ELL students in the last decade (National Clearinghouse for English Language Acquisition, 2007).

This increasing student diversity is coupled with an increase in the importance of knowledge about science and technology in today's world. In addition to the growing number of professions that require a working familiarity with scientific concepts and technological tools, the future well-being of our society may well be determined by decisions made on the basis of general scientific literacy, as well as more specialized scientific knowledge. Systematic reduction of greenhouse gases, controlling the spread of pandemic viral infections, and combating the obesity and diabetes epidemics in the U.S. are just a few examples of critical social issues that can only be adequately addressed by a scientifically literate public. A model of science education that fosters academic achievement and scientific literacy for all students requires an awareness of cultural and linguistic diversity as it applies to teaching and learning.

For example, with ELL students, instruction in science, mathematics, and social studies can and should explicitly support English language and literacy development (Teachers of English to Speakers of Other Languages, 2006). In reality, however, ELL students frequently are required to engage in academic learning through a yet-unmastered language without the instructional support they need. As a result, ELL students often fall behind their English-speaking peers in content-area learning.

If we believe that all students are capable of high academic performance, then gaps in academic outcomes across racial, ethnic, cultural, linguistic, or SES groups must be understood in terms of inequitable learning opportunities, inequitable resources, and/or differences in engagement and motivation to learn. What, then, as educators, can we do to create more equitable and more engaging science learning environments?

At least part of the answer may lie in place-based education. A major challenge facing many teachers is the disconnection that students often feel between school practices and out-of-school practices. What students are asked to do and how they are asked to speak and behave in school may be very different from their actions, behaviors, and language outside of school. While this is at least somewhat true for all students, it is especially true for many students of color, ELL students, and students from low-SES backgrounds. Students are less likely to actively engage in schooling if they do not see their learning experiences as relevant and meaningful to their lives beyond school. All students bring funds of knowledge from their homes and communities that can serve as resources for academic learning (González, Moll, & Amanti, 2005), yet teachers often miss out on ways to build upon this knowledge. Using a place-based approach, academic learning can be connected to activities that occur in day-to-day living, both in and out of school. When these connections are made explicit and actively promoted, all students are likely to find new reasons to engage in science learning.

Bilingual street sign

For example, Rodriguez and Berryman (2002) have worked with academically at-risk students in U.S.–Mexican border communities, using a curriculum they developed collaboratively with students, to investigate local water quality. Students who participated in the project showed an increased enthusiasm for their science classes and an increased understanding of science content. Perhaps more significantly, they also found that a number of the participating students took additional action beyond school-situated projects, such as testing water in their homes and investigating ways to improve water standards in their communities. Students changed their own water use practices and informed their families of ways to conserve water at home. Having come to see science as relevant to their lives and communities, students then considered scientific investigations as worthwhile activities.

In another example, Rahm (2002) created and studied an inner-city youth gardening program. Participants were middle-school students who had been identified as being at risk of dropping out of school. The research took place as part of a summer 4-H community youth program in which the students earned money by gardening and then selling their produce at a community market. Rahm found that working together in the garden supported youth-initiated planning and decision making, as well as enabling connections among science learning, the community, and authentic work. A wide range of science content emerged naturally from participants' engagement in the gardening activities that the students considered valuable and meaningful. Some students volunteered to continue their gardening projects after the summer program was over.

These modern examples show the value of place-based science education for promoting both student engagement and academic science learning. The approaches share characteristics with Dewey's and Lewis's work from nearly a century ago, as well as

White House Garden

qualities of more recent efforts such as Foxfire and Bowers's model of ecojustice. Modern place-based education fosters community connections in ways that build on local funds of knowledge and develop students' intellectual curiosity and motivation in ways that lead to sustained interest in science. Sustained interest is demonstrated when students pursue self-motivated explorations outside of the classroom or use science in an ongoing way to improve, expand, or enhance an activity to which they are already deeply committed. It could be argued that this kind of ongoing and self-directed engagement is the best evidence of place-based science being a worthwhile instructional approach. As a classroom teacher, however, you must naturally be concerned about how to assess student learning that results from a place-based approach. In the following section, we present a wide range of assessment techniques that can be used with place-based instruction.

Assessing Place-Based Science Teaching and Learning

Place-Based science teaching benefits greatly from a broad view of classroom assessment that includes teacher-directed assessments in addition to the mandated state and district testing. Here, we consider the multiple roles that assessment should play in your classroom and how assessment should be conceptualized in relation to teaching and learning.

