

Broadening Views of Learning: Developing Educators for the 21st Century Through an International Research Partnership at the Exploratorium and King’s College London

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This article describes efforts to develop educators, in both formal and informal settings, who possess theories of teaching and learning that not only encompass but, perhaps, depend on bridging institutional and contextual boundaries. It describes the experiences of The Exploratorium, a museum in San Francisco, King’s College London, and the University of California Santa Cruz, in a National Science Foundation-funded project. The article begins with a discussion of the growing interest that science education decision makers and policymakers show in bridging formal and informal settings and resources to make learning in K-12 science more engaging, authentic, and conceptually rich. It then describes how CILS designed programs and partnerships to support the development of educators to have not only expanded views of learning, but also experience and facility with designing and leading programs that draw on features

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and affordances of both formal and informal science settings. The authors close with a discussion of the types of evidence and understanding that are required to expand and sustain educational partnerships that span formal and informal boundaries.

INTRODUCTION

Two relatively recent studies spotlight the importance of making science more interesting and appealing to children. The first is the *Relevance of Science Education (ROSE)* study, an international survey of students, aged 15, from over three dozen countries (Sjøberg and Schreiner, 2006). This study, which is ongoing, notes that students from industrialized nations are less interested in school science and markedly less interested in science careers than their counterparts from developing nations. The second study is a retrospective data analysis, conducted in the US, that found that, independent of grades, standardized test scores, or family background, 8th grade students who indicated an interest in future science careers were much more likely to go on to major in science in college than were students who had indicated other types of career interests (Tai et al., 2008). These two studies together make a strong case for the need to make science education more appealing and engaging to children, especially in the K-8 years. In light of the growing importance of science and science-related fields in almost all economic sectors, providing engaging science education for all children, even in the most under-resourced schools, becomes a critical issue of access, equity, and social justice.

Traditionally, the focus of any improvement in science education would be school – often high school and in some cases elementary school. Many countries have tinkered with or made wholesale changes to their science curriculum and/or their examination and assessment systems with the aim of changing pedagogy in order to raise attainment. Australia, for example, is implementing a National Curriculum just as England celebrates the 21st birthday of its own version. In the US, task groups are working on new versions of the National Science Education Standards. No one, it seems, is happy with the standards of education of their young people.

More recently, however, the attention of education policy makers has turned to the learning affordances provided by the informal science sector. Science on TV, particularly the natural sciences, has maintained high levels of interest among the viewing public. Millions of people worldwide pay to travel to museums and science centers, often spending hours looking at exhibits and trying hands-on science. Whatever the reasons for their visits, it seems that science can be popular, interesting, and memorable. Not unreasonably, some people have wondered publicly and privately if the formal science education sector could learn something from the so-called informal sector.

Of late, researchers and policy makers from around the world have increasingly called for greater attention to be paid to the educational potential of out-of-school settings, citing the many benefits, and indeed, the necessity, of learning in contexts other than the classroom. For example, the policy statement published by the Informal Science Education Ad Hoc Committee for the National Association for Research in Science Teaching argued that learning “derives from real-world experiences within a diversity of appropriate physical and social contexts” (Dierking et al., 2006). The National Education Standards in the US recognize that science museums and science centers, in particular, “can contribute greatly to the understanding of science and encourage students to further their interests outside of school” (NRC, 1996, p. 45). Many school districts and informal science institutions are forming [collaborations to support new curricular programs](#) for students and new training programs for teachers (for example, see Bevan et al., 2010).

But despite a significant number of efforts and experiments to bridge informal and formal settings, most such programs fail to institutionalize as funding dwindles or leaders change. Thus, while the potential power of integrating the resources of the informal sector to support more engaging K-12 science education seems apparent to many, there remain deep-seated institutional divides that appear to draw educators and educational systems back into their organizational boxes when the explicit call or funding for collaboration fades.

This paper describes efforts to develop educators, in both formal and informal settings, who possess conceptions of teaching and learning that not only span but, perhaps, depend on bridging institutional and contextual boundaries. These educators are imbued with broad conceptions of science learning: understanding that it involves not just conceptual knowledge and process skills, but also familiarity with evidence-based ways of knowing in science, as well as how science is used in everyday life and how scientists go about their work. These educators understand that such views of science grow from and also support students’ emerging science interests and identities, which are developed not just in school but also over time and across multiple settings.

We argue that it is critical for the new educator, in both formal and informal settings, to understand and work with the learner as the person who in real life is constantly moving across different institutional fields or contextual boundaries. Educators need to understand that learners’ experiences with science are neither confined to the classroom nor to the museum. In this view, it is essential that the new educator understands how the learner’s interests, identities, and capacities are developed and relate across settings. To do this, educators must understand the possibilities, programs, and experiences provided by other institutions and to seek to build on and expand them.

