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How People Learn Science: Taking a Whole-Life Perspective

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The nature of science learning is changing worldwide as individuals have unprecedented access to science education opportunities from cradle to grave, 24-7, through an ever-growing network of educational opportunities beyond schooling, including visits to national parks and preserves, libraries, museums, zoos, aquariums and science centers; access to diverse broadcast media, such as television, podcasts or film; participation in organized youth programs, such as 4H, after-school or summer camps; adult programs, like Road Scholar or hobby groups; and, increasingly, a vast array of digital media, such as games, the internet and social networks (Falk and Dierking, 2010; NSB 2015; Pew 2013). In recent decades, dependence on broadcast and print media for science information has declined precipitously, while use of digital tools has grown exponentially (NSB 2015). Regardless of what resource people use, though, a hallmark of this revolution in science learning has increasingly become a learner-centered rather than an institution-centered phenomenon. This change has not been fully understood or embraced by either the educational establishment or the general public.

School-first paradigm

The scientific research and education communities have long had a goal of advancing the public's understanding of science. The vast majority of the rhetoric, resources and research on this issue in recent years have revolved around the failure of U.S. school-aged children to excel at mathematics and science, particularly as compared with children in other countries. Most policy solutions for this problem involve improving the practices and escalating the investment in schooling, particularly during the pre-college years. This emphasis is based on the widely held assumption that children do most of their learning in school and that therefore the best route to long-term public understanding of science is through successful formal schooling. This "school-first" paradigm is so pervasive that few scientists, educators, policymakers or members of the public question it, even when the facts increasingly don't seem to support it.

Take, for example, the performance by U.S. school-aged children on international tests, like the quadrennial Trends in International Mathematics and Science Study (TIMSS) and the biannual Programme for International Student Assessment (PISA). For more than two decades,

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U.S. elementary-aged children perform as well as or better than most children in the world, but the performance of older U.S. children has been mediocre at best. On the most recent TIMSS science exam, U.S. fourth graders were out-performed by only one country in the world, Korea, while U.S. eighth graders were right in the middle of the pack of the 43 participating countries. By 12th grade, U.S. students were among the worst in the world, out-performing only students from Cyprus and South Africa (TIMSS 2012). On the PISA test, U.S. eighth graders also performed middling, ranking 20th out of the 34 participating countries (PISA 2012). These results create problems for the "school-first paradigm" for two reasons.

First, why is it that the USA performs so well in the early grades but then declines so percipitously in later grades? Most in the U.S. science learning community agree that the quality of school science education in America is better at the secondary level than at the preschool and elementary levels. Recent statistics show that only about four percent of U.S. school teachers of kindergarten through second grade (K–2) have undergraduate majors in science or science education and many have taken no college-level science courses at all (Fulp 2002). However, the quality of science instruction at that level is almost a moot point since it so rarely occurs. Indicative of the situation nationwide, a study of California elementary schools found that 80% of K–5th grade multiple-subject teachers who are responsible for teaching science in their classrooms reported spend 60 minutes or less per week on science; 16% of teachers reported spending no time at all on science (Dorph et al. 2011). And with increasing emphasis on math and reading high-stakes testing, the time spent on science in the elementary grades continues to decline. Consistent science instruction in U.S. schools only begins at the middle school level when every student takes at least one or two science courses, usually taught by individuals with some science background. Thus, the only time when U.S. children do well internationally is during the time when effectively no science instruction occurs in school.

The second interesting challenge to the school-first paradigm comes from another set of international comparisons, but this of adults rather than youth. Over the same twenty year period, U.S. adults have consistently outperformed their international counterparts on science literacy measures, including adults from South Korea and Japan, as well as Western European nations such as Germany and the U.K. In the most recent assessments, U.S. adults were out-performed by only one country, Sweden (NSB 2015). Although there is still considerable room for improvement in Americans' understanding of science, our consistent success on these international measures of science literacy is worth taking note of. In particular, if schooling is the primary causative factor affecting how well the public understands science, it is difficult to explain the sudden reversal in fortunes of U.S. performance after the cessation of schooling.

The truth is, these U-shaped results cannot be adequately explained if we assume that schooling alone is responsible for Americans' science learning. We cannot fully explain why young children do well or why the science literacy of the U.S. general public suddenly rebounds after high school. Of course all of these tests, both for school-aged children and adults, are flawed, measuring relative performance based upon a set of standardized questions. For better or worse, these are the tests on which international comparisons are made and they do provide a consistent, if flawed, frame of reference. Accordingly, we should at least consider other possible explanations, including the fact that the U.S. has the most extensive informal science learning infrastructure in the world (Falk and Dierking 2010; NSB 2015).

Free-choice science learning

A 2009 report by the National Research Council documents the importance of lifelong sources of learning and describes a range of evidence demonstrating that even everyday experiences, such as a walk in the park, contribute to people's knowledge and interest in science and the environment, as do visits to settings such as national parks, science centers, and botanical gardens. Even more common is the science people learn while engaged in efforts to satisfy their own personal need to know. Sometimes the need is a situational and fleeting curiosity. Other times learning is deep and extended, as when individuals learn science to support pursuits such as gardening, cooking, auto repair, birding or star gazing. This kind of learning, called free-choice learning, describes the learning people do every day throughout their lives not because they have to but because they want to. Free-choice learning is non-linear and self-directed and occurs when individuals have primary responsibility for determining the what, when, where, how, why and with whom of learning. Although the term free-choice learning does not define the *where* of learning, currently most free-choice learning occurs outside of the formal education system.

