NSF Influence on the Field of Informal Science Education

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Abstract

Education has been part of the mission of the National Science Foundation (NSF) for the past 60 years. As part of that effort, the Public Understanding of Science (PUOS) and Informal Science Education (ISE) programs have had significant impact on the field of informal science education through investments in projects involving media, exhibitions, educational technology, community and youth programming, "citizen science," evaluation, research, collaboration, and communities of practice. Although the ultimate goals of these efforts are to increase public interest in, understanding of, and engagement with science, technology, engineering, and mathematics (STEM), the primary program thrust has shifted increasingly from numbers reach to furthering the development of the field through advancing knowledge and practice and building capacity.

Keywords: National Science Foundation, informal science education, public understanding of science

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Since creation of the National Science Foundation (NSF) 60 years ago, education has been part of the agency mission to varying degrees. The National Science Foundation Act of 1950 (Public Law 507, 81st Congress), authorized and directed the new agency “to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences.” The initial focus took the form of scholarships and graduate fellowships through a Division of Scientific Personnel and Education. The launch of Sputnik in 1957 brought significant increases in the education budget for teacher institutes and curriculum development (Mazuzan, 1994), along with creation of the Public Understanding of Science (PUOS) program. The funding climate changed in 1982, when the Education Directorate was abolished due to major budget reductions by the Reagan administration. Following efforts by the National Science Board and others, the Science and Engineering Education Directorate was reestablished and a new Informal Science Education (ISE) program created the following year.

Today, although education activities are supported throughout the Foundation, they are the primary focus for the Directorate for Education and Human Resources (EHR) with a FY 10 budget of approximately $873 million. Its four divisions are Undergraduate Education, Graduate Education, Human Resource Development, and Research on Learning in Formal and Informal Settings (DRL). ISE, managed within DRL, is the primary program that supports the EHR theme of furthering public understanding of science and advancing STEM (science, technology, engineering, and mathematics) literacy by investing in projects that advance the field of informal science education.

Influence on the Field

Figure 1 illustrates one measure of the historical growth of the informal science education field, the number of members of the Association of Science-Technology Centers (ASTC), the professional organization for science museums and related institutions. Shortly after ASTC was founded by 16 members, NSF provided initial operating support for the new organization (Kimche, 1973) and helped catalyze a major expansion of the field in the following decades by investing in exhibitions, broadcast media, film, community and youth programs, learning technologies, professional development, and research. ASTC currently has 583 member organizations in 45 countries.

As shown in Figure 2, the field can be characterized by a wide variety of domains (Falk, Randol, & Dierking, 2008). This diagram portrays their distribution along two axes: “practicing informal education” and “promoting STEM understanding.” Some organizations, such as science centers, natural history museums, zoos, aquariums, view themselves as tightly committed to both dimensions. Others place greater emphasis on one, such as public TV and radio on informal education or science writers on STEM understanding. Over the past six decades, NSF has invested in most of these communities, along with universities, to support and advance their work at the intersection of these two dimensions.

The sections that follow offer selected examples of significant PUOS and ISE awards. Many are the first of its kind or an early project in one of the informal science education domains, and often represent an innovation in product, process, or outcome. This brief survey is meant to be illustrative, highlighting examples of noteworthy NSF investments.

Media

NSF played a critical role in stimulating and establishing public media as vehicles for STEM education. Following funding in 1967 for the Spectrum series on public TV, NSF provided initial funding for the WGBH Science Program Group (Ambrosino, 1973), which led to the first NOVA program (Tressel, 1990), now the longest-running science television show. NSF initiated the National Public Radio science desk (Gwathmey, 1978) and funded Star Date (Smith, 1978), the longest-running national radio science feature, to be followed by others such as Earth & Sky (Byrd, 1992), and Science Friday (Buzenberg, 1992). NSF provided early support for such early children's programmin as 3-2-1 Contact (Gibbon, 1977) in science and with Square One TV (Connel, Schneider, Mielke, & Peel, 1987) in mathematics, and later by many others, such as Bill Nye the Science Guy (Brock, McKeena, Gottlieb, & Nye, 1992).

