# Chapter 70
# Lifelong Science Learning for Adults: The Role of Free-Choice Experiences

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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 which include visits to museums, zoos, aquariums, science centers, natural area parks and reserves, television, radio, films, books and magazines, and increasingly through personal games, podcasts, the Internet, and other social networking media (Falk and Dierking 2002). A hallmark of this revolution in science learning is that collectively these organizations and tools enable a growing number of individuals to customize and take charge of their own learning. This is particularly the case for many adults who are no longer engaged in formal schooling.

Adults engage in science learning every day and across their adult lives – at home, at work, and while out in the community; much of this learning is free-choice learning. We chose this as the focus of our chapter because the companion pieces in this section of the volume primarily focus on school-aged children. This chapter provides a framework for understanding how adult nonschool experiences contribute to a person's ability to stay aware, informed, and engaged in lifelong science learning.

However, before we proceed we should clarify one aspect of our terminology. We coined the term free-choice learning more than 10 years ago in order to capture the essential nature of this paradigm shift in learning – a recognition that people learn every day throughout their lives, but also that learning is first and foremost a learner-centered, not an institution-centered phenomenon. Free-choice learning describes the nonlinear, self-directed learning that 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 entirely, currently most free-choice learning occurs outside of the formal education system.

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## Adult Learners

A striking characteristic of much of the research on science learning has been the almost singular focus on children's learning; in particular children's school-based learning. The vast majority of a person's lifetime is spent as an adult and even the childhood years are not exclusively given over to schooling. By the age of 18 the average child will have spent only about 20% of his or her waking hours in a classroom and the average person over the course of a lifetime will spend considerably less than 10% engaged in schooling (Sosniak 2001). This would suggest that much, perhaps even most science learning occurs outside of school and beyond the years of childhood. Recent investigations by Falk, Storksdieck, and Dierking (2007) support the view that the majority of science learning occurs outside of school classrooms. In fact, adults attribute roughly half of their science learning to free-choice learning experiences (Falk et al. 2007). Although in the online environment, research suggests that the factors that motivate older learners are not substantially different from those of younger ones (Rockman et al. 2007), it has long been appreciated that the learning needs of adults, in science or other areas, differ from those of children, and of course vary as a function of the individual and change with life needs across the lifespan (UNESCO 1997). Despite individual differences though, it is possible to define a set of learning goals that are fairly typical of adult learners (Falk and Dierking 2002). Adults seek:

1. Increased opportunities to fill discretionary time, build identity, and begin establishing intimate relationships
2. A desire to improve oneself, either personally or professionally
3. A desire, and increasingly the time, to pursue hobbies and continue learning in personally meaningful ways
4. A desire to achieve mastery
5. A desire to become a mentor and share what one knows with others

All of these learning goals can and are met through free-choice learning.

In fact, adult learning outside of formal contexts such as classrooms and training facilities is much more important and pervasive than was typically assumed. David Livingstone (1999, p. 49) compares free-choice learning to an iceberg: "mostly invisible at the surface and immense in its mostly submerged informal aspects." A recent survey of Canadian adults found that over 95% of these adults were involved in some form of explicit free-choice learning activity that they considered important. Compared to comparable data collected a generation earlier, adults increased the amount of free time devoted to learning by more than 50%, typically dedicating an average of approximately 15 h per week to free-choice learning. For many adults, enhanced understanding of science and technology represents an important part of the free-choice learning they engage in during their adult life.

## Research on Adult Free-Choice Learning

Although free-choice learning has been engaged in for as long as there have been humans, investigations of adult learning outside the classroom or laboratory have only occurred quite recently. Exacerbating the paucity of this research is the fact that what little research has been conducted, is often scattered across many disciplines and subdisciplines, with few efforts to consolidate, situate, and synthesize it within an overall framework. However, today there is a growing body of research investigating the "how, where, when, why, and with whom" of science learning in and from informal environments, both physical and virtual. Much of this research is still focused exclusively on children but there is growing awareness that investigating adult learning is important also. These investigations tend to fall into one of three, essentially independent lines of inquiry: (a) investigations into how people learn in informal settings like museums, science centers, zoos, aquariums, natural areas, and community organizations; (b) investigations of how people learn through media-mediated experiences (e.g., television, Internet); and (c) the contribution of free-choice learning to public understanding of science.