Assessment should be viewed as an integrated part of science teaching and learning. The metaphor of a three-legged stool is sometimes used to describe this relationship among curriculum, instruction, and assessment—if the three legs are not in balance or are of unequal length, then the stool will at best be wobbly or worse, completely dysfunctional. When teaching, learning, and assessment are conceptualized and practiced as an integrated system, then the metaphorical stool is likely to be balanced. Too often today, the assessment leg seems to be out of balance with the other two, leading to unsound teaching and learning. While we have integrated assessment into the activities in Parts I through V, we wish to explore the idea that practicing place-based science teaching may require teachers to rethink their classroom assessment practices at the same time that they rethink their curriculum and instruction. Given the current assessment pressures, this may make some teachers nervous, but the research evidence seems clear that place-based science instruction will help students meet the science standards to which they are currently held accountable at the same time that it provides additional benefits.

When students are engaged in projects over time, and when they care about what they are learning, then they are likely to retain that knowledge for a prolonged period. When the tests that count are cumulative, end-of-year tests, then knowledge retention becomes a critical piece of student success. Even if the tests fail to assess higher-order thinking, problem solving, reasoning, or communication skills that are also taught through place-based learning, students are still more likely to retain factual information that they learned 6 months earlier during a stream-monitoring project than facts they learned 6 months earlier from reading a textbook chapter on water quality. The learning that takes place through place-based instruction can be further solidified through a teacher's thoughtful and strategic use of varied assessment strategies.

Teacher-directed Assessments

It is understandable that teachers today may sometimes perceive assessment of student learning as being out of their hands. On one level, this may well be true. State-level assessments have the most visibility and the most significant consequences, both positive and negative, for students and teachers. However, teachers still maintain a great deal of control over their daily classroom assessment and should consider ways in which they can use this teacher-driven assessment as an integral part of students' science learning. Using the stool metaphor we referred to earlier, effective teachers find ways to bring the assessment leg of their practice into balance with the teaching and learning legs. To do this, teachers must come to see assessment not just as something that is done to students but also as a form of knowledge sharing that is done with students.

Norm-referenced and criterion-referenced standardized tests are just two variations of one form of assessment (the on-demand, cumulative test). While these tests are an inevitability, teachers can do much more to conceptualize an assessment system along with their students—one that includes diagnostic assessment of prior knowledge, formative assessment of ongoing learning, and summative assessment of major learning goals and that takes into account skills, dispositions, beliefs, and other measures besides factual knowledge. Multiple uses of assessment have unique objectives that come together to both paint a picture of and contribute to student learning. A focus on place-based teaching can and should influence each element of this assessment system.

Diagnostic Assessment and Place-Based Science Learning

Diagnostic assessments are meant to provide teachers and students with a sense both of students' prior knowledge and of their misconceptions about a topic before beginning a learning activity. It is often the case that many students in a class are already familiar with at least some aspects of a topic and that these parts can be treated more as a review than as a new idea. On the other hand, a diagnostic assessment sometimes reveals that many students in a class do not have a working knowledge of a topic that a teacher assumed was clearly understood. In this case, a responsive teacher backs up and reviews that material before proceeding. For example, in order to engage students in a study of the effects of acid rain on a local pond ecosystem, the students need to have a working understanding of the pH scale. A diagnostic assessment may show that some students have a clear understanding of the pH scale, how it is tested, and how it is related to acid rain, while other students may need some instruction and an opportunity to practice testing and interpreting the pH of substances in the classroom before they are prepared to begin the pond study.

Diagnostic assessment can also provide a baseline for later consideration of how much learning has taken place once a unit or project has been completed. There has been a dramatic increase in the number of district or state diagnostic, or benchmark, tests that are aligned to state academic content standards. These assessments are meant to provide teachers (and school administrators) with tools for checking the progress of students toward meeting state standards and are often meant to serve as predictors of end-of-year testing results. Diagnostic assessments for this purpose are generally of the forced-response (multiple-choice) variety. This is because they are quick, easy, and cheap to score on a large scale. Teachers should not limit themselves to this form of diagnostic assessment in their classrooms. Diagnostic assessments can also support place-based teaching and learning and take a variety of forms, including:

Quizzes—quizzes are well known to all of us from our own days as students. The typical quiz has traditionally been used as a mini-summative assessment, for the purposes of grading, or to promote student motivation and keep the class on task. However, quizzes can also serve as a diagnostic assessment when they are given at the start of a unit of study to assess students' prior knowledge. Diagnostic quizzes can support place-based learning when they are used at the start of a project to gauge what directed instruction might be needed to support students' successful learning during the project.