NSF funded films, such as the PBS American Playhouse docudrama initially titled "Walking on Water" (Musca, Menendez, & Long, 1987), which featured the then unknown Los Angeles high school teacher Jaime Escalante; it was distributed as the movie "Stand and Deliver." Awards helped transform the IMAX© film from a World's Fair attraction and travelogue content into an educational media through funding such films as Cosmic Voyage (Silleck, Chaisson, Marvin, Soter, & Harwitt, 1991) and Tropical Rainforest (Day, Shedd, & White, 1991). Subsequently, more than 20 films have been added to the educational film library through NSF investment. In addition, NSF has long supported production of planetarium shows (Littmann, 1979), including development of programs that broadened the scope of domed theaters beyond astronomy (Oles, Taylor, & Ratcliffe, 1994).

NSF continues to encourage innovation with such television programming as Peep and the Big Wide World (Taylor,1999), the first multi-media science project targeted at pre-schoolers and caregivers; Design Squad (Sullivan & Wolsky, 2005), which features team-based challenges intended to increase knowledge and interest in engineering; SciGirls TV (Hudson, 2007), designed to spark curiosity in STEM in its target audience of girls age 8 to 12; and the PBS NewsHour science unit (Crystal & Kennedy, 2003), unique to today's broadcast television news. Recent examples of innovative radio programming include Youth Radio (O'Leary, 2006), created by underrepresented youth learning about science and technology; Radio Lab (Horne, Abumrad, & Krulwich, 2007), which produces "movies for the ear" that blend reporting and documentary; and StarTalk Radio (Tyson & Matsos, 2009), an entertaining show with call-ins on commercial talk radio stations.

Exhibitions

NSF supported the growth and development of science museums by investing in both permanent and traveling exhibitions, helping them expand their audiences. The first were traveling exhibits by the Maryland Academy of Sciences in 1959. NSF invested in the Exploratorium's pioneering exhibits (Oppenheimer, 1972) based on visitor interaction with actual scientific phenomena, which became a model for science centers around the world. It funded a traveling exhibition on Global Warming (Pollock, Grinell, & Booth, 1990) long before this issue reached prominence. Funding for the innovative exhibition Whodunit? (Walter, 1992) drew from the appeal of forensics and was subsequently followed by "CSI: The Experience" (Walter & Lindsey, 2006), building on the popular television series. Approximately 50% of the more than 200 traveling exhibitions toured by ASTC to science museums and other venues have been funded by NSF.

Not all innovative exhibitions require significant funding. The Lion's Mane (Packer, 2003) demonstrated what is possible at a small scale (500 sq ft) with a limited budget. This traveling exhibition, funded through ISE's Communicating Research to Public Audiences (CRPA) program, featured a full-size plush African lion created by toy company with different manes for the researcher to observe effects in the wild, accompanied by actual video footage.

Exhibition awards continue to introduce new ideas, approaches, and technologies to the field. A recent example is the large-scale integration of living collections with interactive science center exhibits in the California Science Center's World of Ecology (Kopczak, 2004). Another is the Queensborough Public Library's Children's Library Discovery Center (Rudder-Kilkenny, Rockwell, & Rudy, 2005), which integrates hands-on science exhibits within a new children's library. The traveling exhibition Race: Are We So Different? (Overbey, 2008) demonstrates how the challenging topic of race and human variation can be addressed from a scientific perspective. The NSF-funded web site http://www.ExhibitFiles.org (Pollock & McLean, 2006) provides a platform for sharing, documenting, and discussing science museum exhibitions.

Learning Technologies

Exhibition projects often involve the application of new technologies for learning. For example, Texas Instruments 99/4A computers were used in the Inquiry exhibition (Ucko, 1981) at Chicago's Museum of Science and Industry (these "state-of-the-art" personal computers had 16K RAM and were programmed in BASIC). In addition to exhibit technology, NSF has encouraged the application of digital technologies to informal learning. For example, Hands-On Universe (Pennypacker, 1995) enabled the public to access professional telescopes via the emerging Internet. An Electronic Guidebook (Semper & Tinker, 1999) connected networked handheld computers to Exploratorium exhibits; Science Now Science Everywhere (LaBar & Bressler, 2006) took the next step, connecting visitor cell phones to exhibits at the Liberty Science Center. The Accidental Scientist (Semper, 2001) linked the science behind familiar subjects like cooking, music and gardening to web sites most commonly visited by those pursuing these avocations. WolfQuest (Spickelmier & Schaller, 2006) is an online multiplayer videogame involving role-playing as a gray wolf avatar to learn about ecology and conservation.