### *Informal Settings*

The collective work on learning in and from museums represents the most coherent body of free-choice science learning research. These investigations have focused on why the public visits science-oriented museums, and what and how these visitors learn from visiting these institutions. In particular, adults seem to use these settings to fill the first three learning needs we identified: to fill discretionary leisure time, to build identity, as a way of improving oneself, either personally or professionally and as places to pursue hobbies and continue learning in personally meaningful ways.

The majority of this research investigates the role of exhibitions, objects, labels, and programs in educating the public. A major organizing model for research in museum settings has been John Falk and Lynn Dierking's Contextual Model of Learning (2000), which posits that learning occurs over time and is always contextual. In particular, three contexts – the personal, sociocultural, and physical – interact and influence the nature of any learning experience. Considerable work has been done in the area of personal context factors such as prior knowledge and experience (Roschelle 1995), prior interest (Falk and Adelman 2003) and motivation, and expectations (Falk et al. 2008); all of which have been shown to positively influence visitor learning.

Learning is also influenced by those with whom one visits. For example, visitors are strongly influenced by interactions they have with others in their own social group (Ellenbogen et al. 2004), with a key focus on the role of conversation (Leinhardt et al. 2002; Feinberg and Leinhardt 2002). Research also demonstrates that the quality of interactions with those outside one's social group (e.g., museum explainers, guides, or even other visitors) influences learning (Rosenthal and

Blankman-Hetrick 2002). Distinct differences in visitor interactions have been observed between all-adult groups and groups with children, particularly in terms of the behaviors of the females in the group, suggesting the importance of focusing research on adults specifically (McManus 1987). In her important dissertation study, Silverman (1990) investigated the content and function of talk by adult visitor pairs in museums observing the way adults connected and made meaning as they interacted and conversed about what they saw.

Given the cumulative nature of learning, the outcomes of museum visits have also been found to have long-lasting impact and a number of studies investigating longer-term learning suggest that short-term outcomes are frequently not predictive of the long term (Falk et al. 2004). These concerns notwithstanding, adult visitors have consistently been found to demonstrate factual and conceptual learning in the short term (Dierking et al. 2002). Finally, research has shown that although all the factors listed above do contribute to visitors' science learning, none by themselves account for a significant amount of the variance. These various factors influence science learning collectively, not individually, as predicted by the Contextual Model of Learning. And because of the personal nature of learning, challenges exist in "measuring" it. Recent research demonstrates that all visitors learn, but multiple methods of measurement are needed to document outcomes and what is learned is likely be different from individual to individual (Falk and Storksdieck 2005).

In terms of museum programming with diverse groups, two common outcomes include an increase in museum interest and/or attendance, at least in the short term, and positive changes in participants' perceptions of museums, among children *and* adults. These programs help some participants understand that museums offer fun and comfortable ways to share quality time together, and for science-interested families, an opportunity to participate in an area of interest together (Dierking et al. 2003) although there is still insufficient data to determine whether impacts from these efforts are long-lasting.

Research on the impacts of science learning from organized programs, in particular family-focused efforts, suggests that these programs are extremely effective when integrated with trusted community-based organizations that share a common goal of supporting families, youth, and communities (Luke et al. 2007). Arts programs studied by Shirley Bryce Heath (1996) showed that youth who attend after-school arts programs: (a) tend to get better grades in school; (b) are far more likely to stay in school longer, (c) are more likely to go on to higher education; and (d) are more likely to give back to their communities as adults.

Findings demonstrate that programs influence family dynamics even when parents are not involved in the program. For instance, there was evidence that interests developed within the program were carried into the home, resulting in additional shared family interests and experiences, influencing learning far broader than content knowledge. The research focused on science learning also finds that after participating in such efforts youth and families better understand processes of science and the importance of science, developing an enriched conceptual understanding and a stronger sense of science's role in their daily lives, appreciating that science is not merely "getting the right answer" but wondering, asking questions, and experimenting.

Outcomes for adults are also observed including increased parental awareness and involvement in their children's (and their own) learning, as well as a better understanding that learning is not just for children but for them also, and that learning together as a family can be enjoyable and rewarding (Adelman et al. 2000).

