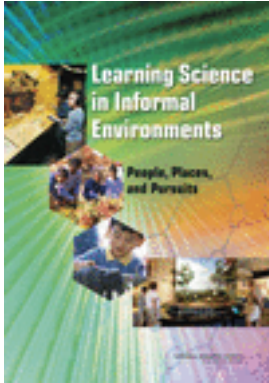


## Free Executive Summary



### **Learning Science in Informal Environments: People, Places, and Pursuits**

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors, Committee on Learning Science in Informal Environments, National Research Council

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*Informal science is a burgeoning field that operates across a broad range of venues and envisages learning outcomes for individuals, schools, families, and society. The evidence base that describes informal science, its promise, and effects is informed by a range of disciplines and perspectives, including field-based research, visitor studies, and psychological and anthropological studies of learning. Learning Science in Informal Environments draws together disparate literatures, synthesizes the state of knowledge, and articulates a common framework for the next generation of research on learning science in informal environments across a life span. Contributors include recognized experts in a range of disciplines--research and evaluation, exhibit designers, program developers, and educators. They also have experience in a range of settings--museums, after-school programs, science and technology centers, media enterprises, aquariums, zoos, state parks, and botanical gardens. Learning Science in Informal Environments is an invaluable guide for program and exhibit designers, evaluators, staff of science-rich informal learning institutions and community-based organizations, scientists interested in educational outreach, federal science agency education staff, and K-12 science educators.*

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## Executive Summary

Science is shaping people's lives in fundamental ways. Individuals, groups, and nations increasingly seek to bolster scientific capacity in the hope of promoting social, material, and personal well-being. Efforts to enhance scientific capacity typically target schools and focus on such strategies as improving science curriculum and teacher training and strengthening the science pipeline. What is often overlooked or underestimated is the potential for science learning in nonschool settings, where people actually spend the majority of their time.

Beyond the schoolhouse door, opportunities for science learning abound. Each year, tens of millions of Americans, young and old, explore and learn about science by visiting informal learning institutions, participating in programs, and using media to pursue their interests. Thousands of organizations dedicate themselves to developing, documenting, and improving science learning in informal environments for learners of *all* ages and backgrounds. They include informal learning and community-based organizations, libraries, schools, think tanks, institutions of higher education, government agencies, private companies, and philanthropic foundations. Informal environments include a broad array of settings, such as family discussions at home, visits to museums, nature centers or other designed settings, and everyday activities like gardening, as well as recreational activities like hiking and fishing, and participation in clubs. Virtually all people of all ages and backgrounds engage in activities that can support science learning in the course of daily life.

The Committee on Science Learning in Informal Environments was established to examine the potential of nonschool settings for science learning. The committee, comprised of 14 experts in science, education, psychology, media, and informal education, conducted a broad review of the literatures that inform learning science in informal environments. Our charge specifically included assessing the evidence of science learning across settings, learner age groups, and over varied spans of time; identifying the qualities of learning experiences that are special to informal environments and those that are shared (e.g., with schools); and developing an agenda for research and development.

The committee organized its analysis by looking at the places where science learning occurs as well as cross-cutting features of informal learning environments. The "places" include everyday experiences—like hunting, walking in the park, watching a sunrise—designed settings—such as visiting a science center, zoo, aquarium, botanical garden, planetarium—and programs—such as after-school science, or environmental monitoring through a local organization. Cross-cutting features that shape informal environments include the role of media as a context and tool for learning and the opportunities these environments provide for inclusion of culturally, socially, and linguistically diverse communities.

We summarize key aspects of the committee's conclusions here, beginning with evidence that informal environments can promote science learning. We then describe appropriate learning goals for these settings and how to broaden participation in science learning. Finally, we present the committee's recommendations for practice.