Current investments support projects involving mobile technologies, augmented reality, virtual worlds, and other rapidly evolving aspects of cyberlearning. Now nearly every ISE project involves technology applications, increasingly Web 2.0 and mobile.

Community and Youth Programs

NSF has invested for many years in the development of STEM learning experiences for after-school and community-based programming. For example, PUOS helped start Outdoor Biology Instructional Strategies (OBIS) (Laetsch, 1976) to provide adults with tools developed by the Lawrence Hall of Science to engage non-school youth groups, ages 10 to 15, in ecology through inquiry-based outdoor learning experiences. Support was provided for the AAAS Mass Media Science Fellows program (Ratchford, 1980), which also continues today. Not-for-profit organizations and community-based projects were early recipients of funding, such as development of an integrated science arts program in New York’s Roosevelt Island community (Litke, 1975), programs for 4-H groups (Fox, Christy, Gilley, Clifford, and Hoffenburger, 1987), and a Girl Scout leader training program (McCreedy, 1988).

“Citizen science” was stimulated in its current form by a grant to Cornell University for “Public Participation in Ornithology: An Introduction to Environmental Research” (Bonney, Walcott, & Butcher, 1992), which led to a wide range of other projects based on public participation in science. Citizen Science Central (Bonney, Dickinson, Rosenberg, Mobley, & Kelling, 2006) now shares knowledge and provide resources for projects involving birds, mammals, invertebrates, plants, invasive species, water and air quality, weather and climate change, and astronomy (http://www.birds.cornell.edu/citscitoolkit).

NSF-funded projects have supported early childhood learning, such as Playtime is Science (Sprung, 1992), a pre-K -3, inquiry-based parent/child science program and Mother Goose Asks Why? (Anderson, DeFrancis, & Nagy, 1994) for caregivers. Many grants have supported learning experiences for out-of-school time, such as through a a national network of Community Science Workshops (Fonteyn, 1995) providing after-school, family, school, and summer science programs in underserved communities and through development of hands-on curricula (Zubrowski, 1999). NSF has invested for many years in projects designed to reach and engage audiences from underserved groups, such as a science column for minority newspapers (Walker, 1977), programs for older adults (Larkin, 1978), programs targeting at-risk youth (Saunders, Orum, & Delgadillo, 1993), programs for children with disabilities (Brewster & Grunewald, 1995), and programs to help Hispanic parents promote mathematics learning for their children (Gay & Civil, 1999).

Today, these programs are viewed as an increasingly important strategy for reaching diverse audiences, with emphasis on advancing the field through such efforts as a Planning Conference: National Initiative for Science After School (Barstow & Bevan, 2004), which led to the formation of the Coalition for Science After School and projects that integrate STEM with local culture and values, such as Native Science Field Centers (Sachatello, Augare, & Fredenberg, 2006).

Research and Evaluation

NSF investments have supported knowledge building of informal STEM building through research and evaluation, starting with such studies as: An Investigation of the Effect of

Field Trips on Science Learning (Falk, 1977); Research Studies on the Scientific Literacy of the Attentive Public (Miller, 1977); An Exploratory Study of 3-2-1 Contact (Crane, 1986); and Naive Knowledge and the Design of Science Museum Exhibits (Borun, 1987).

NSF stimulated the practice of front-end, formative, and summative evaluation, which became proposal requirements in the late 1990s (Cosmos, 1998; National Science Foundation, 1998). The website informalscience.org (Crowley & Leinhardt, 2002), hosted by the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE), contains more than 200 evaluation studies of exhibitions and programs. The recent *Framework for Evaluating Impacts of Informal Science Education Projects* (Friedman, 2008) seeks to further the quality and coherence of summative evaluation by offering guidance on the types of learning outcomes and methods for determining impact.

In 1992, NSF funded a synthesis (Crane & Birk, 1992; Crane, Nicholson, Chen, & Bitgood, 1994) based primarily on evaluation studies of media projects, community projects, and museum exhibitions. A Museum Learning Collaborative (Danvers, 1998) was created with co-funding from NSF in concert with other federal agencies to generate a research base that contained approx. 2,300 citations by the time funding ended five years later. The web site informalscience.org continues this role today with over 5,000 citations from the research literature.