Although efforts often try to engage families in extended informal learning beyond the program, these impacts are much less commonly observed. Community events may encourage active participation, but findings suggest it is difficult to encourage parents to continue activities with children at home. However, participants do identify a main benefit as "expanded horizons," or "exposure to culture" (Garibay et al. 2003). There is evidence that families participating frequently do engage in some learning experiences that build on the program, including related conversations at home, family visits to other similar places, and specifically in science, conducting experiments at home, and adults assisting children with science projects. What is less clear is the long-term impact of these efforts. Preliminary findings from a US NSF-funded retrospective research project, entitled Impact of Informal Science on Girls' Interest, Engagement, and Participation in Science Communities, Hobbies and Careers, suggests that these programs do have lasting impacts on participants as they become adults, including not only choices of education and careers but also hobbies and science habits of mind (Dierking and McCreedy 2008).

Although programs designed specifically for adults, such as activities at museums and science centers, elder hostels, and other formalized experiences are becoming increasingly common, detailed investigations of these programs remain scarce. Also considerably under-investigated are the numerous hobby and science club programs although notable exceptions include the research of Flavio Azevedo (2006) and Marni Berendsen (2003) on the role of interest in influencing science learning amongst adults involved with model rocketry and amateur astronomy clubs, research on the learning of staff and volunteers at Disney's Animal Kingdom (Groff et al. 2005) and research on adults participating in citizen science activities (cf. Bonney et al. 2009). These investigations are providing some foundational understandings of how adults can and do become engaged in efforts to achieve basic science understanding through free-choice learning, but also often strive for highly developed mastery of specialized topics, and in turn serve as mentors for others, the fourth and fifth learning goals we identified.

## *Media-Mediated Learning*

It has long been assumed that mass media, particularly news media, play an important role in informal learning, especially with regard to science and the environment. However, few studies exist which have attempted to determine the direct influence of the news media on learning about science-related issues and topics. Generalized studies include the work of the National Science Board (2008) and Falk and his colleagues (2001), which demonstrate that traditional news media represent a key source of adult information about environmental issues and science topics, even though most citizens and social scientists question the reliability of the information provided (cf. Gaziano and Gaziano 1999). Local television stands out as the main source of science and environmental information for Americans and Europeans (e.g., National Science Board 2008). The Internet is a close second for audiences seeking general science and technology information and is the primary source for those interested in specific science issues (Pew 2006).

News generation and news consumption are linked in a complex feedback loop of perceived demand and real supply (Perse 2001). Indeed, the news media can shape the agenda for public debate and political action ("agenda-setting") and the way in which the adult public perceives an issue ("framing") (Scheufele and Tewksbury 2007). Agenda-setting works largely through increased exposure; a topic becomes more visible and is, therefore, perceived to be of greater importance by the public (and other news makers, editors, and reporters). Agenda-setting can, therefore, influence public opinion and ultimately policy-making (Shanahan and McComas 1997, as cited in Nitz 1999). "Framing" refers to the way in which news media report on issues. While any issue can be reported from multiple angles, the preferred reporting narrative determines how the public understands the nature of an issue (rather than the importance of it). The preferred narrative is a function of the newsroom characteristics cited earlier. The resulting "frames" focus on certain aspects and angles of a topic while ignoring or minimizing others (Nisbet and Mooney 2007). Science and technology (and environmental issues) are often discussed in the mass media with frames that focus on conflict and controversy (e.g., Nisbet and Lewenstein 2002). Particular media content or frames, like public opinion polls, can not only grab the public's attention, but this attention can ultimately impact learning, attitudes, and behavior (Moy et al. 2004).

These investigations reinforce the generally held assumption that broadcast media can and do influence learning, but impacts are typically modest and often very idiosyncratic. The true power and potential of broadcast media may be best understood in culturally popular contexts. The recent popularity of medical emergency and crime scene investigation on television in the USA has resulted in significantly elevated public understanding of these two topics, and significantly increased enrollments in associated graduate programs (including individuals from historically underrepresented groups in science such as women and minorities (Whittle 2003).