## PROMOTING LEARNING

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Do people learn science in nonschool settings? This is a critical question for policy makers, practitioners, and researchers alike—and the answer is yes. The committee found abundant evidence that across all venues—everyday experiences, designed settings, and programs—individuals of all ages learn science. The committee concludes that:

- Everyday experiences can support science learning for virtually all people. Informal learning practices of all cultures can be conducive to learning systematic and reliable knowledge about the natural world. Across the life span, from infancy to late adulthood, individuals learn about the natural world and develop important skills for science learning.
- Designed spaces—including museums, science centers, zoos, aquariums, and environmental centers—can also support science learning. Rich with real-world phenomena, these are places where people can pursue and develop science interests, engage in science inquiry, and reflect on their experiences through sense-making conversations.
- Programs for science learning take place in schools and community-based and science-rich organizations and include sustained, self-organized activities of science enthusiasts. There is mounting evidence that structured, nonschool science programs can feed or stimulate the science-specific interests of adults and children, may positively influence academic achievement for students, and may expand participants' sense of future science career options.
- Science media, in the form of radio, television, the Internet, and handheld devices, are pervasive and make science information increasingly available to people across venues for science learning. Science media are qualitatively shaping people's relationship with science and are new means of supporting science learning. Although the evidence is strong for the impact of educational television on science learning, substantially less evidence exists on the impact of other media—digital media, gaming, radio—on science learning.

## DEFINING APPROPRIATE OUTCOMES

To understand whether, how, or when learning occurs, good outcome measures are necessary, yet efforts to define outcomes for science learning in informal settings have often been controversial. At times, researchers and practitioners have adopted the same tools and measures of achievement used in school settings. In some instances, public and private funding for informal education has even required such academic achievement measures. Yet traditional academic achievement outcomes are limited. Although they may facilitate coordination between informal environments and schools, they fail to reflect the defining characteristics of informal environments in three ways. Many academic achievement outcomes (1) do not encompass the range of capabilities that informal settings can promote; (2) violate critical assumptions about these settings, such as their focus on leisure-based or voluntary experiences and nonstandardized curriculum; and (3) are not designed for the breadth of participants, many of whom are not K-12 students.

The challenge of developing clear and reasonable goals for learning science in informal environments is compounded by the real or perceived encroachment of a school agenda on such

settings. This has led some to eschew formalized outcomes altogether and to embrace learner-defined outcomes instead. The committee's view is that it is unproductive to blindly adopt either purely academic goals or purely subjective learning goals. Instead, the committee prefers a third course that combines a variety of specialized science learning goals used in research and practice.

### **Strands of Science Learning**

We propose a “strands of science learning” framework that articulates science-specific capabilities supported by informal environments. It builds on the framework developed for K-8 science learning in *Taking Science to School* (National Research Council, 2007). That 4-strand framework aligns tightly with our Strands 2 through 5. We have added two additional strands—Strands 1 and 6—which are of special value in informal learning environments. The six strands illustrate how schools and formal environments can pursue complementary goals and serve as a conceptual tool for organizing and assessing science learning. The six interrelated aspects of science learning covered by the strands reflect the field's commitment to participation—in fact, they describe what participants do cognitively, socially, developmentally, and emotionally in these settings.

Learners in informal environments:

Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.

Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science.

Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.

Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.

Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.

Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

The strands are distinct from, but overlap with, the science-specific knowledge, skills, attitudes, and dispositions that are ideally developed in schools. Two strands, 1 and 6, are particularly relevant to informal learning environments. Strand 1 focuses on generating excitement, interest, and motivation—a foundation for other forms of science learning. Strand 1, while important for learning in any setting, is particularly relevant to informal learning environments, which are rich with everyday science phenomena and organized to tap prior experience and interest. Strand 6 addresses how learners view themselves with respect to science. This strand speaks to the process by which individuals become comfortable with, knowledgeable about, or interested in science. Informal learning environments can play a special role in

stimulating and building on initial interest, supporting science learning identities over time as learners navigate informal environments and science in school.

The strands serve as an important resource on which to develop tools for practice and research. They should play a central role in refining assessments for evaluating science learning in informal environments.

