Reconceptualizing a Lifelong Science Education System that Supports Diversity: The Role of Free-Choice Learning

Lynn D. Dierking

Mansour and Wegerif's introduction to this edited volume recognizes the high value being placed on science education by governments around the world with the understanding that the skills embodied in science, technology, engineering, and mathematics (STEM) disciplines do not merely allow nations to compete in the world of work but also enable their citizens to be active participants in a global society. The value of STEM literacy is only heightened by the twenty-first-century challenges nations face, challenges which are increasingly complex and global in nature, often requiring an understanding of STEM to solve. This issue becomes only more sobering in light of decreasing engagement in science in school and declining enrollments in university science courses, indicators that suggest declining societal vitality and less informed democratic participation in science.

It is important to appreciate though that less participation in science in school and university is just one set of indicators of the STEM literacy problem. The societal changes and global challenges we face warrant fundamentally changing the approaches educators and educational researchers take to reforming science education globally. I agree with Mansour and Wegerif's notion outlined in the introduction to this book that diversity is key to any reform, not only the traditional notion of diversity as gender and ethnicity but also "a new understanding of diversity . . . , diversity as a way of thinking about science and about education into science, which does not define specific diversities in advance of practice but embraces openness, responsiveness and responsibility in the nature of the practice of science education itself" (Mansour and Wegerif 2013, p. X). I also agree with their perspective that to take such a diverse approach requires viewing learning and education as not only the transmission of knowledge to prepare learners for further education and a career, but as processes by and through which learners construct their identity and, in so doing, develop their *own* lifelong relationship to science.

L.D. Dierking (✉)
College of Science and College of Education, Oregon State University, Corvallis, OR, USA
e-mail: dierkinl@science.oregonstate.edu

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However, focusing only on school and university indicators and, as a consequence, framing the issue within this activity space diminish one's ability to approach this challenge in a more innovative and comprehensive manner, particularly given current realities regarding school and university participation. Increasing numbers of youth, particularly from low-income, disenfranchised groups underrepresented in STEM, do not graduate from high school, and the vast majority of adults either are not privileged enough or do not choose to further their schooling beyond high school (Falk and Dierking 2010). Solutions that focus only on school- or university-aged children and youth as is the case for the majority of chapters in this volume also do not recognize a vast group of middle-aged and older adult learners who could benefit from continued STEM learning. After all, since science changes so rapidly, science literacy cannot be achieved in any society by merely focusing reform efforts on the young.

Despite these realities though, current approaches to science education reform at least in the USA rarely address disenfranchised youth and adults, and most solutions are neither complex nor innovative, centering solely on improving science teaching in K-12 schools or, if enlightened, extending reform efforts down into the pre-K years or up into the university (Carnegie Corporation 2009; National Academies of Science 2006; National Research Council 2011). These approaches neglect the fact that a "quiet revolution" is underway in societies worldwide, resulting in increasing opportunities for diverse forms of education and learning. The centers of this revolution are not the traditional educational establishment of schools and universities but rather a community network of educational entities: libraries; print and broadcast media; the Internet, personal games, podcasts, and social networking media; and museums, zoos, aquariums, and science centers (Horrigan 2006; Falk et al. 2007).

Taking a school-first approach also neglects the contributions of the workplace as another venue for science learning. Although a relatively small percentage of the public (3.8 %) are employed in jobs requiring a science or engineering *degree* (National Science Board 2004), the percentage rises dramatically to 40 % if one considers the number of people who work in "middle-skill" science- and engineering-related occupations that require technical training such as an associate's degree or occupational certificate. In addition to the free-choice learning arena, the workplace is a neglected yet important third educational sector in our society (Falk and Dierking 2002), a sector that supports the learning of adults and older youth not in school or university.

Given these realities, I think we need to step much further back. It is not enough to simply frame the task as a need to redesign schools and curriculum for school-age children and youth. We need to seriously take on the challenge posed by Mansour and Wegerif by fundamentally changing the *practice of science education*, envisioning a lifelong science learning system that supports diversity broadly. This system would support the lifelong STEM learning of citizens of all ages, backgrounds, and stations of life, recognizing the myriad places and ways in which they engage and participate in STEM, as well as the many reasons they might choose to engage and participate. Most importantly, this system would be designed in a way that acknowledges what is most important for science educators, whether teachers in schools, educators in free-choice science learning settings and environments, or university professors in science and education are to create opportunities for the diverse learners with whom they interact to construct a relationship with and to science that meets their needs and makes sense to them in their everyday lives. This would be the case whether the person is or plans to be a scientist, a technician, someone who engages in science-related hobbies and pursuits, or a citizen with other types of expertise and interests, but whom we hope will have some basic understanding of science in order to lead a healthy life and make sound decisions based on evidence.

This is not meant as a condemnation of school-based learning. The point is merely to emphasize that improving schools and curriculum though important is only one piece of a comprehensive approach to educational reform. Certainly the authoritarian one-size fits all model of the traditional science curriculum is no longer appropriate. We need to be seeking new ways to engage science learners of all ages in co-constructing their own learning of science, not only in school, but throughout their lifetimes. To do this well, we must understand how to more effectively connect science learning opportunities across settings and the life span by working with educational colleagues in the myriad science settings in which science learning occurs. If we understand the connections and interrelationships that learners make within this lifelong science learning web and work collaboratively with learners and colleagues engaged in science education across settings and the life span, we are far more likely to be able to build a system that better leverages and contributes to lifelong science engagement and learning, to a citizenry that identifies at some level with science.

This is a huge, long-term undertaking, requiring careful thought, collaboration across settings, deliberation, and much formative testing, certainly not the purview of a book chapter. What I can do in a chapter though is build a case for such an approach, in particular describing the component of this lifelong STEM learning system that I know best: the free-choice science learning sector. First I will document this growing free-choice science learning movement and the often hidden infrastructure supporting it. Then I will share findings from a US National Science Foundation (NSF)-funded retrospective study of the long-term impacts of gender-focused, free-choice STEM learning experiences on 213 young women from diverse backgrounds underrepresented in STEM who had participated in free-choice programs 10–20 years before. I close the chapter by discussing the need for a research and education infrastructure that embraces this comprehensive view and attempts to understand learning across settings and time.

The Free-Choice Learning Revolution

Much evidence supports the contention that the public learns science in settings and situations outside of school. A 2009 report by the National Research Council, *Learning science in informal environments: Places, people and pursuits* (NRC 2009), 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 STEM. For example, in any given week, a person might watch a television program on evolution, research a diagnosis of high cholesterol by her physician, and build a model rocket with a child. Each of these is an example of free-choice science learning activity—the learning that individuals engage in throughout their lives when they have the opportunity to choose what, where, when, how, why, and with whom to learn (Dierking and Falk 1998). Children *and* adults are spending more of their time learning, not just in classrooms or on the job, but through free-choice learning at home, after work, and on weekends.