As mentioned above, the Internet has revolutionized where, how, when, why, and with whom the public accesses information. However, like other types of educational research, the majority of virtual learning studies have focused on classroom-based practices for children, not free-choice learning among adults (Haley Goldman and Dierking 2005). This research gap exists for several reasons, including most significantly the methodological obstacles in conducting research on a "non-captive" virtual audience. Existing research focuses disproportionately on usability issues, such as ease of navigation. This focus is important and has significantly contributed to improvements in the quality of online learning resources, but unfortunately it also obscures more critical issues such as how, why, and to what end people use the Internet to learn (cf. Dede 2005). For example, the Internet has become a dominant way for adults to get answers to health-related issues and questions about themselves and significant others (Flynn et al. 2006). Given current trends that indicate the Internet and other digital media are increasingly supplanting television as the primary way youth spend their free time (Yelland and Lloyd 2001), it is fair to assume that the impact of media on science learning will become increasingly important to understand as today's youth move into adulthood.

### *Public Understanding of Science*

At the heart of all science education efforts is the goal of promoting public science literacy – a generalized body of scientific understanding and capabilities, historically described as a combination of knowledge and a set of scientific practices and habits of mind (Brown et al. 2005). Science literacy is considered an essential component of a democratic society, supporting a modern technology-based economy and promoting cultural values of society. In particular, civic science literacy, the ability to keep informed about current events in science and to actively participate in a scientifically and technologically advanced society, has been deemed an essential goal of society (Schibeci 1990).

Despite evidence that the majority of the public finds science interesting enough to invest considerable leisure time pursuing science-related learning (National Science Board 2008), most studies attempting to measure public general knowledge and understanding of science and technology conclude that the public is largely scientifically disinterested and illiterate (cf. Bauer et al. 2007). A major conclusion of this research is that the best predictor of public science literacy is college-level courses in science (Miller 2001), although it is acknowledged that informal science education experiences also contribute. Results of this research have been widely used to judge the level of science literacy of entire nations; however, these results need to be interpreted with caution because they primarily assess what adults do not know ("deficit model"), rather than what they actually do know (Irwin and Wynne 1996).

The main thrust of recent criticism of current science literacy assessments has been that the "deficit" model of assessment measures the layperson's knowledge based upon what an expert scientist would deem appropriate across a wide array of topics. These assessments typically use school-like tools that assume an individual's functional literacy would be directly, even linearly, correlated with the extent of his or her factual understanding of a set of generalized scientific information and principles. By contrast, others have argued for a more situated approach, which assumes that attitudes toward and knowledge and understandings of science are more likely to be shaped by an individual's direct and personal experiences, needs, expectations, and culture (Falk et al. 2007).

For most adults, interest in science is linked with decision-making or action, that is, science for specific social purposes (Jenkins 1999), including personal matters (e.g., health or child care), employment (e.g., safety at work, risk assessment), leisure (e.g., choosing the best fishing rod, fabric, mountain bike), or individual or organized protest (e.g., at a proposal hearing to build a nearby nuclear plant). An adult who wishes, individually or as part of a group, to engage seriously in a debate about an issue which has a scientific dimension sooner or later has to learn some of the relevant science. However, matters are rarely as straightforward as simply seeking the relevant scientific information. The information may not be in a form in which it can be used (Layton et al. 1993), it might be unavailable (Wynne 1996) or, as in the case of some situations such as pharmaceuticals, not in the public domain. In addition, even when scientific data are available, there may be argument about the methods by which the data were obtained, about the extent to which generalizations may be sustained, or about the significance to be attached to the findings (Jenkins 1999). When it is available, the scientific information may also be unnecessarily sophisticated and overelaborate for the purposes at hand. For example, heating engineers tend to think of heat as something which "flows" because it is "convenient," rather than the "more correct" kinetic theory of matter.

In much the same way, lay adults choose a level of explanation which meets their needs. In a classic study, workers in a computer company chained to their benches by an earthed metal bracelet in order to prevent damage by static electricity to sensitive electrical components, conceptualized electricity as a fluid which either piled up or was discharged, where it was dispersed or "lost" (Caillot and Nguyen-Xuan 1995). This less than scientific model of electricity enabled the workers to function safely and to make sensible decisions when confronted with problems. These scientifically incorrect understandings or misconceptions were also well tested in the context of experience and action and, in those contexts, had served the workers well. All citizens construct a body of practical knowledge, tested and validated against their individual and collective experience. In deciding how and when to act in practical matters that have a scientific dimension, scientific knowledge is considered alongside other experiential and personal knowledge bases (it is important to acknowledge that while such practical knowledge may be adequate in many contexts, such knowledge can be misleading or even dangerous).