Concept maps—Concept maps provide visual models of a student's thinking about a given topic. They are meant to show the relationships that an individual or small group perceives between key concepts. In a concept map, concepts are connected by arrows (often called links) that should be labeled to clarify the nature of the relationship perceived by the student. The purpose of a concept map is to make student thinking visible. They are flexible assessment tools that can be used as diagnostic, formative, or summative assessments. By focusing on the links between key concepts, concept maps help clarify how well students understand the hierarchy of ideas related to the topic of study. Concept maps not only serve to assess but also to teach. For example, concept maps can help develop student abilities to draw reasonable inferences from observations, to synthesize and integrate information and ideas, and to learn concepts and theories in the subject area. Concept maps as diagnostic assessments can support place-based learning by providing a map of student understanding of a topic before the start of a project. The map can be revisited, edited, and expanded at the end of the project to allow the students to see how their ideas have evolved.

Journal entries—Journaling provides a safe way for students to express what they may already know about a topic in a private way, without having to risk sounding foolish in front of classmates. Additionally, students have the time to craft a clear statement with supporting details that may be missing from an oral response to a question. Journal responses can provide a range of insights into the depth or lack of student understanding of a particular concept or set of skills. The journal entry can be done the day before the start of a new unit of instruction so the teacher can check the range of student prior knowledge and plan to introduce the topic accordingly. A journal response makes a good diagnostic assessment for a place-based project because it provides an open format for students to share their past experiences relevant to the topic of the project. For example, before beginning a project on where our food comes from, a student could share her experiences with gardening (a question the teacher might think to ask explicitly) but could also share that her father is a truck driver and is gone for a week at a time when he carries produce from Mexico or California (relevant but unexpected prior knowledge).

Interviews/small-group discussions—Interviews can be conducted with individual students or in small groups to explore their depth of knowledge on a topic that will be studied. The key to using interviews or small-group discussions effectively as diagnostic assessment is in asking good questions—questions that probe for both relevant experiences and depth of understanding. Asking students if they have ever planted a garden before is important to know before starting a gardening project but by itself tells the teacher very little about what students actually know about gardening. Individual interviews take a lot of time for a full class of students, so they are generally impractical as a diagnostic assessment. Small-group discussions can be done more easily as the rest of the class is engaged in independent work.

Whole-class discussion—While whole-class discussions are among the most common teacher-lead informal diagnostic assessments, they are generally not highly recommended. They are used because they are quick and give feedback right away; however, they rarely give a balanced picture. This is because the students with the most prior knowledge on the topic are likely to volunteer what they know and students with less prior knowledge are likely to remain quiet. This usually gives a false impression of the typical amount of prior knowledge in the class.

Formative Assessment and Place-Based Science Learning

While diagnostic assessment focuses on what students already know, formative assessment is primarily concerned with the question of how students learn. Formative assessments take place during a learning activity to provide the teacher with ideas about how well students are making sense of the learning goals and key ideas of a lesson, activity, or unit. Formative assessments can be seen as evidence that learning is taking place but should also be viewed as learning opportunities in their own right. Nearly all teachers intuitively use some types of formative assessment as they teach, most typically whole-group questioning, to try to be sure that the class is following the lesson. As was mentioned in the discussion of diagnostic assessment, however, whole-group questioning has serious limitations, primarily because not every student will be questioned, and a small number of students will typically push to answer every question. Additionally, many students do not effectively demonstrate what they know in this format of on-the-spot answers in front of all their peers. Other types of formative assessments are available that may provide a clearer picture of how student learning is progressing. For example:

Think Aloud—In a think aloud, students are asked to say out loud whatever they are thinking while they are working on a problem or task. Think alouds can be used with individual students, pairs, or small groups (generally no more than four students in a group). When using pairs or groups of students, it is generally best to ask one student to act as the problem solver and the other student(s) to act as listeners, asking clarifying questions as needed. The teacher can circulate and listen to students thinking aloud as they work on their problem. While the think aloud strategy is most often used in mathematical problem solving, it is very appropriate for place-based science activities as well. The strategy can be used out in the field or back in the classroom. The important thing is for students to narrate their thinking as they do their work. Note that this is different than a small-group interview in that the students are not responding to questions from the teacher but rather talking aloud to describe their thinking as they work on a problem or project.