The question arises though do communities have the resources and expertise to support lifelong science learning among their citizens not engaged in school or university or school-aged children and youth outside of school (Dierking in press-a)? Without hesitation I say it is not only possible, but rich examples already exist in many communities. Science programs take place in parks, shopping malls, during scouts, in senior communities, YMCA/YWCAs, libraries, even cars, and restaurants (CDs featuring current research conducted on site can be borrowed while visiting national parks and French fry wrappers and recyclable paper cups at the Pacific Northwest fast-food chain, Burgerville, feature ecological information about rough-skinned newts, and sockeye salmon).

There are also science-related museums and other free-choice science education settings such as zoos, national parks, aquariums, and science-technology centers. Museums, particularly science-technology-oriented ones, currently rank as one of the most popular out-of-home leisure experiences in the world; the Association of Science-Technology Centers (ASTC) estimates that there were 89.6 million visits to their member science centers and museums worldwide in 2009, with 62.9 million of those visits made in the USA (ASTC 2010).

One can even learn about science in a pub! Science Cafés and Science Pubs, first developed in Europe in the early 1990s, have flourished in the USA for nearly a decade. Although they began in major urban areas, due to their success, they are now being replicated in "less usual" communities: rural areas in Montana and South Dakota in the USA and Cockermouth in the Lake District, UK; on islands, Corfu, Greece, and Orkney, Scotland; within immigrant and gypsy communities in Europe; and even in Palestine (Dierking in press-a).

The above examples are community-based, but expanding beyond one's local community, there are books. Despite the hype about declining literacy, the number of books sold in the USA in 2006 was up from 2005, and with the increasing adoption of e-books (the share of adults in the USA who own an e-book reader doubled from November 2010 to May 2011), the number of books sold is at an all time high; many of these are science and/or technology-related (Purcell 2011; U.S. Bureau of the Census 2010).

There is also television and radio. Not only is television viewing up (U.S. Bureau of the Census 2010) but, so too, are the number and diversity of information-oriented programs, many of them are science and/or technology-related (Miller et al. 2006). And then there is radio, a medium in which there are many science-related programs.

For instance, the 20-year-old *Talk of the Nation: Science Friday* radio program has a weekly audience of 1.3 million listeners. *Science Friday* presents STEM news and policy analysis, as well as the interplay of science and society. Scientists and science policymakers debate and disagree, argue, and analyze, live and unedited—just as they do in their working lives. Listeners hear about science as a work in progress and are offered a unique opportunity to speak directly with the show's guests, so that the conversations on the program become distinctively relevant to the lives of the general public.

There is also the staggering growth of the Internet—and science and technology topics are being communicated there also; data shows that once people turn to the Internet for science news and information, they learn to rely on it as a source, especially young people (Horrigan 2006). And these media are not silos either. For instance, *Science Friday* described above is active on the Internet and social media sites. It was the first national radio program to broadcast on the Internet and to introduce the then unfamiliar concept of the "World Wide Web" to its listeners. It was also the first National Public Radio (NPR) program to produce podcasts (they register 24 million podcast downloads per year) and remains the second most popular NPR program available in podcast. Listeners can submit questions via Twitter, Second Life, and www.sciencefriday.com, and also can engage in science discussions via a Facebook community and website blogs. In 2006, as YouTube's popularity with younger audiences became apparent, *Science Friday* began including STEM videos on their website. SciFri Videos, available in both English and Spanish, are designed to appeal to a younger demographic and were viewed more than one million times in 2009. Due to this success, *Science Friday* has recently received US NSF informal science education funding to expand in new and innovative ways via broadcast, portable media (e.g., smartphones, tablets), and the Internet (e.g., websites, Facebook, and other social communities), all with a focus on reaching youth, in particular Latino/Latin, between 12 and 24 years of age.

These are but a few examples of a vast and vibrant free-choice science education infrastructure which is unseen, undervalued, and underfunded (certainly by public dollars), because the window through which most science educators and policymakers gaze is focused on K-12 (Dierking in press-a). From the growth of the Internet to the proliferation of gaming and educational programming offered by IMAX, educational television, and museums, there are more opportunities for self-directed, free-choice learning than ever before, much of it science and health related. Most of the examples I have shared are indoor activities but people also engage in such learning outdoors every day—hiking, visiting national parks, and engaging in other nature activities—tapping into a vast science learning infrastructure available 7 days a week, 24/7, across a life span. These opportunities are important, in fact, essential ways that people learn. Even more critical, these modes of learning allow individuals to *contextualize* and *personalize* their science knowledge, interest, and understanding throughout their lifetimes. It is hoped that these science experiences contribute, along with schools and the workplace, to building science identities that meet the needs of lifelong learners and enable them to become science-informed citizens, perhaps even *engaged science participants*, broadly defined, to include scientists, engineers, mathematicians, and technicians, as well as youth and adults who choose to engage in science-related hobbies, pursuits, and habits of mind.

The Lifelong Science Education Infrastructure

Well over a decade ago, St. John and Perry (1993) proposed that science educators rethink the entire learning enterprise, suggesting that school and free-choice learning sectors be considered components of a single, larger educational infrastructure which supports and facilitates science learning in a society. John Falk and I expanded upon this idea, positing that there were actually three educational sectors in society: schools and universities, the free-choice learning arena, and the workplace (Falk and Dierking 2002). We argued that in the twenty-first century, society needs a broad-based and richly integrated educational infrastructure capable of supporting millions of unique individuals attempting to meet widely varying learning needs at any point in their lives, any time of day. The educational entities that compose this basic infrastructure form the fundamental backbone of a learning society and provide citizens with current and accurate information about health, politics, economics, the arts, and sciences. As suggested, this infrastructure already exists in communities and ideally all the entities work together to support and sustain learning across the life span (Dierking and Falk 2009). From this perspective, the educational/learning infrastructure is vital to a nation's economic well-being—as well as its intellectual and spiritual well-being.

Each educational sector—schooling, workplace, and free-choice learning—contributes to the science learning of the public. However, of the three, the free-choice sector is far and away responsible for providing more people educational opportunities, more of the time, than either of the others. The free-choice learning sector also is the most diverse, fastest growing, and arguably the most innovative. The explosion of the Internet and World Wide Web provides significant evidence for the perceived value of having a readily accessible tool that can provide virtually anyone, anywhere, with any information, any time. The Web, though, is just one aspect of an ever expanding, and hopefully improving, network of learning resources available to the general public.