What is important to note though is that this latter approach to assessing science literacy begins from the premise that science learning is a natural and common outcome of living within a science-rich world, situated within activities of everyday life (cf. Roth and Calabrese Barton 2004) and posits that science learning, like all learning, is driven by each individual's need to know. From this perspective, each individual in a community is likely to have a different science knowledge repertoire; a level of science understanding determined by his or her specific needs, abilities, and socio-historical context. Public understanding of science is not some generalized body of knowledge and skills that every citizen should have by a certain age, but rather a series of specific sets of only moderately overlapping knowledge and abilities that individuals construct over their lifetime. From this perspective, individuals possessing comparable science understandings would best be predicted by convergences in life experiences, professions, hobbies, and interests rather than convergences in schooling.

This view of science literacy suggests that accurately assessing public "working" science knowledge requires one of two approaches: (a) more qualitative methods that allow individuals themselves to self-select and direct data collection; or (b) more quantitative methods that restrict assessment to a subset of STEM topics appropriate to the situated realities of a specific population. The former approach was used by Wolfgang Wagner (2007) and a variation on the second approach was used by Falk, Martin Storksdieck, and Dierking (2007). Both studies concluded that informal experiences such as reading unrelated to schooling, museum-going, interactions with peers and workmates, and Internet use were the predominant mechanism by which the public sought and acquired science understanding. One of the interesting, counterintuitive findings from the research on Canadians' free-choice learning (Livingstone 1999) was that among those surveyed, the less schooled appeared to be at least as competent as the more highly schooled on significant dimensions of science understanding. In another study, adult amateur astronomers were found to be highly knowledgeable about astronomy, and years of club membership and engagement in education and public outreach activities were far better predictors of their astronomy knowledge than formal training in science and astronomy (Berendsen 2003). These findings were also reinforced in a recent study focused on public understanding of evolution in which many knowledgeable adults' sources of information about evolution were nonschool in origin including television programs, books, magazines, and museums (MacFadden et al. 2007). We know that the public engages in leisure science learning, and we understand some of the rudimentary ways in which adult learning differs from that of children (Sachatello-Sawyer et al. 2002). However, what remains relatively poorly understood, is the extent of the adult public's free-choice science learning and the cumulative effects of free-choice learning experiences on their self-defined knowledge of science, what we call working knowledge of science.

## Future Directions

As we strive to understand and support efforts to foster increased public science interest, knowledge, and understanding we need to be aware of the vast number of ways, ages, and places in which a person learns science across his or her lifetime including as an adult. Free-choice learning institutions such as museums, the Internet, and broadcast media to name but a few, are assuming an evermore prominent role in lifelong science learning. All of these opportunities represent important, in fact essential ways that we learn and most importantly, *contextualize* our science knowledge and understanding throughout our lifetimes. If we, as science learning researchers and educators in the twenty-first century, want to move beyond the rhetoric of supporting lifelong science learning, it is critical that we recognize, understand, and learn how to facilitate free-choice learning as a powerful vehicle for lifelong science learning. Free-choice learning is not just a nicety, nor is it merely a way to support school-based science learning. Free-choice learning is an essential component of *lifelong* science learning in its own right. To not understand and embrace this form of learning as an essential component of an *adult* citizen's science education is to seriously impede our ability to enhance public science learning. In order to do so effectively, two key aspects of this enterprise must be considered: (a) awareness and recognition of the true scope and scale of the science learning infrastructure of a community; and (b) a vision of future science education research that reframes questions of science learning within the context of a person's entire lifetime.

## *The Science and Technology Education Infrastructure*

Over a decade ago, educational evaluators Mark St John and Deborah Perry (1994) proposed that the educational field rethink how they conceptualize the entire learning enterprise, suggesting that the school and free-choice learning sectors (and we would add the workplace) be considered components of a single, larger educational infrastructure. They used the term infrastructure to describe the system of supports, conditions, and capacities that permit the smooth functioning of daily life. The educational infrastructure in a community supports and facilitates the learning that takes place there. Ideally each community has a richly integrated, broadly supported educational infrastructure, a system of support that enables millions of unique individuals to meet their widely varying science learning needs anytime of the day, at any point in their life. This basic educational infrastructure already exists, composed of schools and universities, the Internet, print and broadcast media, libraries, museums, zoos, aquariums, community-based organizations, the workplace, hobby groups, social networks and friends and family, and many facets of which already function as an integrated community of practice (Falk et al. 2008). However, there is still considerable room for improving the ways all of these educational entities work together to support and sustain science learning across the life span, particularly for adults.

