THE ROLE OF INFORMAL ENVIRONMENTS AND EXPERIENCES IN THE LEARNING OF SCIENCE

Statement of

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Good morning, Mr. Chairman and members of the Committee. Thank you for the opportunity to appear before you today to discuss informal STEM education in science. I am Philip Bell, Associate Professor of Learning Sciences in the College of Education at the University of Washington. I served as a co-chair of the Committee on Learning Science in Informal Environments of the National Research Council (NRC), the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies.

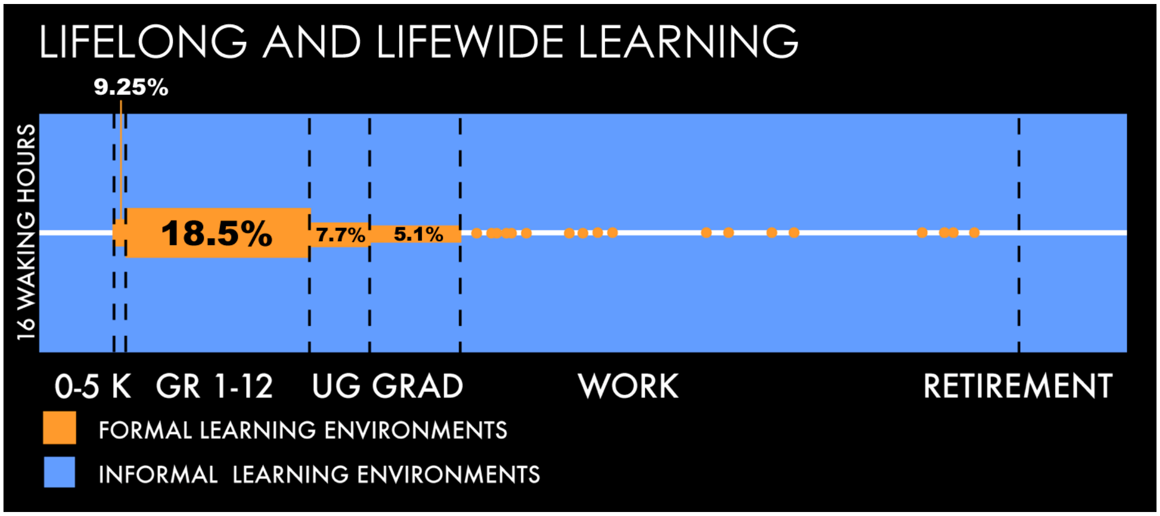
In the following statement I will briefly describe what research tells us about how and why people learn science in informal environments, what role informal environments can play in broadening participation in STEM fields, and what priorities exist for research and evaluation related to informal science education. Let me start by stating that a synthesis of the research clearly indicates that informal learning environments represent a crucial part of our society's educational infrastructure for STEM education. ***Informal learning environments routinely support significant science learning for individuals of all ages from a broad variety of backgrounds in ways that uniquely serve their personal and professional interests—and the broader STEM-related interests of society as well.*** At the same time, additional research is needed to better understand the cumulative effects of how people learn across formal and informal learning environments, to better understand the influence of contemporary media on science learning, and to document how people from groups that are underrepresented in STEM fields learn science, which we take to be both a basic and applied area of research. These inquiries can provide critical information for developing better programs and experiences for learners.

I was asked to describe the work of my research group at the University of Washington and to summarize the conclusions and recommendations of the recent NRC consensus study on *Learning Science in Informal Environments*. Let me start with the research of my group as I think it sets the stage for summarizing the report. Over the past five years the National Science Foundation has been supporting six large-scale, long-term research centers around the country through the Science of Learning Center program focused on advancing the frontiers of the sciences of learning through integrated, interdisciplinary research. I participate on the faculty leadership team of one such center called the Learning in Informal and Formal Environments Center—or the LIFE Center—which is a collaboration primarily among researchers at the University of Washington, Stanford University, and SRI International. The scientific mission of the LIFE Center (http://life-slc.org/) is to document the social foundations of how people learn across formal and informal learning environments using cognitive, social and cultural, neurobiological, and developmental perspectives on learning.