Most recently, a major NSF-funded synthesis of the growing body of diverse research literature underlying informal learning of science has been published (Schweingruber, 2005; National Research Council, 2009a). It is worthy of note that approximately half of first authors listed in the references for this study have been recipients of NSF support. The intent of Learning Science in Informal Environments (LSIE) was to provide a foundation for future research by making prior work more widely known and through recommendations for fruitful areas of study, and also to enable practitioners to build on research and evaluation in designing and implementing informal learning experiences. That outcome was reinforced through support for a companion publication—Surrounded by Science—designed specifically for practitioners (Schweingruber, 2007; National Research Council, 2009b). In addition to addressing these needs, the study broadened the usual definition of learning to recognize the importance of interest and motivation, as well as identity development. Perhaps most important from a policy perspective, LSIE provides a measure of external validation of the value of learning in informal settings (Ucko, 2010).

Collaboration and Communities of Practice

The ISE program has encouraged collaboration to build capacity and encourage innovation, facilitating outcomes not otherwise possible. For example, the Science Museum Exhibit Collaborative (Danilov, 1985), formed to cooperate in the development and funding of exhibitions that travel among its members, received early support and still continues today. Others include the Science Carnival Consortia (Schatz, 1991), which combined exhibits and training for new and developing museums; the Magic School Bus Collaborative (Reynolds & Sanford,1993), in which six museums developed activities, programs, and exhibits based on the books and television show; TEAMS [Traveling Exhibits at Museums of Science] Collaborative (Goudy, Trautmann, Wolf, Sinclair, Frenza, & Yao, 1996), formed to develop traveling exhibitions, build capacity, and conduct research among small museums; the Philadelphia Informal Science Education Collaborative (Borun, Horwitz, McGonigle, & Wagner, 1994), which brought together a science museum, natural history museum, zoo, and aquarium to study and foster family learning across settings; and the Playful Invention and Exploration (PIE)

Network (Resnick, Rusk, Mikhak, Petrich, & Wilkinson, 2001), a partnership between the MIT Media Lab and six museums that created learning activities using small programmable devices (“Crickets”).

A recent example is Communicating Climate Change (Staveloz, Bonney, & Leiserowitz, 2008), which links science centers with 12 NSF-funded Long Term Ecological Research Centers to engage the public in climate change science. Another is KQED’s Quest (McCann & Rockman, 2009), a large-scale cross-platform collaboration involving research institutions, science and nature centers, and community-based organizations that combines web, television, and radio production, community engagement, and educational resource development.

Several major NSF investments have been helping further professionalization and foster communities of practice. In addition to serving as an online database, the previously-mentioned Exhibit Files web site also provides a forum for exhibit developers to share knowledge and ideas. The Center for Advancement of Informal Science Education (CAISE), a partnership of ASTC, UPCLOSE, Oregon State University, and the Visitor Studies Association (Pollock, Falk, Crowley, & Friedman, 2007), seeks to bring together the diverse segments of the informal learning field through such activities as Inquiry Groups that synthesize research and practice addressing cross-cutting issues such as public participation in science and the synergies between formal and informal learning. The Nanoscale Informal Science Education Network (NISE Net) is connecting science museums nationally with scientific researchers locally (Bell, Semper, Rockwell, Martin, & Alpert, 2005). This project of the Museum of Science, Boston with the Exploratorium and Science Museum of Minnesota now in its fifth year includes 14 organizational partners and involves activities at more than 100 sites.

Discussion

Identification of these and other projects represents a step towards documenting the impact of NSF funding on the field of informal science education. They are suggestive of influence in several ways. These investments have advanced practice through the development of innovative media, exhibitions, diverse programs, and many other types of informal learning experiences. NSF funding has built capacity by helping nurture and support emerging and developing institutions, supporting the tremendous expansion of the field that occurred from the 1970s through the 1990s. They have created infrastructure that supports all (e.g., CAISE, informalscience.org) or parts (e.g., exhibitfiles.org) of the field. Many, if not most, awards provided professional development experiences for the Principal Investigators and other staff. And through research and evaluation, they have added to our expanding knowledge of informal STEM learning.