The science learning infrastructure serves as a web of influence that shapes people's understandings, attitudes, aesthetic beliefs, and values. And although schools and universities are important parts of this infrastructure, so are museums and science-technology centers, broadcast media, community-based organizations, libraries, and increasingly a whole host of "bottom-up" organizations such as hobby groups and web-based social networks. The implications of this notion of infrastructure are that we look for science and technology teaching and learning in novel places. For example, the Astronomical Society of the Pacific, based in San Francisco, CA, with funding from the US NSF over the last 15 years, has explored and experimented with ways to tap into the vast resource of adult amateur astronomers (Dierking and Richter 1995). They have involved these astronomers in supporting elementary and middle school teaching in classrooms through Project ASTRO, created Family ASTRO, an effort to provide fun and engaging astronomy experiences to families through the network of museums, science-technology organizations, and community-based organizations such as scouts, and now are providing more focused astronomy training to free-choice learning educators working in small science centers, museums, and planetariums. This effort represents a creative way of brokering connections within the science and technology learning infrastructure since there is growing evidence to demonstrate that the more the three educational sectors of school, work, and free-choice learning overlap in people's lives, the more successful they are at becoming lifelong science learners (Knapp 1997).

If the goal is to embrace a broader notion of learning, it is critical to identify what we might be looking for, where to start looking, and how to look. Here are some brief and tentative ideas for such a strategy. Given how limited our current understanding of lifelong science learning is, coupled with the rapidly changing social, cultural, and economic landscape of the twenty-first century, we offer these ideas with great humility.

We envision two broad lines of research. The first is a top-down view that attempts to deeply understand the structure and functioning of existing, as well as potential interrelationships between actors and agents in the learning landscape with a focus on adults. The second is a bottom-up view that begins with the adult learner and attempts to deeply understand the ecology of learning for life from a learner-centered perspective. Both of these lines of inquiry will require teams from multiple disciplines and will be more robust if they involve both researchers and practitioners and occur across extended time frames (*at least* 5–10 years).

## *Future Research Directions: The Learning Landscape*

Although it is not a large conceptual stretch to envision a complex community infrastructure of learning resources that supports and facilitates the science learning that takes place there, it is quite another thing to understand how it actually functions on the ground for learners. We know that this basic science learning infrastructure already exists in virtually every community, including traditional constituents such as schools and universities, print and broadcast media, libraries, museums, zoos, aquariums, community-based organizations, and the workplace. We also know that increasingly these institutional constituents are being supplanted by noninstitutional, more fluid entities such as hobby groups and social networks, both virtual and physical. Yet currently, we know precious little about how this learning infrastructure functions and how the various pieces intersect and interact. Gaining better insights into the structure and workings of this learning infrastructure will need to be an important element of any future research endeavor. As the historical distinctions between formal and informal education are increasingly less useful, we need a better understanding about the basic nodes of the learning infrastructure, how they interconnect, and how much variability exists in the nature of these infrastructures from community to community. In short, we need to investigate the structure and functioning of the learning landscape.

Historically, investigations of science learning have been quite bounded. Most studies have investigated a single topic area, a specific age cohort, within classrooms, over the time frame of a unit or at most a school year. Even investigations of free-choice learning have typically been equally bounded (visitors to a specific museum, often a single exhibition, framed by the duration of a single visit). Everything we have learned about the nature of learning in general and science learning in particular, suggests that it is rarely instantaneous and does not occur in one place at one time; instead it is strongly socioculturally framed and cumulative. We need to expand the scope and scale of our investigations to better encompass the realities of lifelong science learning. We need to give greater emphasis to the adult years of science learning since this is not only where most people spend the majority of their lives it is also the time when most science learning occurs. In particular, the aging of America represents another research opportunity. We know that learning is important to staying young and fit but there is little research that has specifically focused on the learning of seniors and elders (Doering and Bickford 1994). Over the next few decades, older adults will become an ever-larger percentage of the population (U.S. Department of Commerce 1996), but they will not be like past generations of older adults (Krugman 1996). Aging Baby Boomers will be better educated, healthier, more affluent, and more adventuresome than their predecessors (Foot and Stoffman 1996). Collectively, this population will represent an important, and as of yet, poorly understood group of adult science and technology learners. Implementing these changes will require different methods, different questions, and different types of financial investments. It also will require new partnerships between organizations and individuals – partnerships that better reflect the actual structure and functioning of where and how the public learns science.