Lesson Study—In lesson study, two or more teachers jointly plan, teach, and observe a lesson and collectively analyze student work. One member of the group teaches the lesson, while the other(s) observes students and collects evidence of their learning. After the lesson, the teachers discuss the student learning that was taking place and consider how to build upon that learning in subsequent lessons. Unlike the other formative assessments discussed here, in lesson study the students are not explicitly asked to perform an assessment task. Instead, the presence of additional teachers who are focused on studying student learning during the lesson can provide insights about that learning to the teacher who was running the lesson. Paraprofessionals and other adult volunteers in the classroom can also be taught to do lesson study in order to help the teacher get a better understanding of the learning that is taking place in her classroom. Lesson study is especially appropriate for place-based science projects that involve leaving the classroom since these trips will generally require additional adults for supervision in any case. Those adults can do more than just supervise; they can also help to provide formative assessment.

Exit slips—An exit slip (also known as a "ticket out the door") is a short form of formative assessment that can be used at the end of a lesson to help the teacher gauge student understanding of one or two big ideas that were presented in the lesson. This insight can then guide planning for the subsequent lesson. Students write a one-sentence summary on a slip of paper of what they feel was the most important thing that they learned during the day's lesson and hand it in on their way out the door. Alternatively, the teacher can ask one question for the students to respond to on their exit slip. Teachers will get a clear and immediate picture of whether or not they successfully conveyed the big idea they were trying to present in the lesson. A journal entry can be used in much the same way but to capture a bit more detail. Using an exit slip on a regular basis also gets students in the habit of summarizing what they are learning in their own minds as the lesson progresses, since they know that they will be asked to write this down at the end of class. Exit slips are appropriate for place-based teaching since they provide the flexibility for the students to choose for themselves what they feel the most important idea of the lesson was. Putting more responsibility on students for thinking about the value of what they are learning is well aligned with the goals of place-based education.

Performance assessments—In a performance assessment, students are asked to demonstrate their ability to use a particular tool or technique. Performance assessments are common in science classes that emphasize experimentation since the proper use of the tools and techniques is essential to successfully doing experiments. Typical examples of a performance assessment would be demonstrating the ability to focus a microscope and identify an amoeba or being able to do a hardness test to differentiate between the minerals quartz and calcite. While performance assessments are common in college lab science courses, they are less common in K–12 teaching. Additionally, the current push toward more fact-driven science standards has further decreased the perceived value of performance assessments in many cases. Performance assessments are appropriate as formative assessment during place-based learning, however, due to the emphasis on the use of tools and techniques that often go along with place-based projects. Tracking the weather, monitoring water quality, using bird identification charts, and many other activities presented in this book require students to master the use of tools.

Summative Assessment and Place-Based Science Learning

Summative assessments are meant to provide a measure of cumulative learning over time and are given at the end of a unit of study to assess mastery of key concepts or ideas. Summative assessment is what generally comes to mind first when assessment is discussed. The most traditional methods of summative assessment are written unit tests and term papers, but a range of other summative assessments are possible. There has been a push in recent years for teachers to model their summative assessments after the state high-stakes tests that students will take at the end of the year to give them more practice with this format. While students do need practice with these formats, the increase in district- and state-mandated benchmark tests means that students will already get plenty of practice with standard forms. As a teacher, you should guard the flexibility that you still have when it comes to assessment. Be sure to use that freedom to ensure that your students get access to a balanced variety of assessment styles, as this will improve their learning and your teaching. The following list is certainly not exhaustive, but it provides examples of varied summative assessments that can support the goals of place-based teaching and learning. Additionally, some of the assessment styles that were discussed under diagnostic and formative assessments above can be extended over time to serve multiple assessment purposes, including as a summative assessment. The example of concept maps used in this way is given below.

Multimedia presentations—Multimedia presentations using PowerPoint or other similar software have become a ubiquitous part of teaching, replacing the traditional notes presented on the chalkboard. More and more, students are being asked to do the same kinds of presentations to demonstrate their learning. Such presentations can foster creativity and problem solving and show the connections students are making between school learning and the real world, but they rarely do. Instead, student multimedia presentations frequently just summarize and restate factual content without reflection or synthesis of ideas. As a way to assess place-based learning, teachers can encourage students to create multimedia presentations that both document activities that were done beyond the classroom and reflect on what was learned from those activities. The rest of the class can participate in assessing how well the presentation moves beyond the restatement of facts to include the synthesis of ideas.