One consequence of taking a broad-based approach to science education is that one begins to notice science teaching and learning in novel places (like cafes and pubs!). For example, over the last 20 years, the Astronomical Society of the Pacific, based in San Francisco, California, has explored and experimented with ways to tap into the vast teaching potential of amateur astronomers. With initial funding from the informal science education program of the NSF, they have involved amateur astronomers in elementary and middle school teaching in classrooms through *Project ASTRO* (Dierking and Richter 1995) and through *Family ASTRO* have provided engaging astronomy experiences for families through a network of museums, science-technology organizations, and community-based organizations such as amateur astronomy clubs. They are now providing more focused astronomy training to free-choice learning educators in small science centers, museums, and planetariums. Although NSF funding ended several years ago, programs remain in communities around the country supported by existing networks of educational partners.

As the US population ages, there are also significant and increasing numbers of young elders. All of these adults have the potential to participate in science-related special interest groups and leisure pursuits, watch nature or science specials on television, and/or participate in noncredit university courses or Road Scholar programs; many focused on STEM (formerly called Elderhostel; "Road" connotes a journey and real-world experience, and "Scholar" reflects a deep appreciation for learning). Research shows that many adults also visit settings such as national parks, science centers, and botanical gardens to satisfy their intellectual curiosity and stimulation, as well as fulfill a need for relaxation, enjoyment, and even spiritual fulfillment (Ballantyne and Packer 2005; Brody et al. 2002; Falk 2006, 2007; Azevedo 2004). Some of these elders also have STEM expertise that they can share as free-choice educators and mentors.

School-age children also spend a significant amount of time outside of school (current estimates are 80–90 % of waking hours are *outside* of school), and some of this nonschool time is devoted to free-choice science learning, most often with family: they visit parks, zoos, and libraries and participate in various after-school and extracurricular experiences, including scouting and summer camps (e.g., Korpan et al. 1997; Dierking and Falk 2003; Dierking in press-b; Rounds 2004). A small but growing movement of home educators also values science and mathematics learning for their children and engages in it regularly (Bachman 2011). As noted earlier in the chapter though, free-choice learners are not always school-aged children and their families. They include post-high-school adults (some of whom did not further their schooling), as well as those who did not graduate from high school at all (Falk and Dierking 2010).

Free-choice learners sometimes "choose" to engage in science learning for very different and sometimes profound reasons that may not even occur to us. Recently I heard about Safecast, a small not-for-profit citizen science organization whose mission is to empower people with data, primarily by building a sensor network which empowers nonspecialist citizens to collect and interpret data and freely use it through an Internet portal (Penuel 2011; *Scientific American* 2011). The organization was featured in a recent issue of *Scientific American* as a citizen science project exemplar.

The impetus for Safecast's creation was a real-world catastrophe. After the earthquake and resulting radiation leak at Fukushima Diachi in March 2011, it became clear that people in the area wanted more data about the earthquake, resulting tsunami and damage to nuclear power facilities than was available from the Tokyo Electric Power Company (TEPCO). With the support of Safecast, citizens build Geiger counters, measure radiation levels, making existing data more robust since multiple sources are better and more accurate when aggregated, and make the data available to the public through maps, a website, and data feeds to citizens and scientists around the world. As of July over 300,000 data points had been collected; while Japan and radiation are the primary focus of Safecast at present, this work has made the organization aware of a need for more global environmental data, and their long-term goal is to engage in collaborative research with citizens in additional areas.

Most people find the radiation data collected difficult to read and interpret, but the disaster has created a need for ordinary citizens to engage in deep science learning about safe and unsafe levels of radiation in water and food, using complex scientific instrumentation. It is a visible and striking example of the point of this chapter, namely, that as a field we include organizations like Safecast and other citizen science movements that have been in operation for many years (Audubon bird counts, Cornell's Pigeon Watch), as critical entities supporting lifelong STEM learning even though they support the learning of nonspecialist citizens, 18 years or older. Some citizen science projects even involve participating citizens in professional science practices such as conceptualizing research studies and analyzing data, even collaborating on peer-reviewed publications.

In projects like Safecast, science and learning about science are central, but new cultural practices around science are being constituted. The goals of these practices are not focused on learning science in an abstract manner. They are about living and surviving in a particular place and learning that science is a tool which allows one to do so, a tool for empowerment and identity building. To my mind Safecast is an excellent example of authentic science practice. Although that term has become a popular buzzword in science education reform, often used as a synonym for science activities that resemble scientists' everyday practice (Martin et al. 1990; McGinn and Roth 1999; Roth 1995, 1997), I agree with Rahm et al. (2003) that this focus often neglects acknowledging what authenticity means, to whom, and according to whom. I prefer to define authentic science practice as what emerges as facilitators, citizens, and scientists interact, make meaning of, and come to own the activities they engage in collaboratively. Thus, authenticity is not viewed as only the scientist's science but instead as an emergent property of those engaged, the task, and the environment, as they interact in complex ways (Barton 1998a, b, 2001a, b; Fusco 2001; Hodson 1998; Wellington 1998). Not only does Safecast embody authentic science practice but it also is a rich example of Roth's notion of the *Fullness of Life* (or *Total Life*) unit of analysis, an approach that suggests one must understand STEM learning from the perspective of life as a whole, rather than focusing on STEM learning as abstract, decontextualized activity (Roth and Van Eijck 2010).

Such efforts test the very roots of authoritarian science. Safecast is releasing data openly and pushing the Japanese government, as well as universities and researchers, to share their data. They argue that open data is an important trend, which adds a new layer of robustness and democratic participation in scientific research that the Internet and data science affords. However, pushing scientists to release their data as well as their results and findings, particularly to the public, is likely to be controversial and contested even though it represents a willingness to share the authority and power of science with citizens of all ages, walks of life, and backgrounds.

Evidence of the Potential for Free-Choice Learning Opportunities

For more than a decade, the US National Science Foundation (NSF) has funded more than 300 free-choice/informal education projects focused on enhancing girls' interest, engagement, and understanding in STEM, a total investment of more than $100 million. Despite this significant investment, little is known about the strategic impact of these efforts, in part because their impacts have been conceptualized and measured differently, often in ways not generalizable across projects (Darke et al. 2002).