## **BROADENING PARTICIPATION**

There is a clear and strong commitment among researchers and practitioners to broadening participation in science learning. Efforts to improve inclusion of individuals from diverse groups are under way at all levels and include educators and designers, as well as learners themselves. However, it is also clear that laudable efforts for inclusion often fall short. Research has turned up several valuable insights into how to organize and compel broad, inclusive participation in science learning. The committee concludes:

- Informal settings provide space for all learners to engage with ideas, bringing their prior knowledge and experience to bear.
- Learners thrive in environments that acknowledge their needs and experiences, which vary across the life span. Increased memory capacity, reasoning, and metacognitive skills, which come with maturation, enable adult learners to explore science in new ways. Senior citizens retain many of these capabilities. Despite certain declines in sensory capabilities, such as hearing and vision, the cognitive capacity to reason, recall, and interpret events remains intact for most older adults.
- Learning experiences should reflect a view of science as influenced by individual experience as well as social and historical contexts. They should highlight forms of participation in science that are also familiar to nonscientist learners—question asking, various modes of communication, drawing analogies, etc.
- Adult caregivers, peers, teachers, facilitators, and mentors play a critical role in supporting science learning. The means they use to do this range from simple, discrete acts of assistance to long-term, sustained relationships, collaborations, and apprenticeships.
- Partnerships between science-rich institutions and local communities show great promise for structuring inclusive science learning across settings, especially when partnerships are rooted in ongoing input from community partners that inform the entire process, beginning with setting goals.
- Programs, especially during out-of-school time, afford a special opportunity to expand science learning experiences for millions of children. These programs, many of which are based in schools, are increasingly folding in disciplinary and subject matter content, but by means of informal education.

## **RECOMMENDATIONS**

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The committee makes specific recommendations about how to organize, design, and support science learning. These recommendations provide a research and development agenda to be explored, tested, and refined. They have broad reach and application for a range of actors, including funders and leaders in practice and research; institution-based staff who are responsible for the design, evaluation, and enactment of practice; and those who provide direct service to learners—scout leaders, club organizers, front-line staff in science centers. Here we make recommendations to specific actors who can influence science learning in practice. Additional recommendations for research appear in Chapter 9.

### **Exhibit and Program Designers**

Exhibit and program designers play an important role in determining what aspects of science are reflected in learning experiences, how learners engage with science and with one another, and the type and quality of educational materials that learners use.

**Recommendation 1:** Exhibit and program designers should create informal environments for science learning according to the following principles. Informal environments should:

- Be designed with specific learning goals in mind (e.g., the strands of science learning).
- Be interactive.
- Provide multiple ways for learners to engage with concepts, practices, and phenomena within a particular setting.
- Facilitate science learning across multiple settings.
- Prompt and support participants to interpret their learning experiences in light of relevant prior knowledge, experiences, and interests.
- Support and encourage learners to extend their learning over time.

**Recommendation 2:** From their inception, informal environments for science learning should be developed through community-educator partnerships and whenever possible should be rooted in scientific problems and ideas that are consequential for community members.

**Recommendation 3:** Educational tools and materials should be developed through iterative processes involving learners, educators, designers, and experts in science, including the sciences of human learning and development.

### **Front-Line Educators**

Front-line educators include the professional and volunteer staff of institutions and programs that offer and support science learning experiences. In some ways, even parents and other care providers who interact with learners in these settings are front-line educators. Front-line educators may model desirable science learning behaviors, helping learners develop and expand scientific explanations and practice and in turn shaping how learners interact with science, with one another, and with educational materials. They may also serve as the interface between informal institutions and programs and schools, communities, and groups of professional educators. Given the diversity of community members who do (or could) participate

in informal environments, front-line educators should embrace diversity and work thoughtfully with diverse groups.

**Recommendation 4:** Front-line staff should actively integrate questions, everyday language, ideas, concerns, worldviews, and histories, both their own and those of diverse learners. To do so they will need support opportunities to develop cultural competence, and to learn with and about the groups they want to serve.

### REFERENCE

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Committee on Science Learning, Kindergarten Through Eighth Grade. R.A. Duschl, H.A. Schweingruber, and A.W. Shouse (Eds.). Washington, DC: The National Academies Press.