Video or photo projects—A video or photo project can be used to document student learning in a visual format. This format may allow some students to more easily share what they have learned. All students must learn to express their understanding in writing, but since most assessments will continue to be in written form, using assessments that draw on a wider range of media can provide a clearer picture of what students have learned and makes for a fairer assessment system. Some teachers are hesitant to use video or photo projects as assessments because students sometimes spend too much time working on the aesthetics of the project and fail to dedicate enough time to the substance they are presenting. Usually, this problem can be addressed by giving clear assessment guidelines and a clear rubric that is explained to students in advance. There are many assessment rubric templates available on the web for project-based multimedia that can be easily modified to meet your needs. The most important thing, however, is that the video or photo project should demonstrate how the students made sense of what was learned. Place-Based education is well suited to this type of assessment since the focus will generally be on a project that encourages students to take ownership of their learning and apply it in some way.

Series of concept maps—Concept maps were described earlier as a form of diagnostic assessment, but in fact, they are quite flexible assessment tools. They were designed to serve multiple instructional and assessment purposes. Concept maps can provide a visual image of what students already know about a topic (diagnostic assessment). They can then be revisited, edited, and expanded during instruction to serve both as a teaching tool and as a formative assessment. Finally, new concept maps can be drawn at the end of a project or unit of study and compared to earlier maps to document growth and development of understanding of a topic. Assessing learning through a series of concept maps can be aligned with the goals of place-based education in that concept maps highlight the relationships between ideas, and place-based teaching encourages students to make connections between their local environment and academic learning.

Exhibits or museum-style displays—In Part V we use the example of museum visits as a source of place-based learning in the community. When students visit a museum, they notice that there is a style to the learning that takes place there that is different from classroom learning. It is more flexible and free flowing. You are free to wander about and spend as much or as little time as you like thinking about and perhaps interacting with a certain topic. Students will also notice that some museum exhibits draw them in to learn more while other exhibits cause them to walk by. This understanding of how and why we learn in informal contexts can be put to use in student assessment. Having your students construct their own science museum exhibits and then sharing them with parents or other classes can be both a powerful learning experience and a powerful summative assessment tool. Students can design interactive exhibits to specifically address topics that they found confusing or challenging when they were learning them. This can help the students to develop a deeper understanding of a topic they struggled with as they consider how to teach this idea to others. A good science museum exhibit is informational and engaging and leaves you wondering something as you walk away. These serve as good evaluation criteria for a summative assessment and are well-aligned with the goals of place-based education.

Mock scientific conferences—Once students have engaged in a place-based science learning project, they should have something to share about what they learned. This could be information about plant growth in a garden, rock types in buildings downtown, the duck population in a local park, or any of a wide number of topics. Students should learn that when scientists have findings to share, the first thing they usually do is present those findings at a scientific conference. This allows them to present their results to an informed audience who will ask them questions and push their thinking. In the same way, a mock scientific conference in the classroom makes a meaningful summative assessment that can be informative and fun. A conference allows students to share opinions, support ideas with evidence, and demonstrate their understanding of key issues. It also provides an opportunity to teach the importance of skills such as listening carefully, respecting others' ideas, communicating clearly, evaluating ideas, and asking good questions. A mock scientific conference is well aligned with a place-based teaching model since students are asked to take ownership of the assessment rather than just being passive recipients of a test.

Peer teaching lesson to younger students—It is an old saying that the best way to be sure that you understand something is to try to teach it to someone else. Having students teach a lesson on what they have learned to other students a year or two younger than they are can serve as a powerful summative assessment. Students will learn that it takes a lot of preparation to teach a lesson even once they have figured out what they want to teach. It is generally best to have students try this in groups of three or four, and the class of younger students may also be split into smaller groups. Be sure to give your students ample time to prepare so that you are not setting them up to fail. Help them think about setting a reasonable learning goal, the materials needed, the timing of the lesson, and even how they might assess their "students'" learning in a creative way. Be sure that they have something active for the younger students to do. As a class, discuss how peer teaching demonstrates their own learning and how that could be assessed. Peer teaching as summative assessment can support the goals of place-based education because, like the other examples given here, it places some of the responsibility for considering how they will demonstrate their learning on the students themselves.

Assessments and Nonmainstream Students

Given the high-stakes nature of science assessment in our schools today, it is crucially important to consider whether assessments are fair for all students. In particular, concerns have been raised about the fairness of assessments given the increasing cultural and linguistic diversity of students in U.S. schools. Are the assessments we are using to decide students' futures biased in ways that we are not considering? These questions are true for state-level standards-based tests, but they are also true in your own classroom-level assessments. Are the assessments you are using fair? Fairness in this context can be thought of as the probability that a given assessment will allow all students to adequately demonstrate what they have learned about the topic being assessed. Assessments that are aligned with place-based teaching may improve the fairness of assessments for nonmainstream students. This is because place-based teaching more easily builds on students' prior knowledge from family and community settings. If assessments, whether diagnostic, formative, or summative, also build on these community-based experiences, then they are likely to provide better and fairer measures of what and how well nonmainstream students are leaning.