## *Future Research Directions: An Ecology of Learning for Life*

Like the prevailing economic models of that time, throughout the twentieth century the focus of science learning investigations was top-down with an emphasis on instruction and curriculum. The organizing framework was that institutions could provide all that was necessary for an informed, science-literate citizenry. Nations and states set up school systems to cater to the learning needs defined by the society and specific institutions in the society, such as corporations and government entities; schooling was designed to satisfy these constituencies and insure that learners met specific competencies. Learners were expected to appreciate having these opportunities and to meet curricular demands in order to further their career development. While there is increasingly greater openness toward learner participation in structuring the learning experience and the environment in which it takes place, the learner is still basically expected to accept the package for what it is. The learner is the consumer of a highly "engineered," readymade or, at best, partly customizable product.

This is not the reality of the twenty-first century. Learning, like economic innovation, is increasingly becoming bottom-up, controlled by the individual, and highly focused on meeting personal needs and interests, particularly for adults. This shift has huge implications for not only how learning occurs, but how research on learning should be conducted. In the new world order, the learner's role is quite different. Although the reasons for learning may sometimes still be associated with the pursuit of formal learning objectives or career goals, as research cited in the above documents, the majority of individual-generated science learning will be aimed at meeting identity-related needs unassociated with degrees and employment – science learning related to hobbies, personal curiosities, or individual needs such as environmental preservation in the neighborhood, or responding to health issues. Not too long ago only the few had access to society's collected knowledge; knowledge was housed in carefully guarded and preserved libraries and universities behind cloistered walls. Individuals were initiated into the world of knowledge by the "knowledge priests," but only if they followed the rules of the order. Today and in the future, anyone can have access to the world's knowledge, anytime of day, wherever they may live, with just a few keystrokes. Adults now are faced with a panoply of science education offerings, at home through online programs, games, or websites or via broadcast media, by venturing outside and visiting science museums, natural parks, in summer camps, elder hostel events, while vacationing or after work at a science pub night. All of these offerings now compete in the leisure marketplace; all are attempting to put the learner's needs and interests first. This changed learning landscape makes historical top-down models of science learning research as obsolete as the institutions sponsoring them.

Arguably, also obsolete are traditionally narrow notions of what constitutes learning. Most science education research is still predicated on conceptualizations of learning that make sense within academic contexts – mastery of facts and concepts in order to orally or in writing describe and defend an idea or proposition. Within the world of free-choice learning, learning is primarily for personal fulfillment and often strongly motivated by the needs of identity formation and reinforcement. In this context, learning tends to take the form of confirmation of existing understandings, attitudes, and skills in order to allow the individual to be able to say: "Okay, I now know that I know/believe that." The goal is not "mastery" in the traditional sense, but rather to provide the individual with a feeling of personal competence. We currently are not well equipped to measure and assess this kind of learning.

We need a more learner-centered approach to science education research that places issues of learner motivation and identity at the center of inquiry. One approach to this perspective has been pioneered by Jan Visser (1999) who has argued that learning entities at different levels of organizational complexity – ranging from the individual to the social – behave like Complex Adaptive Systems (CAS). He argues that it is crucially important to recognize the ecological wholeness of the learning environment, where learners are simultaneous producers and consumers; resources and users of resources.

We would suggest that future investigations of science learning need to situate the learner at the center rather than the periphery of the learning process; as an active co-constructor, not merely a passive recipient. In order to meaningfully understand what learning is but even more importantly, why it happens, studies also should frame learning within the larger ecological context of an individual's life and the learning landscape in which he or she participates. We believe these findings and new directions support the necessity of further exploration of science learning across the life span. Taken together, increasing an emphasis on free-choice learning and its connection to other aspects of the learning landscape, holds the promise for more effectively understanding and achieving measurable, long-lasting impacts on the adult public's science understanding and interest, science learning for personal fulfillment, as well as for an informed citizenry.

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