Modest existing research suggests that free-choice learning settings can be beneficial, providing influential experiences and building capacity and confidence in science among girls and women (Dierking and Martin 1997; Fehrer and Rennie 2003; Fadigan and Hammrich 2004). The influence that significant adults/facilitators bring to these experiences is also an important factor. Female scientists often cite family members, youth program leaders, or contexts outside of school as significant influences in their career choices (Baker 1992; Campbell 1991; Fort 1993) and reflect on the importance of informal networks and supporters. While every girl may not have support from her family or school, the presence of a significant adult or mentor in an out-of-school setting can make a vital difference. Studies have begun to investigate the impact and nature of experiences in which influential adults are involved (Crowley et al. 2001; McCreedy 2003; Jones 2006). For instance, McCreedy (2003) investigated the informal context of community-based organizations such as museums and scouting, identifying social/cultural factors that led to adult engagement in science learning and to their role in transforming young women's science-related identity (and their own). Findings suggest that informal contexts can offer unique opportunities for youth to engage in science practices, supported by caring and influential adults, and when designed and facilitated well, these experiences come close to the Safecast model of authentic science practice.

Studies within schools and family contexts and outside of schools have also begun to examine how personal frameworks and identities in science can be influenced by free-choice science experiences (Davis 1999, 2001; Ellenbogen 2002; Katz 1998; McCreedy 2003); however, there is much more to learn. In an effort to fill this research gap and better understand the processes and strategies that enhance opportunities for girls and women to meaningfully participate and identify with science, I am completing an NSF-funded retrospective research study with a colleague at Franklin Institute Science Museum, Dr. Dale McCreedy, to investigate the long-term impact of gender-focused free-choice STEM programs. Based on Clewell and Burger's (2002, p. 249) perception that "Quantitative data can only take us so far; it will be the words of the young women themselves that will inform our future programs and projects to make science and technology careers more welcoming for women," the study was designed to explore girls' long-term science involvement in rigorous but more qualitative ways.

The overarching research question for the study was: What role do free-choice STEM experiences play in girls' interest, engagement, and participation in science communities, hobbies, and careers? Sub-questions included: (1) How do girls describe their relationship to science and their sense of themselves (identities) as science-interested learners and advocates? (2) How does participation facilitate and lead to additional opportunities for engagement? (3) What role, if any, do significant adults play in facilitating these impacts? Research goals included:

- Document the long-term impacts of girls' participation in free-choice science programs and their perception of the ways if any of these experiences influenced their future choices.
- Determine the ways in which free-choice contexts contribute to girls' science learning and achievement broadly defined to include careers and education but also hobbies and habits of mind.
- Share the results of this research within and across the free-choice science learning community in order to influence program policy.

The study was framed within a sociocultural perspective that posits that human learning and development are best understood within their cultural, historical, and institutional contexts. Thinking and doing are intertwined within these contexts (Vygotsky 1981; Wertsch 1985, 1998; Rogoff 2003). The specific sociocultural framework of the study was Community of Practice (CoP). CoP identifies three key elements of participation in a learning community (Wenger et al. 2002). In the case of these programs, they included: (1) a *domain of knowledge,* the content or focus of the free-choice STEM activity; (2) *shared practices,* the science practices and processes in which girls and women in these programs engaged; and (3) *community,* who was involved and how was individual and community learning supported. This study explored whether and, if so, how participation within a free-choice science Community of Practice (CoP) led to learning, broadly defined to include interest, engagement, and participation in science communities, hobbies, and careers. The study also probed how this learning related to an individual's perspective about herself, her relationship to science, and issues related to gender and culture. Since CoP theory also posits that identity and community are interconnected with the individual evolving as a result of her participation in the community and the community evolving through her participation and influence, we were also interested in observing these impacts as well.

Methodology

Sample Research participants were recruited from five successful initiatives whose focus was to engage girls in informal science education practices. All projects from which we recruited women met the following five criteria:

1. Were informal programs, targeting girls, particularly from communities under-represented in STEM
2. Represented long-standing efforts, initiated more than 10 years ago
3. Had access to participants who are now 18 years or older and had participated at least 5 years ago
4. Had staff and/or evaluators who were willing to facilitate contact with these girls and to share existing evaluation and research efforts
5. Were diverse programs with regard to the three elements of engagement described by the CoP literature

The projects were: (1) *Women in Natural Science* (WINS), developed and implemented at the Academy of Natural Sciences in Philadelphia, is a year-long natural science enrichment program with opportunities to work in science labs and conduct research, offered to academically talented females who are entering grade 9 or 10, enrolled in public school, maintain a C or better average in all major subjects, live in households where one or both parents are absent, and demonstrate financial need (free or reduced school lunch); (2) *National Science Partnership* (NSP), initiated and piloted at Franklin Institute and then disseminated nationwide through Girl Scouts of the USA and informal networks, prepares and supports Girl Scout leaders to do science badge work with girls ages 6–11, as well as involves older girls as mentors in these efforts; (3) Girls, Inc.'s *Eureka* and *Project SMART* engage women in under-resourced communities nationally in STEM experiences and mentoring projects; (4) *Techbridge*, an after-school and summer program in the San Francisco-Oakland area of CA, encourages girls underrepresented in STEM in technology, science, and engineering activity, as well as field trips to STEM-related businesses; and (5) the *Rural Girls in Science* project developed and implemented at University of Washington, Seattle, engaged rural young women, primarily Latina, in community-based STEM projects to improve their communities. Based on previous evaluation studies, each of the programs from which we recruited research participants was a highly successful free-choice science learning program, characterized by social, open-ended, voluntary, and noncompetitive structures.

Design The study had two individual investigations:

Investigation 1 (I#1)—Personal Meaning Mapping/in-depth interviews with active/core girls

Investigation 2 (I#2)—Web-based survey

Data Collection: Investigation #1

In keeping with the sociocultural perspective of the study and to ensure that young women's own ideas and terminology were centermost, Investigation #1 explored the ways in which young women discussed their early free-choice science learning experiences and identity. Two data collection approaches were utilized, both face to face: Personal Meaning Mapping (PMM) and an in-depth qualitative interview with each young woman to discuss the maps she had created. Each program identified

2–3 young women who were past active/core participants and had kept in touch with the program. They may, or may not, have continued to engage in science-related activities in their lives (college science classes, science-related hobbies, clubs, careers, etc.). The goal was to interview a range of women, although in this phase of the project, McCreedy and I were not concerned about whether the young women interviewed constituted a representative sample. All participants (or their parents if they were minors) received information about the study and were asked to complete a consent/assent form before participating in the study.