Assessments should be particularly attentive to social, cultural, and linguistic influences that might affect some students' ability to understand and respond to assessment items more than others. Students of differing cultural backgrounds may express their ideas in ways that hide their knowledge and abilities in the eyes of teachers who are unfamiliar with the linguistic and cultural norms of students' homes and communities. While all students, including mainstream students, are subject to cultural influences, the linguistic and cultural knowledge that mainstream students use to express their understanding is more likely to be aligned, or congruent, with the language and culture of teachers, researchers, and test developers. Thus, the backgrounds of mainstream students are more likely to support their performance on assessments than to interfere with it, while the opposite may be true for many nonmainstream students.

Since teaching, learning, and assessment all mutually reinforce each other (remember the three-legged stool), instruction that is better aligned with students' experiences and communication patterns may also improve assessment outcomes for those students. Place-Based teaching, because it can be readily situated within the communities, experiences, and discourse patterns of a given teacher's students, can lead to the development of meaningful place-based assessment measures. Results of these assessments, can, in turn, guide subsequent place-based instruction. It is important to remember the critical role of assessment "for" learning as well as assessment "of" learning. That is, when assessment is thoughtfully done, it contributes to students' learning rather than simply measuring that learning.

Assessments that aim to be equitable should consider the knowledge and abilities that students bring from their home and community cultures while also measuring the science standards that are expected of all students. Traditional science assessments have generally made few, if any, connections to nonmainstream students' lived experiences. In most cases, this is not due to a desire to be unfair but rather to the fact that few teachers or test developers have an in-depth knowledge of nonmainstream students' cultural and linguistic beliefs and practices. Also, because science is usually thought of as being universal and culture free, the idea that cultural backgrounds might influence science instruction or assessment may seem alien to many teachers and test developers. However, a growing number of assessment experts have come to understand that the inclusion of authentic tasks drawn from students' real-life situations can motivate students, more accurately reflect their knowledge, and actually enhance their performance (García & Pearson, 1994; Solano-Flores & Li, 2008). Place-Based teaching can provide the context to support these kinds of more equitable assessments.

In addition to considering the content of assessments, it is important to consider the formats used for assessing student achievement. Traditional multiple-choice tests have been criticized for failing to adequately measure the types of knowledge and abilities that scientists and science educators feel it is most important for science students to learn (National Research Council, 2000). Instead, performance assessments and other alternative assessments, such as the kinds discussed above, have been proposed as better measures of meaningful science learning. Advocates of more varied science assessments claim that this variety provides students with flexible and multiple opportunities to demonstrate their knowledge, are more consistent with cultural preferences, may be less heavily dependent on academic language proficiency in English, and permit students to communicate their ideas in multiple ways. The overarching goal for using a place-based approach to science teaching is to promote more meaningful and engaging learning experiences for our students (remember Dewey, Lewis, and the other place-based educators discussed earlier). Using a range of diagnostic, formative, and summative assessment strategies can be an important part of this learning experience.

Place-Based Science and Thinking Like a Scientist

One of the advantages of a place-based approach to science teaching is that it supports students in developing the skills of thinking like a scientist. What does it mean to think like a scientist? More than anything else, thinking like a scientist means learning to use scientific inquiry practices when studying the natural world. Science inquiry has many definitions, but following Kuhn (2005), the definition we prefer is this: *The ability to coordinate hypothesis and evidence through the study of controlled, cause-and-effect relationships*. This definition highlights three key inquiry practices that can be readily taught through a place-based approach to science teaching:

1. Coordinating hypothesis and evidence
2. Controlling variables
3. Studying cause-and-effect relationships

Focusing on these three inquiry practices will help students learn to think like a scientist. Below, we discuss each of these practices in turn. In each of the 40 place-based science activities in the second part of this book, we highlight one of these practices and how the activity can help students master this practice as they learn to think like a scientist. If students participate in a number of the place-based science activities in this book, one thing they will learn is how to think like a scientist.

Coordinating Hypothesis and Evidence

We all have personal hypotheses about many of the things we experience in life. What the best streets are to drive on during rush hour to avoid traffic, what temperature to set your air conditioning to minimize your electrical bill, and how long to microwave a bag of popcorn to get the most kernels to pop without burning them are just three everyday examples of personal hypotheses. Scientists also work with hypotheses on a daily basis. A scientist might hypothesize that igneous rocks are harder than sedimentary rocks, that tall people have faster heart rates that short people, or that bikes with skinny tires will roll faster than bikes with fat tires.