At the heart of this article is the experience of three institutions separated by thousands of miles but united in a desire to challenge the formal/informal divide. The Exploratorium, a museum in San Francisco, King’s College London, and the

University of California Santa Cruz worked together to create a center funded by the National Science Foundation to produce young scholars, new educators, and new knowledge about the relationships between teaching and learning in school and non-school settings. Founded in 2002, the [Center for Informal Learning and Schools \(CILS\)](#) has to date worked with more than two dozen doctoral students in science education, developmental psychology, and also the natural sciences; offered about a dozen postdoctoral research fellowships; provided multi-year professional development programs to about 100 informal educators; hosted several conferences for a mix of more than 250 formal and informal educators, researchers, and policymakers. These training programs were largely structured around partnerships between academic and informal science institutions, both in London and in California, that provided practicum sites for CILS participants, and that ensured a two-way dialog across the organizational boundaries. In the next section we highlight hybrid programs at two of the CILS institutions.

KING'S: DESIGNING A HYBRID PROGRAM IN AN ACADEMIC SETTING

[King's College London](#) has a long history of teacher education, dating back to the late 1800s. When the Exploratorium was first developing a plan and proposal to fund CILS, King's was an ideal partner for many reasons: because of its wealth of experience in science education, because of its pioneering work in informal science education, and because of its location in the heart of a city with internationally leading informal science institutions, such as the London Science Museum, the Natural History Museum, and the London Zoo. King's Science and Technology Education Group was also an international leader in environmental education, and already blended many aspects of learning—working with teachers to develop their capacity to use non-classroom resources in their teaching repertoires. Despite this leading work, at the time that CILS was founded, the group had few sustained contacts with the informal science institutions in London. CILS offered King's an opportunity to rethink some of its education programs and to expand its boundary-crossing work in environmental education to include the development of educators and educational strategies that encompassed a broader range of cultural resources.

Studying connections

At the time that CILS began, many of the major London science museums were beginning to commit to significant educational research and evaluation efforts intended to study the reach and impact of their programs on the visiting public. These organizations were highly receptive to working with King's faculty and the CILS team of postdocs and doctoral students, including serving as sites for dissertation research. King's responded to this interest by setting up a reading group

that included graduate and postgraduate students as well as informal educators. The reading group's quarterly meetings rotate around various institutions including King's, the British Museum, the Natural History Museum, and the Victoria and Albert Museum. Potentially interesting papers are circulated to around 40 group members and recent topics have included a consideration of outcome-based evaluation and possible alternative ways of thinking about or arriving at outcomes. What CILS has learned through these collaborative discussions is that education staff want to engage critically with a diverse range of literature and can evaluate the relevance and generalizability of studies from the point of view of professionals who have daily contact with museum visitors. The traditional "researcher/practitioner" divide has been blurred by the fact that many of the CILS doctoral and postdoctoral students have themselves worked in museums in the US and elsewhere. The success of the reading group is indicated by the fact that it continues to this day. Indeed, the number of participating organizations grows year by year. Museum staff are able to develop ownership of the reading group by taking turns to host the reading group and by making their own suggestions for reading. Sometimes discussions have focused on new exhibitions at the partner institutions such as the Darwin exhibition at the Natural History Museum.

CILS students and faculty at King's have also engaged in research projects such as the design of new galleries in the Science Museum and an evaluation of the public engagement offer of the Natural History Museum's Darwin Center. These projects have led to a cementing of existing networks between academic and museum professionals and a widening circle of involvement. The projects have enabled doctoral students to broaden their experience of research methods and contexts. Staff in departments other than the Department of Education and Professional Studies have taken part in some of these projects, in particular the Work, Interaction, and Technology Group and the Materials Library, further broadening the students' understanding of a range of methods and methodologies. Involvement with projects beyond their own studies has increased the pressure on the doctoral students who have been under pressure to finish their doctoral studies within 4 years. Another issue is that some of the studies have focused more on evaluation than on research, which again has distracted students from their core work.