PMM is an approach designed specifically for use in free-choice learning settings (Falk et al. 1998) and is grounded in a relativist-constructivist paradigm, which recognizes that individuals participating in programs in informal, free-choice settings bring varied backgrounds and knowledge to the experience. This varied background and knowledge, as well as the social/cultural and physical context of the experience itself, shapes how a person perceives and processes the experience. The approach measures the unique conceptual, attitudinal, and emotional impacts of a specified learning experience on an individual and the community in which she participated, focusing both on *the degree of the change* but equally on *the nature of the change*. Importantly, PMM provides a valid way to understand the personal meaning people construct from learning experiences.

The protocol for PMM involves asking individuals to write down on a piece of paper as many words, ideas, images, phrases, or thoughts that come to mind related to a specific concept, picture, or word. Similar to the concept mapping approach from which PMM was adapted, the word, picture, or phrase prompt is placed in a circle at the center of the page. The words, ideas, images, phrases, or thoughts written down by the individual in response to the initial cue then form the basis for an open-ended interview in which research participants are encouraged to explain why they wrote down what they did and to expand on their thoughts or ideas relative to the circled concept. The discussion allows participants to elaborate in their own words and from their own frame of reference on their perceptions and understandings of the prompt. The researcher records participants' responses on the same piece of paper using the participant's own words and conceptualizations. To permit discrimination between unprompted and prompted responses, the follow-up interview data is recorded in a different color ink.

In this study we asked young women to complete two personal meaning maps, the first with the prompt "me" and the second initially with the prompt "science," later with a prompt of the program in which they participated, for example, *Women in Natural Science*. All sessions were face to face and tape recorded. After the first "me" map was completed, the young woman was interviewed about that map. Then they made their second map and were interviewed. Finally with the two PMM's side by side, each young woman was interviewed about how the ideas expressed on the two maps overlapped in their lives—if at all. The purpose was to get participants to articulate what makes them "me" in their own words and whether science (or ultimately the program) had played any role in their life decisions and personal identity.

Data Collection: Investigation #2

Findings from phase 1 were the foundation for creating a valid and reliable questionnaire, as well as helping us develop a baseline sense of the range of possible outcomes that might result from these experiences. In keeping with our theoretical framework, young women's own ideas were used to help focus item development within the three dimensions of CoP. Given that young women in our study were scattered around the country (and in a few cases around the world), the instrument was web-based.

Item Development Since the questionnaire was the primary tool for understanding the long-term impacts of gender-based programs, the questionnaire's organization needed to reflect a general understanding of the programs and the CoP framework as well as utilize the language and concepts learned in phase #1. In close collaboration with a national (US) Research Advisory Committee, McCreedy and I created a matrix of data categories and subcategories which should be included in the questionnaire. Questions were then developed to explore each of these concepts at least once. In the interest of reducing response time, instrument items related to descriptions of the program or organization were asked only once. Questions related to performance, planning, and outcomes were asked in a minimum of two different locations with at least two question types (i.e., open ended vs. forced choice). Where possible, drop-down menus were created to reduce the time required for response. WebSurveyor was used to develop a logic-based questionnaire constructed around a core framework which allowed young women to answer items tailor-made for the program in which they participated.

Usability and Reliability Usability, reliability, and validity of the instrument were thoroughly tested. First drafts were circulated to project team members for comments and suggestions. A close-to-final draft of the web-based questionnaire was completed by our advisors to identify questions that were unclear, missing choices from drop-down menus, and other problems.

Survey Implementation Administering the questionnaire involved five major tasks: (1) receiving Institutional Review Board (IRB) approval of the final version of the questionnaire; (2) development of an initial database of young women (18 years or older) with which to recruit based on information collected from program leaders; (3) making initial contact with young women and program leaders announcing the study via e-mail and providing IRB information; (4) creation of a survey invitation and a link, with necessary follow-up by e-mail and phone; and (5) additional follow-up phone calls and use of Facebook to increase the sample size. The web-based questionnaire was launched in January 2009 and closed in March 2011.

Data Analysis: Investigation #1

Personal Meaning Mapping, along with the accompanying in-depth interview, is generally used to measure four dimensions of impact—extent, breadth, depth, and mastery. For the purposes of this study, the first three parameters were used, and responses were analyzed through content and cross-case analysis. *Extent* in this study was defined as whether a young woman developed a STEM-rich life and identified strongly with STEM, be that through education, career, or hobby choices. By coding the vocabulary an individual used to discuss a concept or experience, the extent of a person's awareness and understanding of STEM was documented, and because young women made two PMMs, the overlap between the vocabulary/ideas presented in the two maps was also assessed.

The second parameter assesses the *breadth* of a person's sense of impact, for instance, how many different ways did participants discuss or explore relationships between their lives and the informal science program in which they participated. The interviews of the young women were carefully reviewed, to quantify and qualify the kinds of connections that were made in order to identify the full range of relevant ideas/connections possible.

The third parameter investigates the *depth* of a person's knowledge to document how deeply and richly someone understands a particular concept. The connections that young women saw between their lives and the program were more intensively probed, as well as a specific either negative or positive experience in STEM that they recalled to determine whether they felt the experience shaped their understanding/perception of STEM.

Data Analysis: Investigation #2

Data Compilation, Coding, and Analysis To ensure the safety and integrity of the data during the period that the survey was being implemented, data from completed questionnaires were downloaded from WebSurveyor nightly to an Excel file stored on a hard drive and to a removable memory stick. Upon the closing of the survey, data were backed up in a similar manner. Questionnaire data included demographic (age, current educational status, career) and psychographic data (interest in science, science-related hobbies, etc.), as well as open-ended questions. It also included young women's course selection and other evidence of academic achievement and leadership in science.

Data were analyzed with SPSS; quantitative, non-numeric responses were assigned numeric codes and responses converted numerically. Coding rubrics were also created for qualitative items and responses coded numerically, utilizing a CoP lens (participants' level of perceived engagement in the program, and if relevant, other informal science learning experiences, as well as their current participation in science communities, be that education, career, or avocation). The numeric coding system distinguished between questions that were skipped due to programmed logic in the questionnaire and those that were asked but not answered. An extensive code sheet with codes, field names, and question text for each survey question was developed. Findings were reviewed and validated by core/active youth who had not participated in these programs and by science-engaged adults (either in education, careers, or avocations).

Findings: Investigation #1

Investigation #1was completed in 2008. Twelve young women were interviewed: two who had participated in the *Eureka* project in the San Francisco Bay area; three in the *NSP* project, primarily in Philadelphia and New Jersey; three in *WINS*, primarily in Philadelphia; two in *GAC*; and two in *Rural Girls in Science*. Young women ranged in age from 20 to 29 and most had participated in the program 10–15 years before.