LIFE has a portfolio of research studies that investigate STEM learning—including how families engage in math learning in everyday activities like personal finance and health decisions, how youth develop expertise about technology, and how young girls and boys develop stereotypes about academic subjects like math and reading. We do that work across a broad range of venues for learning—from classrooms, science centers, aquaria, and zoos to afterschool programs, Internet sites, virtual spaces, hobby groups, and in the midst of family life. My research group investigates how youth and their families develop science and technology related expertise across a broad range of formal and informal environments, groups, and activities in their lives. We construct finely detailed cultural and ecological accounts of where, how, why, what, and with whom children learn over years with special attention to knowledge and expertise that has real consequences for the youth and families in our studies. We also conduct extended multi-week curriculum design studies in elementary science classrooms in collaboration with teachers to test theoretical questions about how we can bridge what the children learn and do at home with what they are learning at school. The fieldwork generates principles of learning that inform educational design principles that are tested in the context of classroom instruction.

Our research takes place within multicultural, urban communities, and we are strongly focused on understanding how to broaden participation in STEM learning and activities. As we document how children learn across different settings, we have found a surprising and troubling pattern where children pursue and engage in sophisticated STEM learning outside of school but where those interests and early competencies are not recognized or built upon in the classroom. Just as one example: we followed an elementary school-aged boy with significant expertise with mechanical systems—from building robotic kits at home and designing solutions to complex puzzles at a science center—who, at school, was perceived as not being interested in academic subjects. Such disconnects in learning between home and school are putting these particular children at a higher risk of academic failure in STEM. At the same time, many of the cases document how interest, personal identification with STEM endeavors, and practice with the tools of STEM disciplines are sustained in important activities happening outside of school—while in summer programs at science centers and in collaborative activities with peers and parents. That is, ***STEM academic achievement in school, although crucial, is only part of what is needed to cultivate personal expertise in STEM—and the activities with which people engage in informal learning environments are an equally crucial platform for STEM learning*. *This point highlights the truly complementary role of schooling and informal learning environments in STEM learning.***

Researchers in the LIFE center developed the following diagram to roughly characterize the amount of time individuals spend in formal and informal learning environments. The diagram highlights changes in this split between formal and informal learning environments over the life course of the individual—what we call *life-long learning*—and it gives a sense of the breadth of different social settings in which people spend time in daily life—what we refer to as *life-wide learning*. As it indicates, the majority of our time is spent within the range of informal learning environments in which we participate—in the "sea of blue" as we call it.



The knowledge and practices of science shape people's lives in fundamental ways. It is increasingly understood that the science and technology enterprise plays a crucial role in our economy as well as in our communities and in our personal lives. This makes it imperative that we leverage informal learning to support workforce development, civic participation in STEM issues and policy, and to promote scientific literacy among all citizens.

Efforts to enhance the scientific capacity of society typically target schools and focus on such strategies as improving science curriculum and teacher quality and strengthening the STEM pipeline. What is often overlooked or underestimated is the potential for science learning in non-school 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. Countless others choose to learn about science topics in ways that serve their interests or needs and engage in science-related hobbies with others who share their interests. So, if we ask the crucial question: Where do people learn science? The answer is *everywhere*—in ways that we only partially understand.

The National Science Foundation funded a consensus study through their Informal Science Education program with the Board on Science Education at the National Research Council with the goal of synthesizing the existing research about how people learn science in informal environments. The

Board on Science Education at the NRC is an advisor to the nation on all issues of science education and oversaw the project. In response, the Committee on Science Learning in Informal Environments was established to examine the potential of non-school 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. The charge we were given specifically included assessing the evidence of science learning across settings, for different age groups, and over different time frames. We were asked to identify the qualities of learning experiences that are unique to informal environments and to explore the relationship between the science learning that happens in informal environments and the learning that goes on within school. And we were also asked to develop an agenda for research and development related to how and why people learn science in informal environments.

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" that we considered included: *everyday experiences*—like hiking, pursuing a hobby, or farming; *designed settings*—such as visiting a science center, zoo, aquarium, botanical garden, planetarium; and *educational programs*—such as after-school or summer science programs for youth, environmental monitoring experiences for citizens, or Elderhostel and senior center programs for elders. We also examined cross-cutting features that shape informal environments including: *the role of media* as a context and tool for learning and the opportunities these environments provide for *broadening participation in STEM* for individuals from diverse communities that are historically underrepresented in STEM fields.