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# **Learning Science in Informal Environments: People, Places, and Pursuits**

**Committee on Learning Science in Informal Environments**

Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors

Board on Science Education  
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We also acknowledge the contributions of participants in the planning process. In particular a number of people participated in a planning meeting to define the scope of the study. We thank Alan Friedman, New York Hall of Science for chairing that meeting. We also thank Lynn Dierking and John Falk, Oregon State University; Kathleen Mclean, Independent Exhibitions; and Martin Storksdieck, Institute for Learning Innovation, for preparing papers to elicit discussion at the planning meeting. The success of the meeting was largely due to the insights provided by the meeting participants, including Sue Allen, The Exploratorium; Dennis Bartels, TERC; Rick Bonney, Cornell Lab of Ornithology; Kevin Crowley, University of Pittsburgh; Zahava Doering, Smithsonian Institution; Sally Duensing, King's College London; John Durant, At-Bristol; Kirsten Ellenbogen, Science Museum of Minnesota; Patrice Legro, Koshland Museum of Science; Bruce Lewenstein, Cornell University; Mary Ellen Munley, Visitor Studies Association; Wendy Pollock, Association for Science-Technology Centers; Dennis Schatz, Pacific Science Center; Leona Schauble, Vanderbilt University; Marsha Semmel, Institute of Museum and Library Services; Cary Sneider, Boston Museum of Science; Elizabeth Stage, University of California, Berkeley; David Ucko, NSF; and Ellen Wahl, Liberty Science Center. Following the planning meeting Julie Johnson, Science Museum of Minnesota, consulted with the project to help assemble the committee.

Over the course of the study, members of the committee benefited from discussion and presentations by the many individuals who participated in our four fact-finding meetings. In particular, our initial framing of the domain of science learning in informal environments underwent significant revisions and refinements as a result of the scholarly and thoughtful contributions made by the background paper writers, presenters, and responders. At our first meeting, Lynn Dierking, Oregon State University, gave an overview of the informal learning field in science, technology, engineering, and mathematics. Shalom Fisch, MediaKidz Research and Consulting, discussed the effects of educational media. Sheila Grinell, Strategic Visions for Cultural Institutions, spoke about the recent evolution of practice in informal science. George Hein, Lesley University and TERC, discussed the need for the field to be both cautious and bold. Jon Miller, Northwestern University, described a framework for understanding the processes through which children and adults learn about science, technology, and other complex subjects.

The second meeting included a diverse set of presenters. Maureen Callanan, University of California, Santa Cruz, described the sociocultural and constructivist theories of learning. Kevin Dunbar, University of Toronto, summarized the cognitive and neurocognitive mechanisms of science learning and how they play out in informal environments. Margaret Eisenhart, University of Colorado, Boulder, discussed the aspects of informal learning environments that afford opportunities to underserved or underrepresented populations. Leslie Goodyear and Vera Michalchik, SRI International, Education Development Center, Inc., presented methods and findings from evaluations of informal programs that serve underrepresented or underserved populations. Kris Gutiérrez, University of California, Los Angeles, gave specific examples of



how informal learning environments serve diverse populations. Karen Knutson, UPCLOSE, University of Pittsburgh, discussed views of learning science in informal environments inherent in programs and evaluations. K. Ann Renninger, Swarthmore College, gave an overview of theories of motivation and how they map to learning in informal environments.

At the third meeting, the committee heard evidence about the science learning that takes place in various informal venues and pressing policy issues in the field. Christine Klein, an independent consultant, Bronwyn Bevan, The Exploratorium, and Elizabeth Reisner, Policy Study Associates, participated in a panel discussion of current policy issues in informal learning environments. Deborah Perry, Selinda Research Associates, Inc., described how exhibits and designed spaces are constructed for learning science. Saul Rockman, Rockman Et Al, discussed the evidence of science learning from traditional forms of media. Bonnie Sachatello-Sawyer, Hopa Mountain, Inc., gave an overview of the design and impact of adult science learning programs.

At the fourth meeting, the public session was concerned primarily with the status of the papers prepared to support the committee's work and the organizational structure being implemented in NSF as it relates to this project. David Ucko provided an overview of the new organizational structure and focus of the education program offices at NSF.