A hypothesis is basically an expectation of what should happen barring unforeseen circumstances. We develop hypotheses over time based on our personal experiences and things that other people tell us that we choose to believe. Hypotheses, however, cannot stand alone. They need to be supported by evidence. Children (and many adults too) have a hard time distinguishing between hypothesis and evidence. People also have a hard time connecting the two. Sometimes our hypotheses can't account for the evidence we gather. The highway with heavy rush hour traffic still gets us home faster than the surface road with less traffic. We find a piece of sandstone (a sedimentary rock) that is harder than a piece of pumice (an igneous rock). Students must learn that when our hypothesis fails to accommodate our evidence, the hypothesis needs to be refined, revised, or totally replaced. This can be quite difficult for people to do, especially if they have held onto their hypothesis for a while.

There is a good deal of research in psychology showing that most people are very resistant to giving up ideas they already believe to be true when confronted with evidence to the contrary. Scientists work hard to train themselves to become better at this—to test their hypotheses by gathering and critically examining evidence and then refining, revising, or totally replacing their hypotheses based on that evidence. This is difficult for students and takes lots of practice. In many of the activities in this book, students will be asked to gather evidence and then use it to generate or revise a hypothesis about how things work in the natural world. Because place-based activities tend to be engaging for students, they are a good way to support the development of challenging thinking such as coordinating hypothesis and evidence.

CONTROLLING VARIABLES

A variable is anything that can change. This can be in a science experiment or in life more generally. The weather, the speed of a bike going down a hill, and the height of students in your class are all variables. When we think about inquiry practices, the only way to be sure that we correctly understand what we observe is if we account for all the possible variables.

When we conduct science experiments, we usually manipulate one variable to determine the effect of this manipulation on another variable. Any other variables that could possibly affect the experiment need to be kept constant or controlled. The variable we manipulate is usually called the independent variable. The variable we want to observe is usually called the dependent variable (because what happens to this variable *depends* on the changes we make to the first variable). The other variables we wish to control are usually called controlled variables or constants.

If we consider a question such as what is the effect of nitrogen fertilizer on the growth of bean plants, the independent variable would be fertilizers with different amounts of nitrogen (what we would manipulate). The dependent variable would be a measure of bean plant growth (where we would look for change). We would try to control all other possible variables that could influence bean plant growth, such as soil type, amount of sunlight, size of container, amount of water, and other ingredients in the fertilizers. Another way to say this is that we would make sure that each variable such as soil type, amount of sunlight, and amount of water would be the same for every bean plant. The only thing we would want to be different for each plant is the amount of nitrogen in the fertilizer (the independent variable). When all these variables are controlled, we can logically conclude that the differences we see in bean plant growth are likely due to changes in the nitrogen level in the fertilizer.

Controlling variables can be difficult for students because not all of the variables that could cause a change are always obvious. It can also be hard to plan for keeping many possible variables controlled at the same time. When we do experiments in the natural world, sometimes it is impossible to control all the variables we would like to. Learning to control variables to the best of our ability takes practice and planning. The place-based activities in this book will give students ample opportunity for just this kind of practice.

STUDYING CAUSE-AND-EFFECT RELATIONSHIPS

The third inquiry practice we wish to emphasize is the study of cause-and-effect relationships. While cause-and-effect reasoning may seem to be a fairly simple skill, it is actually more abstract and more complex than it may appear. Particularly for children and young adolescents, this is generally a new way of thinking that takes time and practice to develop. It is worth the time to help students develop this skill because it is useful in everyday life and not just in the study of science. A simple definition is that *a cause-and-effect relationship exists when one event, the cause, brings about another event, the effect, through some mechanism.*

Sometimes people assume that when two events occur together, then one of the events must have caused the other. Sometimes this is the case—when we see lightning we almost always hear thunder and so we conclude that the lightning causes the thunder. Sometimes, though, two events may occur together but not be linked by a cause-and-effect relationship. When the weather gets cold in the winter, people are more likely to get the flu, so we may conclude that cold weather causes the flu, but this turns out not to be the case. The onset of winter and the increase in flu cases occur together because when the weather turns cold, people are more likely to stay inside and in close proximity to each other, allowing viruses and bacteria to more easily pass from person to person. So cold weather can be linked to flu season but not in a direct cause-and-effect relationship. Research has shown that humans naturally try to construct cause-and-effect relationships as a way to explain our observations of the world around us. These mental models help us to predict and control our environment. We do this even when not consciously thinking about it, probably as a survival mechanism.