A critical missing piece in this area of research and development is a clear statement of goals that are appropriate for these settings and which can be measured. The committee developed and used 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 the NRC *Taking Science to School* report from 2007. The six strands illustrate how schools and informal environments can support complementary educational goals, and serve as a tool for organizing and assessing science learning. The six interrelated aspects of science learning covered by the strands reflect the field's commitment to getting learners to participate and connect to science as a stimulating, creative, and personally relevant endeavor.

Our efforts to improve STEM education frequently focus on the importance of the disciplinary content of science and how people come to understand scientific concepts, principles, and established facts. The committee agreed that the knowledge of science is an important outcome of science learning, but there is more to the learning of science than understanding content. The other five strands help bring a more complete image of learning into view. These broader dimensions of science learning are necessary for developing interest in young learners. For example, early interest in science is clearly associated with entry into STEM fields. In this vein, it is also crucial for people to develop science-related interests and to experience enjoyment, to come to identify with science, to know how to develop and evaluate scientific arguments and explanations of natural phenomena, to know how scientists actually inquire and build new knowledge using specialized tools and equipment, and to understand the multifaceted role of the institution of science in society.

The six science learning strands help us understand how 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.

With this multi-dimensional definition of science learning, we then explored the question: What is the contribution of informal environments towards these outcomes? The report describes the state of our knowledge about how the strands of science learning are supported across the different informal learning environments. For example, educational television and museum experiences can support conceptual learning. Family conversations can help children learn to produce scientific conversations. Afterschool programs can give learners access to learning to use the specialized tools of science and support the learning of science content. Prior knowledge, interest, and identity—long understood as integral to the learning process—are especially important in informal learning environments, where opportunities to learn can be fleeting, episodic, and strongly learner-driven. At any point in the life span, learners have knowledge and interests, which—given opportunities and support—they can develop into for further science learning. This includes their comfort and familiarity with science. Although learners' knowledge may remain tacit and may not always be scientifically accurate, it can serve as the basis for more sophisticated learning over time. Educators can support learners of all ages by intentionally querying, drawing on, and extending their interests, ideas about self, and knowledge.

So, do people learn science in non-school 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 educational programs—individuals of all ages learn science in significant ways. We know from vast literatures in the science of learning field on cognition and development that sophisticated learning only results from concerted effort and sustained practice. It is crucial for us to recognize and understand how such learning and expertise gets supported and cultivated across the settings and pursuits in a person's life. Understanding the cumulative effects of STEM learning as it occurs across formal and informal learning environments is a high-priority area for future research.

Virtually all people of all ages and backgrounds engage in informal science learning in the course of daily life. Informal environments can stimulate science interest, build learners' scientific knowledge and skill, and—perhaps most importantly— help people learn to be more comfortable and confident in their relationship with science. Researchers and educators interested in informal settings are typically committed to open participation in science: building and understanding science learning experiences that render science accessible to a broad range of learners and in ways that serve their interests.

Everyday experiences can support science learning for virtually all people in response to the interests and needs that matter most to them—including environmental risks, health decisions, and appreciation of the natural world. If educators can attend more deeply to the ways in which people already intersect with science and technology in their lives then our educational efforts will be more powerful and meaningful.

Designed spaces—including museums, science centers, zoos, aquariums, botanical gardens, and environmental centers—can also support science learning. Rich with real-world phenomena and unique learning experiences, these are places where people can pursue and develop science interests, engage in science inquiry, and reflect on their experiences through sense-making conversations.

Educational programs focused on science learning take place in schools and community-based and science-rich organizations and include sustained, self-organized activities of science enthusiasts. Such programs are growing in number, with the support of significant federal funding, and there is mounting evidence that structured, non-school 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 increasingly pervasive and make science information increasingly available to people across venues for science learning. Science media, especially interactive forms that are web-based, are fundamentally changing people's engagement with science and offer new ways to support science learning. Although the evidence is strong for the impact of educational television on science learning, substantially less empirical evidence exists on the impact of other media—digital media, gaming, radio—on science learning specifically. There is good reason to believe that such media are increasingly supporting science learning, but we need more research focused on how and why people learn science specifically through interactive and social media.