The PUOS and ISE programs encouraged projects to build on prior work and make use of effective practices. Projects were required to ensure content accuracy through use of STEM experts as partners or advisors. Program emphasis on reaching underrepresented groups and underserved audiences encouraged broader participation in projects and involvement of community-based organizations as grantees and collaborators. Linkages to schools were encouraged, leading to connections to science and mathematics standards, spin-offs for classroom use, and teacher professional development.

Because NSF funding is highly competitive, only a portion (20% or less) of proposals can be funded, although many more are typically highly rated. It is not unreasonable to postulate that those declined also benefited from the process of preparing a grant proposal and having it reviewed, even though they may not have received NSF funding. In addition, many hundreds of professionals have served as panelists over the years, gaining from the professional development offered by serving as a reviewer.

These NSF-funded efforts have contributed to moving the field towards a "tipping point" in terms of recognition of the value of informal learning experiences (Ucko, 2010). Indicators of external acknowledgment of their educational role include greater recognition by education journals (e.g., *Science Education*) and monographs (e.g., Ucko & Ellenbogen, 2008), private funders (e.g., Noyce Foundation), and the federal government (e.g., Academic Competitiveness Council). The 2010 ISE Summit organized by CAISE attracted some 450 participants from a very wide range of institutions and organizations. A recent editorial in *Nature* called for education policy makers to take note of the impact of learning experiences "in the wild" (Waldrop, 2010).

Created at a time when the number and types of organizations engaged in informal science education were much more limited, the PUOS program sought "to help the public learn about and understand science and technology" (National Science Foundation, 1982, p. 4). Directly reaching wide, diverse audiences has been a program goal for many years (Cosmos, 1988) and remains important. However, as the informal science education matured and capacity increased, the primary thrust for ISE investment has shifted away from simply numbers reached. Increasingly, emphasis has been placed on directly or indirectly furthering the development of the informal science education field through advancing knowledge and practice and building capacity, leveraging project investments to strengthen the nation's informal science education infrastructure.

This transition is illustrated by the change in performance measures. In a Cosmos Corporation report (1999), the performance measures were based on such outcomes as levels of audience interest, attentiveness, and understanding and the percent or number of participants who gain knowledge, are excited by a topic, acquire skills, and take an action based on exhibits, media, and community programs. In contrast, the program metrics submitted with the NSF FY 2011 budget request (National Science Foundation, 2010), are based on the number of professionals who use ISE-funded resources to improve their knowledge and/or practice and the percent of development-intensive projects that employ appropriate evaluation methods and apply them with appropriate rigor.

Opportunities

As knowledge building assumed greater importance to the program, the numbers of proposals from institutions of higher education has grown (Suter, 2010). The involvement of academic Principal Investigators will help to strengthen the research base and enrich discourse in the field, which has been largely practitioner-based. Collaboration between academic institutions and informal learning organizations will be needed to provide access to audiences and experience, as well as to encourage research-based practice. The LSIE report offers fruitful recommendations for future research (National Research Council, 2009a, pp. 310-314). Building the capacity of schools of education in the area of informal learning would further strengthen this effort, since only a limited number of universities currently offer graduate degrees in that area.

Cyberlearning is playing a rapidly expanding role in the portfolio as nearly ubiquitous mobile devices and computers enable learning anytime and anyplace by anyone (NSF Task Force on Cyberlearning, 2008). These technological advances are bringing greater attention to the notion of an “ecology” of learning, the “set of contexts found in physical or virtual spaces that provide opportunities for learning” (Barron, 2006) that will help to blur traditional boundaries. As a result, the integration of approaches within projects is increasingly common, with multiple platforms helping extend experiences and reach new audiences. The aforementioned KQED Quest project, for example, demonstrates how public media can extend its reach beyond broadcast television by integrating multiple partners and platforms.

Boundary crossing between formal and informal science education provides additional opportunity. Currently, informal learning institutions support and complement classroom learning through such means as afterschool programs, museum field trips and outreach, hands-on activities, curricula, and media. In fact, 90% or more offer at least one such program and more than half provide at least one form of teacher professional development (Finkelstein, 2005). Based on this survey, 72% of elementary schools nationally are served by these organizations. That impact is likely to increase as the role of key affordances of informal learning (e.g., learner-centric focus, intrinsic motivation) gain greater recognition. In this sense, informal learning can play an important role in K-12 education reform, stimulating creation of new kinds of learning environments that have the potential to transform the traditional conceptions of classroom and school. NSF recently supported a series of “blue sky” workshops that began to explore the possibilities (Reys & Reys, 2009).