Extent Findings revealed the range and power of these programs as memorable and lasting, even for young women who had not pursued science careers. Most of the 12 young women (all active participants) were able to describe specific activities they had engaged in with great detail. Most impacts were positive though not all. Young women did not discuss much traditional "science content" per se but were able to talk about doing science and engaging in science processes. Science-related hobbies suggested a broad perception about "what science is," and impacts were not only related to science but included leadership skills and positive changes in self-esteem.

Breadth demonstrated how many different ways participants discussed or explored relationships between their lives and the science within the free-choice science program in which they participated. For example, girls/women were asked about saved items from the programs in which they participated and were invited to share ways in which the program made a difference in their lives that included a wide range of options—confidence, relationships, community, a safe haven, etc. Although the sample size was small, there were some differences in impact observed between women who had pursued science and those who had not. For example, there was evidence for the role of community, access to STEM networks, and the building of social capital, particularly for women who had pursued further science education and careers. These women indicated that the network established by the program had been beneficial in their later pursuit of STEM, informing/reinforcing their choices and ensuring that they had "no stereotypes about a future in science." For young women who were not pursuing STEM careers or education, they indicated that the program had expanded their world, sense of self, and their awareness of science, helped them be successful in future nonmajor science courses and influenced their interest in STEM generally and in STEM-related hobbies specifically.

Depth Findings again demonstrated that these programs were memorable. Years after, women were able to describe experiences they had in great detail, as well as their connection to other STEM experiences in which they had engaged, both in school and out of school. Women engaged in STEM felt the program added to their science portfolio. Women now engaged in STEM, as well as those not engaged, also indicated that the program built self-esteem/self-efficacy, developed their leadership skills, and helped them be empowered and proud to be smart. One young woman who had participated in *Eureka* both as a participant and later as a mentor commented that "[The program] made me a better person. I was a very angry young woman and the program helped me channel those feelings in positive ways."

It was also possible to use data to develop trajectories of impact for women engaged in STEM now (either through a vocation, education, or avocation) and those who were not engaged, which reinforced that the approach being taken was a valid one which could effectively frame Investigation #2.

Findings: Investigation #2

Research participants in the web-based survey ($n = 213$) were from multiple, diverse sites, including urban, suburban, and rural communities, representing different cultures, ethnicities, socioeconomic status, and participation levels (Girls, Inc.—*Eureka* and *Operation SMART*; $n = 102$; *WINS*; $n = 44$; *NSP*; $n = 34$; *Techbridge*; $n = 30$, and *Rural Girls in Science*; $n = 3$). All were 18 years of age or older and had participated in one of the programs at least 5 years earlier. Not surprisingly, girls who participated more recently were easier to locate, possibly because they were more accessible via the web-based avenues we used to recruit: 107 were in the 18–23 age range, 79 were between 24 and 30 years old, 22 were between 31 and 35, 3 were between 36 and 40, and 2 were over 40. One hundred forty (140) were from urban settings, 61 suburban, and 12 rural. Eighty women identified themselves as Black/African American; 74 were White/Caucasian, 29 Asian/Asian American, 3 American Indian/Alaskan Native, 1 Hawaiian/Pacific Islands, and 9 identified themselves as other (some chose more than one category with which they identified).

Findings from the web-based survey reinforced the findings from Personal Meaning Mapping and in-depth interviews. Programs were memorable and lasting, even for women not pursuing STEM careers or education currently. Most impacts were positive though not all. While the majority were early in their careers, some not only reflected on how program participation influenced their career and education choices but also specifically how it had affected hobbies/interests and even parenting. Long-term impacts of participation with a representative quote demonstrating how women expressed these outcomes included:

1. Increased understanding, appreciation, and enjoyment of science
   "*Eureka* inspired me to actively participate in science and math because I found it could be fun when it pertained to me." (Existing program that engages women in under-resourced communities nationally in STEM experiences and mentoring projects)

2. Increased interest/choices around STEM
   "It gave me a chance that no other program or my school did. I was a poor white girl in a good school who no one paid attention to and was dying for a different type of science than what school offered (only lab sciences). I craved environmental and animal science programs. *WINS* opened that door for me and allowed me to take part in free programs." (Existing year-long natural science enrichment program with opportunities to work in science labs and conduct research)

3. Enhanced skills/performance more broadly (organizational/leadership skills; opportunities to be a mentor)
   "It was through this program that I was able to get my first exposure to the work field. Through these experiences, I was able to shape my leadership and interpersonal skills for future jobs and interviews. It was because of the staff members' support and help that I made it to college today."
   (*National Science Partnership*, existing program that prepares and supports Girl Scout leaders to do science badge work with girls ages 6–11, as well as involves older girls as mentors in these efforts)

4. Enhanced social networks—long-term friends, mentors, and program leaders, who offer support, advice, access to communities of interest (STEM and other), etc.
   "It gave me mentors, especially female mentors. It also gave me a network of professionals that helped me grasp how to be professional and the opportunities that science has for women. No one in my family or immediate circle had gone to college or worked in science so these introductions were invaluable."
   (*Rural Girls in Science* engaged rural young women, primarily Latina and low-income White girls, in community-based STEM projects)

5. Increased sense of agency—increased confidence, self-esteem and aspirations, and self-initiating new behaviors or considerations
   "It influenced me to have the confidence to be smart, and to own my intelligence. It also allowed me to find out that I deserve to be smart." (*Techbridge*, existing San Francisco-Oakland, CA, after-school/summer program that encourages girls underrepresented in STEM in technology, science, and engineering activity)

6. Evidence of changes in identity (changes in trajectory, interests, and sense of self—both in STEM and more general)
   "I can't express enough how much the program helped me. I wouldn't be who I am today. I'm more aware and involved with my kids in every way, both nurturing their education and their physical activities because I know how important that is. Now that I'm a mother of three, looking back at my years in the program, I wish my parents were more involved in my education and in my growing up as a teenager because it is so important."
   (*Eureka*, existing program that engages women in under-resourced communities nationally in STEM experiences and mentoring projects)

7. Increased awareness, recognition, and pride around gender and race-ethnicity-specific issues
   "I received support and motivation, which I did not receive from others. The program gives young girls an opportunity to participate in activities schools do not offer. It helps girls set aside any stereotypes set for women in the field of science and engineering."
   (*Operation SMART*, existing program that engages women in under-resourced communities nationally in free-choice STEM activity)

A series of individual quantitative items that captured a variety of possible program impacts were also collapsed into eight outcome scales, and Cronbach's alpha was used to calculate their reliability. Scales were (1) academic/career interest in science (.95), (2) social skills development (.94), (3) self-Awareness/self-confidence (.92), (4) awareness/understanding of science careers (.91), (5) leisure interest in science (.91), (6) science identity (.85), (7) critical thinking (.84), and leadership (.73).