Evidence for the importance of free-choice science learning comes from many sources, but some of the best documented relate to public learning from experiences at science centers. For example, decades of research at the at the California Science Center in Los Angeles have shown that roughly two-thirds of Los Angeles residents have visited the science center since it was renovated in 1998, including residents of all races and ethnicities, neighborhoods, incomes, and education levels. A series of random telephone surveys in Los Angeles have shown that a large majority of these former visitors, in fact 95%, self-reported that the experience increased their understanding of science and technology, as well as piqued their interest in science and prompted further inquiries after the visit (Falk and Needham 2011). Consistent with these findings, and even more definitive, are data from a recent international investigation of the role of science centers on public understanding of science. Results from a random sampling of 11,881 residents of 17 communities with active science centers in 13 countries, revealed that individuals who visited science centers had significantly greater science understanding, greater interest and curiosity, more participation in free-choice science leisure activities, and were more likely to identify themselves as science-capable than did individuals who did not visit. Results from a random sampling of 11,881 residents of 17 communities with active science centers in 13 countries revealed that individuals who visited science centers had significantly greater science understanding, greater interest and curiosity, more participation in free-choice science leisure activities, and were more likely to identify themselves as science-capable than did individuals who did not visit science centers. Even when potential self-selection biases such as household income, education level and prior interest were taken into consideration, the roughly half of the population of these communities who visited science centers evidenced significantly higher science knowledge and understanding than did the half of the population who did not visit (Falk et al., forthcoming).

Considerable attention has been focused lately on the role of out-of-school experiences in supporting children and youth science learning. Data from a variety of sources is accumulating to show that participation in after-school youth programs such as 4-H, Girls, Inc. and Boys and Girls Clubs significantly enhance a range of key educational outcomes, including interest and engagement in science-related learning, as well as success in school (NRC 2015).Although the number of young people enrolled in afterschool and summer programs has skyrocketed over the last decade, with currently one in five children participating in such programs, supply is not meeting the demand, particularly in terms of science programing, with only one-third of the national need being met by existing programs. This reality reflects the growing disparity in access to quality, free-choice experiences highlighted by the now classic research showing that much of the current "performance gap" between high and low income youth can be attributed to summer experiences, or more accurately lack of summer experiences, rather than in-school opportunities (cf. Alexander, Entwisle and Olson 2007).

Historically, the majority of attention paid to free-choice science learning has been focused on short-term experiences, like visiting a science museum, zoo, or aquarium, or watching a science television show such as NOVA. Although these science learning experiences are important contributors to the public's science literacy, they represent only the most conspicuous part of the free-choice science learning landscape. Equally important, but much less discussed and studied, are education situations that support long-term, more in-depth opportunities for science learning. A wide range of adolescents and adults are engaged in leisure-time activities that involve science, including model rocketry, raising ornamental fish, gardening, rock collecting, birding, scuba diving and star gazing; hobbyists such as these often possess deep specialized knowledge of science and invest considerable amounts of time and money in equipment, travel, education and training to refine their craft. Research conducted by Berendsen (2005) showed that amateur astronomy club members lacking college-level astronomy training generally knew more basic astronomy, than did undergraduate astronomy majors. Equally important are the many events in life, often highly personal, which demand increased understanding of science "right-now." For example, when an individual is diagnosed with leukemia or heart disease, that person and their loved ones invest large amounts of time researching websites and medical reports to learn as much as possible about the particular disease. Similar behaviors arise when an environmental crisis such as a toxic spill or the imposition of water rationing occur. With an increasingly accessible internet, opportunities to become informed about such issues are easy and common (Pew 2013).

Investigations of everyday science literacy have yielded other interesting data. For example, a series of studies by Canadian science education researcher Roth and colleagues (e.g., Roth and Van Eijck 2010) found that members of an activist group working on the environmental revitalization of a local creek and its watershed acted and learned using knowledge derived from a wide variety of resources, virtually none of which required or drew from school-based sources. The research reinforced that much of what is learned in school actually relates more to learning *for school*, as opposed to learning *for life*.

Finally, there is a small but compelling set of data that is beginning to emerge showing that the public also gathers in-depth science knowledge outside of school. For example, research by my colleague Mark Needham and I (2013) found that when multiple sources of science learning were considered together, free-choice learning experiences represented the single greatest contributors to adult science knowledge; childhood free-choice learning experiences also significantly contributed to adult science knowledge, as did work experiences (as well as gender, income, race, or ethnicity). Schooling was also significant but it ranked at the bottom of sources of adult science knowledge.

Conclusions

There is a revolution afoot! We are witnessing a tectonic shift in how, when, where and even why people learn. Just as the information revolution dramatically transformed our nation, this learning revolution too is changing the way the people live and compete in the twenty-first century. Learning today is 24-7, continuous and on-demand. Whether aged 5 or 95, learners seek educational experiences from a myriad of sources while at home, on weekends and even while on vacation. For the past 100 years we've come to believe that the words "*learning*," "*education*" and "*school*" were synonymous—today public education doesn't just happen at school. Today's learners spend only a fraction of their lives in a classroom. In fact, research indicates the achievement gap is less a factor of disparities in classroom learning than inequities in access to enriching experiences in the out-of-school time space. Most learning is *free-choice*, driven by an individual's needs, interests and access to learning opportunities.

Schools remain important components of the new science education ecosystem, but increasingly important are informal educational institutions and resources such as libraries, museums and national parks. In order to successfully fulfill their role as public science educators, institutions such as national parks must not only seek to understand what and how people learn in the twenty-first century but also why. As free-choice learning increasingly becomes the dominant form of learning, all educational institutions need to place greater emphasis on the needs and interests of learners rather than just what people "need to know." They also need to increasingly see themselves as just one part of a complex ecology involving multiple players and modalities (Falk and Needham 2013; NRC 2015). These are the challenges and opportunities the National Park Service faces in its second century as it increasingly asserts its role as one of America's key public educators.

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