As noted in the LSIE report, “Informal environments can have a significant impact on science learning outcomes for individuals from nondominant groups who are historically underrepresented in science” (National Research Council 2009a, p. 301). Informal learning experiences provide an alternative pathway for STEM learning that have the potential to address the “achievement gap,” an ever more critical need as the U.S. population becomes progressively diverse.

Another opportunity is the further development of measures and tools for assessing informal learning, particularly “on the range of intellectual, attitudinal, behavioral, sociocultural, and participatory dispositions and capabilities that informal environments can effectively promote" (National Research Council, 2009a, p. 310). Such measures and tools must be appropriately rigorous and should be made widely available to encourage sharing and collaborative refinement. Capacity building in the field of informal learning evaluation represents a related need and opportunity.

The value of widespread sharing of knowledge and resources goes well beyond assessment. NISE Net has demonstrated that informal learning institutions can collaborate effectively on a national scale, reducing the need to redevelop content, exhibits, programs, or experiences that could be applied or adapted for local use. That project, and many others, also demonstrate how informal learning organizations can tackle societal issues, not only to create relevance, but also to encourage public engagement with critical national and international concerns.

While the field pursues these and other opportunities, further study of the impact of past NSF awards would be of value. This paper has selectively identified less than 5% of the approximately 1,500 awards funded all or in part by the PUOS and ISE programs. A multi-year contract evaluation of the ISE program currently underway should contribute to our knowledge of impact and influence. Social network analysis could trace the connections among Principal Investigators and other professionals. Case studies that demonstrate their influence on subsequent work would enhance our understanding of the role played by NSF in advancing informal STEM education and could begin to identify factors that lead to the greatest impacts. These and other studies may well suggest changes in ISE program design and emphasis, as well as in funding policies for other funders seeking to advance knowledge, practice, and capacity of the field.

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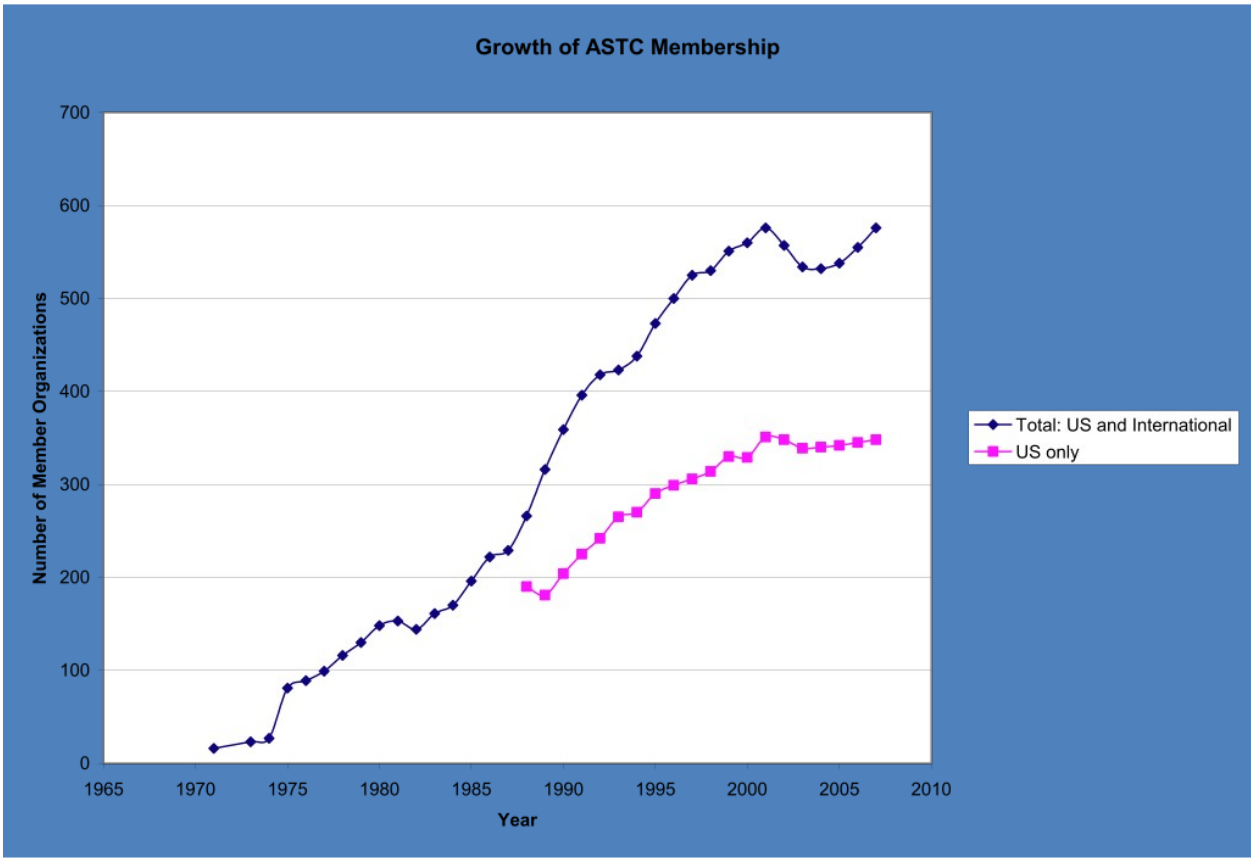