Nevertheless, as a result of such institutional structures and relationships, CILS students at King's have developed a set of studies that look at issues that are of both practical and theoretical importance. Issues include designing teacher development programs based in museums (Wever-Frerichs, 2008); developing a framework for designing field trips that support a stronger integration of the field trip experience into classroom learning goals, both cognitive and affective (DeWitt, 2007); and understanding how museum exhibits afford opportunities for play and learning (Meisner, 2008). Taken together, these studies have found that although informal science learning settings hold great potential for sparking interest and engaging

learning, there are many barriers that impede the use of informal resources to transform teaching and learning in the classroom. For example, in the study of teacher development programs based in the museum, although teachers have been inspired and have developed their inquiry-based teaching skills, limitations as to the extent to which there is time for inquiry in the classroom have contained the potential for the professional development programs to deeply affect classroom learning. A further outcome of the collaboration has been that King's has developed a strength in researching public engagement with science in a range of contexts – an area of growing interest and opportunity for funding.

EXPLORATORIUM: BUILDING BRIDGES IN A MUSEUM SETTING

The [Exploratorium](#) was founded in 1969 as one of the first interactive science museums in the world. Many of the earliest exhibits were museum-sized versions of tabletop classroom curricula developed in the 1960s science education reform movement, such as the Science Curriculum Improvement Study (SCIS) or Elementary Science Studies (ESS). From the beginning, the founder of the museum envisioned the museum as “an adjunctive institution,” one that could both supplement and complement science that people had learned or were learning in schools. A core faculty of scientists and classroom educators came together to form two initiatives designed for classroom teachers: The School in the Exploratorium led elementary professional development workshops that provided teachers with firsthand experiences doing and learning science through tabletop inquiries integrating art and science to explore topics such as optics, sound, and electricity. Teachers were provided activity notebooks and curriculum kits to provide the same experiences for their students. The Teacher Institute provided middle and high school teachers with summer institutes and academic-year workshops designed to bolster their science content knowledge and advance their hands-on pedagogical strategies for the classroom. Over time, with significant funding from the National Science Foundation, both of these programs developed and evolved to offer new programs aimed at systemic support of the educational infrastructure. Today, the [Institute for Inquiry](#) provides professional development programs for elementary school staff developers from districts across the country. The [Teacher Institute](#) provides a two-year novice teacher induction program for teachers from throughout the Bay Area. Both programs have significant evidence of their impact.

DEVELOPING “SCHOOL SENSE”

Most informal science centers in the US, UK, and elsewhere offer programs, such as field trips to classroom teachers, that seek to bridge informal and formal settings.

Some also develop curricular resources (whether in print or on the web), and some offer teacher programs, mostly designed to prepare teachers to make best use of the field trips. However, a growing number of informal science institutions and educators seek to play a more significant and sustained role in supporting high quality and engaging science in the classroom. These informal educators seek to create, develop, or expand teacher development programs that offer teachers opportunities for content learning, inquiry-based pedagogical strategies, classroom resources, and collegial communities of like-minded educators, thus building the capacity of the formal system to provide engaging, conceptually rich science to school-aged children. This effort is seen as critical to expanding public engagement with science.

In response to this interest and need, CILS created the Informal Learning Collaborative (ILC) program, a professional development program for informal educators who lead teacher development programs. Based at the Exploratorium, over the course of the last five years, the ILC has worked with more than 100 informal educators, representing about 60 institutions and communities around the US and in the UK. The central strategy of the program has been to build a community of informal educators who are conversant in the policy contexts of schools, the inquiry resources of informal science institutions, and the design of professional development programs.

Informal educators, from zoos, aquaria, botanical gardens, and science museums, have participated in the ILC for a period of three to four years, attending workshops every 6 months or so. The 5-day workshops have addressed topics such as Inquiry-Based Science, Theories of Learning, Educational Policies and Assessments, and Professional Development Design. Faculty from King's and UC Santa Cruz have been invited to address particular themes or topics, along with experts from within the Exploratorium and from other informal and formal institutions. ILC participants have also attended the annual Bay Area Institute where they have presented and participated in sessions designed for the broad CILS community of faculty, postdocs, doctoral students, informal educators, and approximately another 100 "friends of CILS" who represent policy agencies, universities, research groups, and informal settings. An independent evaluation, conducted by Inverness Research Associates, has found that participation in the ILC has led to an increase in both the quantity and quality of programs the participating institutions offered to classroom educators.

Bridging settings through theories of learning

The ILC started with an understanding that learning involves not just knowing, and not just knowing and doing, but rather knowing, doing, being, and becoming (see Herrenkohl and Mertl, 2010). All participants, who enrolled in the program in cohorts of about 30 educators, participated in a 5-day inquiry into light and shadows.

This inquiry served as a touchstone for the program experience; it provided participants firsthand experience with the ways in which learners' interests, questions, fears, doubts, learning partners, and prior conceptual knowledge contributed to the ways in which they persisted in their inquiries to gain new insight into the science of light and shadow. Throughout the program, participants were able to reflect back on the shadow inquiry to consider the ways in which their interests and identities positioned them to engage with and in science. Interest and identity became key constructs when thinking about how to support learning across formal and informal settings and boundaries.