At our final meeting, the committee discussed the planned practitioner volume on science learning in informal environments that the Board on Science Education is developing as a resource for practitioners based on the evidence, findings and conclusions of this consensus study. Two of the current study members are also members of the oversight group for the practitioner volume: Sue Allen, The Exploratorium, Gil Noam, Harvard University. The five other members of the practitioner volume oversight group also attended our final meeting: Myles Gordon, consultant; Leslie Rupert Herrenkohl, University of Washington; Natalie Rusk, MIT Media Lab; Bonnie Sachatello-Sawyer; and Dennis Schatz, Pacific Science Center. We are grateful to each member of the group for providing us with excellent feedback. The practitioner volume, sponsored by NSF's Division of Research on Learning in Formal and Informal Settings, the Institute for Museum and Library Services, and the Burroughs Wellcome Fund, will be released following publication of this report.

We also acknowledge the efforts of the eight authors who prepared background papers. Arthur Bangert and Michael Brody, Montana State University, along with Justin Dillon, King's College London, were asked to review the literature on assessment outcomes. Laura Carstensen and Casey Lindberg, Stanford University, along with Edwin Carstensen, University of Rochester, were asked to synthesize the literature on older adult learning in informal environments. Shirley Brice Heath, Stanford University and Brown University, was asked to describe how issues of diversity influence individual conceptions of science. The Institute for Learning Innovation was asked to review the evidence in evaluation studies of the impact of designed spaces. Bryan McKinley Jones Brayboy, University of Utah, and Angelina E. Castagno, Northern Arizona University, were asked to review and synthesize the literature on native science. K. Ann Renninger, Swarthmore College, was asked to review research on interest and motivation in the context of learning science in informal environments. Rockman et al. was asked to provide a review of the evidence of the impact of traditional media (e.g. television, radio, print). Sarah Schwartz, Harvard University, was asked to provide a synopsis of the scope and institutional investments in after-school and out-of-school-time programs.

Many individuals at the National Research Council (NRC) assisted the committee. The study would not have been possible without the efforts and guidance of Jean Moon, Patricia

Morison, and Heidi Schweingruber. Each was an active participant in the deliberations of the committee, helping us to focus on our key messages and conclusions. In addition, they made profound contributions to the development of the report through periodic leadership meetings with the committee co-chairs and the NRC staff. We are grateful to Victoria Ward and Kemi Yai, who arranged logistics for our meetings and facilitated the proceedings of the meetings themselves. We would also like to thank Rebecca Krone for assisting with the construction of the reference lists in each chapter of the report. The synthesis of the diverse literatures reviewed in this report would not have been possible without the efforts of Matthew Von Hendy, who conducted multiple literature searches and acquired copies of studies essential to our review.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the Report Review Committee of the NRC. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank the following individuals for their review of this report: David Anderson, Department of Curriculum Studies, University of British Columbia; Bronwyn Bevan, Informal Learning and Schools, The Exploratorium, San Francisco, CA; Shirley Brice-Heath, Anthropology and Education, Stanford University; Ilan Chabay, Public Learning and Understanding of Science (PLUS), University of Goteborg, Sweden; Lynn D. Dierking, Free-Choice Learning and Department of Science and Mathematics Education, Oregon State University; Shalom Fisch, Office of the President, MediaKidz Research and Consulting, Teaneck, NJ; Bonnie L. Kaiser, Office of the Dean of Graduate and Postgraduate Studies, The Rockefeller University; Frank C. Keil, Department of Psychology, Yale University; Leona Schauble, Peabody College, Vanderbilt University; Cary I. Sneider, Boston Museum of Science, Portland, OR.

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Adam Gamoran, Wisconsin Center for Education Research, University of Wisconsin–Madison, and May Berenbaum, Department of Entomology, University of Illinois, Urbana–Champaign. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report, however, rests entirely with the authoring committee and the institution.

Phillip Bell and Bruce Lewenstein, Co-chairs  
Andrew W. Shouse, Senior Program Officer  
Michael A. Feder, Senior Program Officer  
Committee on Learning Science in Informal  
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