Figure 1. Numbers of institutional members of the Association of Science-Technology Centers by year (ASTC).

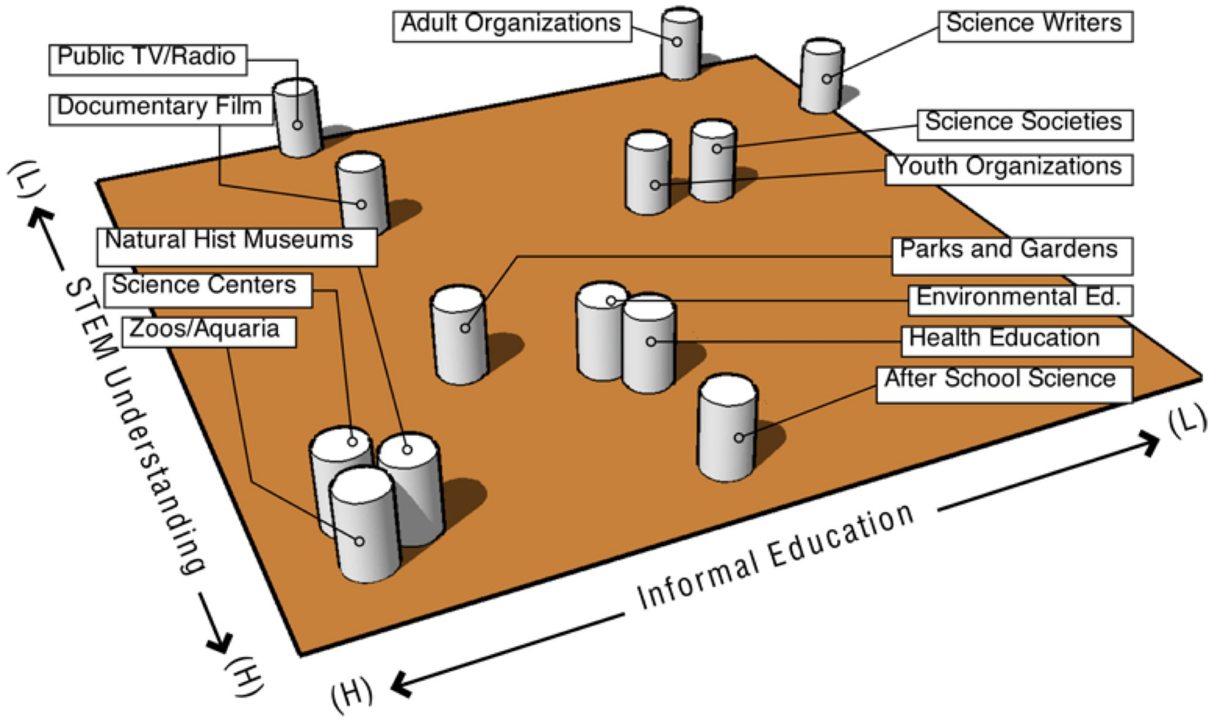

Figure 2. The "landscape" of communities engaged to varying degrees in informal science education as positioned across the two dimensions of STEM understanding and informal education (Falk, Randol, & Dierking, 2008).