Comparative analyses were conducted for these scaled outcomes and significant differences found for 7 of the 8 scales as a function of the program young women participated in and whether they lived in an urban setting, for 5 scales if young women had a current science hobby (including significance for the academic/career interest in science outcome scale), 4 scales if they currently use science websites, 3 scales if they currently watch science-related television, and 2 scales based on their current job status (those currently working outside their field rated the science identity scale higher than those working in the field and those working in a science-related job rated the academic/career interest in science outcome higher than those who were not so employed).

Findings strongly support the notion that participation in gender-focused free-choice STEM programs contributes to lasting effects on young women's interest, engagement, and participation in science communities, hobbies, and careers, influencing their identities and relationship to and with science. Program participation also supported participants' interest in STEM and their appreciation for the diversity of disciplines and practices embodied within it and built social capital, such as long-term mentors and friends who could further interest and persistence in STEM, both while participating in the program, but also long after, and increased agency, influencing future careers, education, and hobbies/pursuits. Noteworthy, these program effects were particularly significant and impactful for girls living in urban areas when compared to those in suburban areas (unfortunately the sample size for rural girls was too small for statistical comparisons).

The focus of this study was to determine how participation in these programs *contributed* to women's long-term understanding of science and most importantly to their relationship to and with science, so it is important to reinforce that these programs alone were not the reason for these impacts; participation in them *contributed* to these impacts. There was evidence throughout the data that young women's experiences in these programs were not isolated but connected to their activities at school, home, and in other free-choice learning settings and programs. There was also evidence that these science experiences contributed, along with schools and the workplace, to building science identities that met the needs of these young women, encouraging them to become science-informed citizens, perhaps even *engaged science participants*. As a result of participating in these programs, many of the women have an idea for and appreciation of what science is, not an abstract, decontextualized activity, but as a useful tool for life, reinforcing Roth's notion of the *Fullness of Life* (or *Total Life*) unit of analysis (Roth and Van Eijck 2010).

Results reinforce the thesis of this chapter that free-choice science learning should be a critical player in a comprehensive, whole life approach to science education reform for diversity, one component of a lifelong science learning system in which learning of a variety of kinds are respected and supported. By participating in these diverse communities of free-choice STEM learning, these young women were able to *contextualize* and *personalize* their science knowledge, interest, and understanding over the long term. Although they learned about science, it was not merely as a body of knowledge but as processes by and through which many of these young women were able to construct their identity and, in so doing, develop their *own* lifelong relationship to science.

In a later analysis, my colleague and I hope to be able to show that when meaningful connections were made across settings, even greater impact resulted. To that end, further analyses will determine at a more fine-grained level if there are patterns in outcomes as a function of a host of variables that emerged as important or that the literature suggests are important:

1. Girls' motivation for participating
2. Their childhood interests
3. The age at which they participated
4. The length of time they were in the program
5. The intensity of their participation
6. The length of time since they participated
7. The type of program and "community" afforded by the experience
8. Whether they had opportunities to mentor other girls
9. Whether there were opportunities for outdoor activities, including camping, hiking, and/or physical leadership experiences
10. Whether the program included academic and college preparation activities such as monitoring grades, helping with schoolwork, facilitating trips to visit colleges, assistance in preparing for college testing and the completion of applications
11. The influence of significant adults in science thinking

Although this study focused on young women, I am certain that similar outcomes would result for young men and hope to have the opportunity to extend this research and justify that claim. It is hoped that these findings inform science education practice and research and provide useful information to educators designing and implementing free-choice science experiences and teachers in schools striving to achieve more diverse, in-depth outcomes. I also hope they provide evidence for how more purposeful articulation and collaborations between and among educators in schools, universities, free-choice learning settings, and the workplace could create strategic impact for learners.

An Infrastructure to Support Free-Choice Science Education and Research

It is not only the learners who are different in this new system. The traditional boundaries and roles that have distinguished various groups of science educators are changing also. In the twenty-first century, free-choice learning institutions such as museums, the Internet, and broadcast media are assuming ever more prominent roles in the science education of the public—but the facilitators of free-choice science learning are not classroom teachers. They include nontraditional teachers and mentors, such as after-school youth leaders, professional and amateur scientists, museum educators, educational web developers, and even parents. This point is not trivial. To make a comprehensive lifelong science education system work, science educators who have traditionally only considered schooling must embrace free-choice science learning institutions and organizations, as well as the educators who work within them, as equal partners.

Unfortunately, the value of these educators (or in some cases even their presence) is not recognized nor is there a broad-based realization that they require expertise in teaching science in different ways and configurations than classroom teachers, with learners of all ages (Tran 2006, 2008). Typical teacher education programs only are effective for these educators if they plan to work within schools or at free-choice learning institutions that primarily serve schools. The vast majority of such educators work with other learners or children and youth in out-of-school time. Value also should extend to compensation. Although the public discusses how underpaid public school teachers are, a little-known fact is that most free-choice science educators work year-round, yet earn less annually, receive more modest benefit packages if at all, and have less job security than their counterparts in classrooms (Biggs and Richwine 2011a, b; Bureau of Labor Statistics 2011a, b; Grayson 2011).

There have been some efforts to recognize this sector. For instance, two leading science education organizations, one focused on research and another on practice, have provided some leadership. A free-choice/informal science learning strand was formed in 1995 by the National Association for Research in Science Teaching (NARST), after years in which research in this area was in an "other" strand. In 1999, the NARST board established an ad hoc committee focused on informal science education with the goal of exploring interest among NARST members for additional leadership in this arena. A major product was a policy statement in the area of out-of-school (free-choice) science education research published in the *Journal of Research in Science Teaching* (Dierking et al. 2003).

In 1998, the National Science Teachers Association (NSTA) published a policy statement on informal (free-choice) learning, and in 2000 NSTA leadership established a board seat representing this community of science educators, allowing them to play a larger role in developing policy. And in 1998, the American Educational Research Association also created a Special Interest Group focused on Learning in Informal Environments, and though multidisciplinary in focus, this group has provided an outlet for scholarship in free-choice science education also.