The goal of studying cause-and-effect relationships through place-based science is to make these subconscious practices conscious and explicit. When we study cause-and-effect relationships, we learn to think critically and to focus on identifying the actions, events, or conditions (the causes) that lead to or create specific consequences (the effects). Multiple activities in this book will give students the chance to practice making these connections. Practicing cause-and-effect reasoning, like learning to control variables and learning to coordinate hypothesis and evidence, provides students with rich opportunities to think like a scientist, skills that are very useful for navigating the world as well as for succeeding in science class.

Modifying Activities for Grade Range and Other Learner Differences

Considering how to modify activities (often called "differentiated curriculum" or "differentiated instruction") based on the grade range of students is not as simple or as straightforward as it may first appear. Every experienced teacher can testify that within any class or grade level, there exists a wide range of student abilities and experiences. For example, the typical elementary or middle school science class today is likely to include students with physical or cognitive special needs, students who are English language learners, students from multiple cultural, ethnic, and racial backgrounds, students with a range of previous academic success, students with a range of attitudes toward science and toward school in general, students with a range of reading levels, and students with different learning style preferences, as well as other types of student diversity. Thus, to say that students at a particular grade level need a certain type of instruction is a gross oversimplification of the reality of teaching children. Every teacher at any grade level needs to think about how to differentiate her lessons to meet the unique learning needs of the students in her class. These modifications can take a number of different forms, including modifications to the content, the conceptual difficulty, the intended learning goals, the methods of instruction, and the methods of assessment, among others.

For example, English language learners may need the same content with the same conceptual difficulty as native English speakers but with modifications to methods of instruction and assessment, while a gifted student may require an increased cognitive difficulty and a modification to the learning goals. To further complicate the issue, a student might be both an English language learner and gifted. Thus, there is much more to modifying curriculum and instruction than just considering the grade level of the student. That said, it is also true that there are developmental differences that occur as students grow and develop through the elementary and middle school years. For this reason, in the activities in the second part of this book, we present suggestions for curricular modifications for lower elementary grades, upper elementary grades, and middle school grades as well as for other learner differences. For each of the 40 activities, we present a sample curricular modification based on one or more type of learner difference. Teachers should take these ideas as a starting point for discussions about the broader range of learner differences in their classrooms.

INTERDISCIPLINARY TEACHING THROUGH PLACE-BASED SCIENCE

As we have mentioned several times in this introduction, place-based education is quite conducive to interdisciplinary teaching or teaching across the content areas. Interdisciplinary teaching can play a critical role in addressing the wide range of content standards that teachers are responsible for covering and that students are responsible for learning. When these lists of standards are considered separately, they can be daunting to teachers and students alike, because there are so many topics that need to be covered in each of the core content areas. However, when the standards are considered in unison across the content areas, there are ways in which multiple standards from different content areas can be addressed simultaneously in the same lesson. For example, language arts standards for expository reading and writing, math standards for data representation and analysis, and social studies standards for civics could all be addressed along with relevant life science standards during a place-based science activity on the role of exercise in life-long heath and wellness.

Interdisciplinary teaching may look quite different at the elementary and the middle school levels, but it can be done at both levels (and beyond). In elementary schools, where one teacher is generally responsible for teaching multiple content areas, a decision to try more interdisciplinary teaching can be made and carried out by a single teacher (although it can often be easier to do this using a team planning approach). In middle schools, where most teachers teach only one content area, interdisciplinary teaching will require a team effort with multiple teachers planning activities together and then each carrying out his or her part to contribute to the larger goal. In either case, place-based science can serve as a centerpiece for this approach.

In each of the 40 place-based science activities in the second part of this book, we highlight one example of how the activity can lend itself to interdisciplinary connections. While many of the science activities could be connected to multiple content areas in meaningful ways, we provide one example of an interdisciplinary connection and encourage the reader to use this example as a starting point for considering additional interdisciplinary connections.

Throughout this book, we try to provide the reader with as many resources as we can for making placed-based science instruction possible. Interdisciplinary connections, modifications for grade range and other learner differences, and support for thinking like a scientist included with each activity are three of those resources. In the remainder of this book, we provide a series of 40 activities that can be used to enact place-based science teaching with elementary and middle school students in both formal and informal settings. The Appendix at the conclusion of this book includes a catalogue of resources (many Internet connected) that can be found in most communities to help provide settings for worthwhile placed-based science instruction.

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