What role can informal learning environments play in broadening participation and promoting diversity in STEM fields? A report on diversity and learning recently edited Professor James Banks from the University of Washington states: "Being born into a racial majority group with high levels of economic and social resources—or into a group that has historically been marginalized with low levels of economic and social resources—results in very different lived experiences that include unequal learning opportunities, challenges, and potential risks for learning and development."

The committee recognized that there is increasing interest in the informal learning research and practitioner fields for understanding cultural variability among learners and its implications: how learners participate in science in relation to the values, attitudes, histories, and practices of their communities and those of science.

Studies suggest that informal environments for science learning may be particularly effective for youth from historically non-dominant groups—groups with limited social and political status in society who are often marginalized in educational experiences. For example, evaluations of museum-based and after-school programs suggest that these experiences can support academic gains for children and youth from historically non-dominant groups. These successes often draw on local issues and the prior interests of participants—for instance, by integrating science learning and service to the community. Similarly, case studies of community science programs targeting participation of youth from historically non-dominant groups—such as children in Native American or recent immigrant communities—document participants' sustained, sophisticated engagement with science and sustained influence on school science course selection and career choices. In these programs, children and youth play an active role in shaping the subject and process of inquiry, which may include local health or environmental issues about which they subsequently educate the community. Equally interesting in these contexts is the cross-generational learning – the ways in which informal learning opportunities help connect children, parents, grandparents, and other community elders.

Many designers in informal science learning are making efforts to address inequity and wish to partner with members of diverse communities. Effective strategies for organizing partnerships include identifying shared goals; designing experiences around issues of local relevance; taking the everyday patterns of participation of learners into account; and designing experiences that satisfy the values and norms and reflect the practices of all partners. These efforts merit replication and further study, including analysis of how science-rich institutions can collaborate with and serve community-based organizations and how these programs support and sustain participants' engagement.

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 non-standardized 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—for example, the six strands of science learning developed in the report.

In closing, the following are some high-priority policy considerations related to research on the role of informal learning environments in STEM education:

- There should be sustained support for high-quality informal programs and experiences that focus on STEM, whether they occur in museums, aquaria, zoos, science and technology centers, botanical gardens, in out-of-school program settings or other informal efforts. Significant and unique science learning occur in these venues—in ways that can be leveraged to support school-based academic outcomes and in ways that represent important experiences with STEM disciplinary fields as an end in and of themselves. The report offers guidance for how these activities should be evaluated and studied so that we can gain a better understanding of how and when they succeed.

- Although it is important to understand the impact of informal environments, a more important question may be how science learning occurs across the range of formal and informal environments. The science learning literatures and fields are segmented (e.g., into school learning, informal education) in ways that are at odds with how people routinely traverse settings and can engage in learning activities across settings. Thus, research should attempt to explore learners' longer term, cross-cutting (or "life-wide") learning experiences. Further work should increase understanding of the connections or barriers in learning between more formal and more informal science learning environments. These inquiries can provide critical information for developing better programs and experiences for learners.
- Media, in particular television and Internet resources, are the most sought-out tool for learning about science. Through various forms of digital media—blogs, virtual spaces, wikis, serious games, RSS feeds, etc.—access to scientific ideas and information and knowledgeable others has become, if not pervasive, at least widespread. Arguments about the transformative power of media for informal science learning are based on very modest evidence and warrant further investigation. Research on the impact of media is needed to understand how the unique features of media can support different aspects of science learning (e.g., the six strands).
- The committee concluded that informal learning environments may be particularly important for science learning for diverse groups. Research exists on how specific groups can come to participate in specific venues, but questions remain about how to best empower science learning for diverse groups through informal learning environments. There is variability in the success of these environments in attracting and engaging diverse audiences. We believe that a better understanding of the naturally occurring science learning in historically non-dominant and dominant cultures is needed to inform basic theory about learning and to inform the design of learning experiences that meaningfully attend to the cultural practices of diverse communities.

Thank you for the opportunity to present to the sub-committee on this important set of topics. I look forward to your questions and comments.