Significant funding also was given to a few consortia in the early 2000s through the US NSF's Centers for Teaching and Learning effort enabling two small research communities to be fostered: the Center for Informal Learning and Schools (CILS), a collaboration among The Exploratorium, San Francisco; King's College, London; and the University of California, Santa Cruz, focused on the intersection of informal and formal education institutions and provided graduate education for a handful of free-choice learning researchers, and the Center for Inquiry in Science Teaching and Learning (CISTL), at Washington University in St. Louis, devoted some of its resources to studying inquiry in informal learning environments. Both of these centers were part of teacher education programs and thus focused primarily on free-choice learning research designed to improve schooling. Neither center was refunded by the NSF, although CILS, through The Exploratorium, has successfully procured funding focused on after-school science. Unfortunately, neither of the academic programs continued; thus, no full-time faculty members solely committed to free-choice learning remain at the three universities.

A handful of graduate programs support free-choice learning educators and researchers. In particular, programs at the University of Pittsburgh, the University of Washington, and Oregon State University (OSU) now exist. The University of Pittsburgh's Center for Learning in Out of School Environments (UPCLOSE) supports students through doctoral programs in the Learning Sciences and Policy. One of the PIs at the University of Washington's Learning in Formal and Informal Environments (LIFE) Center, one of the first of four Science of Learning Centers funded by the US NSF, is focused on free-choice learning, and although he primarily engages in teacher education, the program has been able to support a few graduate students solely interested in free-choice science learning.

Probably the most extensive effort is being undertaken at my own university, OSU, in Corvallis, Oregon (Dierking 2010). With leadership from Oregon Sea Grant and initial funding from the National Oceanic and Atmospheric Administration (NOAA), a graduate program in lifelong STEM learning has been established by the College of Science, in partnership with the College of Education. The program is the first comprehensive, lifelong learning research program in the USA. The free-choice learning area of concentration offers an online master's program which is supporting the education of practitioners working in this arena. Students have included national park interpreters, museum and science center educators, and public health program managers among others. Even a veterinarian technician, who appreciated that much of her job was about communicating science and health information to the owners of her animal patients, was a student. She did not need to know how to develop a lesson plan or manage a class; she needed to understand how to motivate and educate adult learners to take better care of their pets. In the doctoral program, core courses are taken by all students together (there are K-12, college teaching, and free-choice learning options), building a community of researchers that crosses settings, ages, and backgrounds, fostering cross-disciplinary and cross-institutional learning. Each area of concentration also builds specific knowledge base and expertise.

The OSU group is trying to make a difference in terms of the type of research conducted and the practices scaffolded and supported. Current or recently completed research by free-choice learning doctoral candidates includes studies of (1) handheld use in a marine science center, (2) STEM learning activity across a range of home-educating families, (3) STEM learning among Koi fish hobbyists, (4) whale-watching tours in the context of ecotourism, (5) a citizen science project, and (6) informal staff-family interactions in a science center.

Our group is also trying to understand STEM interest development and learning ecologically, across multiple settings and time. For example, with funding from the Noyce Foundation, I am collaborating with OSU colleague John H. Falk and University of Colorado, Boulder colleague, William R. Penuel, on a four-year longitudinal study of the STEM learning of 10-year-olds, in school and out of school, in a diverse Portland community. The premise of the project is that if one more fully understood how and why people, in particular early adolescent children within poor, under-resourced communities, develop STEM-related interests (or not) in their everyday lives, it would be possible to create a more synergistic and effective STEM education system, a system that more successfully supported STEM learning for all. A key feature of this effort, called *Synergies*, is defining the "STEM education system" as the STEM learning resources/assets of the entire community, including schools, but not exclusively. Researchers are also actively involving members of the community in a collective effort to first understand and then try to enhance children's STEM interest and engagement. Currently we are preparing 12 high-school-age youth to be community ethnographers and ambassadors.

Also underlying this effort is the development of a comprehensive agent-based model (ABM) of STEM interest and engagement that will allow key STEM educators in Portland (in school and out), as well as community members themselves, to better visualize and understand the STEM resources/assets available and the complex, multidimensional dynamics of a child/youth's lifelong and life-wide STEM learning. In years 3 and 4 of the project, this model will serve as a tool to formulate alternative strategies for enhancing the effectiveness of educational interventions to improve this community's STEM learning system.

These efforts though ambitious are still small and nascent. Currently lacking is a critical mass of established programs, each with sufficient resources to attract clusters of faculty and graduate students, each cluster pursuing long-term and sustained research aimed at answering basic and applied questions fundamental to the field. This landscape is changing as evidenced by this growing research community, but there is still much that needs to happen.

Ultimately also, taking such a comprehensive approach to whole life science teaching and learning has implications for funding. Currently at the national, state, and local levels, more than 95 % of all public resources for education are spent on schooling, and research monies studying whole life learning are equally scanty. Building a more comprehensive educational system suggests rethinking what constitutes public education. If a comprehensive educational system encompasses all community resources that citizens access for learning across their life span, including those in the workplace and free-choice learning sectors, we should also consider how federal funding for education (and educational research) is allocated. Data certainly supports the claim that free-choice learning is vitally important, in particular for youth and families living in poverty (Bouffard et al. 2006). Yet most of the institutions/organizations supporting such learning are either small underfunded not for profits or institutions that have to charge fees for their use. Equal access to free-choice learning resources, particularly for communities that could benefit most from them, is a tremendous issue that societies worldwide face.

In summary, in order to actualize a comprehensive whole life science education system, I argue for increased efforts that document (and fund) the cumulative and complementary influences of both in- and out-of-school science learning. Given that school-based science education efforts and research currently receive an order of magnitude more resources than free-choice or workplace learning, even a modest change in this ratio could make a huge difference for practice and research. The data suggests it would be a wise investment.

Author Bio

Lynn D. Dierking is Sea Grant Professor in Free-Choice Science, Technology, Engineering and Mathematics (STEM) Learning, College of Science, and Interim Associate Dean for Research, College of Education, Oregon State University. Her research expertise involves lifelong STEM learning, particularly free-choice, out-of-school time learning (in after-school, home- and community-based organizations), with a focus on youth, families, and communities, particularly those underrepresented in STEM. She is currently working on two research projects: an NSF-funded investigation of the long-term impact of gender-focused free-choice learning experiences on girls' interest, engagement, and involvement in science and a Noyce Foundation-funded four-year longitudinal study of the STEM learning ecologies of 10-year-olds, in school and out of school. Lynn has published extensively and serves on the Editorial Boards of *Journal of Research in Science Teaching* and the *Journal of Museum Management and Curatorship*. She received a 2010 John Cotton Dana Award for Leadership from the American Association of Museums.

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