The second workshop focused on learning theory. An informal "fireside chat" with Barbara Rogoff, CILS faculty at UCSC, and George Hein, Professor Emeritus at Lesley University, reviewed theories of learning from Dewey to Vygotsky to Bruner and beyond. Again, the goal was to move beyond constructivist ideas of knowing and doing, to include issues of being and becoming: to understand the learner in the processes of teaching and learning, a learner who is constantly crossing borders dividing different institutional or formal and informal settings. Discussions focused on how theories of the learner and learning underpinned teaching approaches. Participants observed learners on the museum floor as well as in videos of classroom teaching from around the world, with a focus on beginning to articulate their own operating theories of learning and to consider how that shaped their program designs.

These theories of learning were brought to bear in examination of school policies in the third workshop and of professional development design in the fourth workshop. Both workshops attended to the ways in which informal programs could be designed to support teachers in today's culturally and economically diverse school classrooms.

In general, CILS and the ILC aim to bridge formal and informal learning as well as research and practice. One early measure of success was that at the first Bay Area Institute (BAI), which gathered together all CILS participants from universities and informal science institutions, there was a mini revolt of the informal practitioners who felt that the language and questions of the academics were not applicable to the real questions that they faced on a daily basis. After two days of frustration, a number of the informal educators showed up on the last morning with a long scroll of questions with which they needed help. The divide felt very deep. But a year later, at the second BAI, as an external evaluator noted, the conversations and presentations were so fluid that it was difficult to know who was a researcher and who was a practitioner. A common language was beginning to emerge (supported by the inquiry and learning theory workshops for the practitioners and by a cohort of new CILS graduate students who were keenly attuned to the needs of informal educators because many of them had been in that role only months before), and a shared vision about the purpose and need to bridge formal and informal learning was becoming established – despite the concrete differences in role, questions, and

professional practices that exist between academic researchers and informal educators.

DEVELOPING A NEW EDUCATOR

Through the work in London, San Francisco, and also in Santa Cruz, faculty and students in CILS came to see the formal/informal dichotomy as highly problematic. Indeed, CILS participants became increasingly frustrated with the term “informal learning.” The more time we spent looking at “informal learning,” the more apparent it became that we were looking at “learning in informal environments” and trying to understand how it supported, expanded, or was different than “learning in formal [and other] environments.” There was not some fundamental difference in the learning, or even the teaching, but rather in the organizational or institutional framework that affected goals, curricular resources, assessments, and perhaps outcomes.

This work through CILS and the institutional partnerships with the Exploratorium and local London informal science institutions has begun to impact the highly regarded environmental education program that has long existed at King’s. King’s recently recruited a Chinese PhD student who is studying the pedagogy of botanical garden educators and is a key partner in ‘Inquire,’ a newly funded European Commission project involving the development of inquiry-based learning in 11 botanical gardens in Europe and beyond.

At King’s, preservice courses focus primarily on preparing teacher candidates to teach in high schools. Over the years, the course has broadened to reflect the increasing awareness of the outdoor classroom, which is a clear commitment in official UK educational policy documents. However, while government documents and research findings point to the benefits of learning outside the classroom, it would appear that such opportunities are rarely taken up in practice. Indeed, some research points to a decline in the provision and condition of outdoor learning. A study in London found that there are relatively few planned opportunities for learning outside the classroom in science for students at middle and high school levels and that where such provision does occasionally occur, it tends to focus on particular areas of the science curriculum, such as Biology and Ecology.

Underpinning King’s preservice course is a belief that all students deserve to benefit from a range of opportunities (not just in Biology and Ecology) and potentially gain the knowledge, skills, and experiences provided in out-of-school settings. However, we also acknowledge the challenges faced by teachers in providing such opportunities. Furthermore, we note that there are many possible reasons why resources beyond the classroom are not being used. For example, the issues of health and safety, risk management, and cost are amongst the most significant factors in limiting out-of-school learning. Reviewing the literature on learning outside the classroom, Rickinson et al. (2004) also highlighted teachers’ confidence and

expertise in teaching and learning outdoors; requirements of school and university curricula and timetables; difficulties due to shortages of time, resources, and support; and more generally the susceptibility of outdoor education to the wider changes in the education sector and beyond. Despite the challenges facing teachers, we believe that the learning opportunities afforded by contexts other than the classroom are such that the disparity in provision has serious implications for issues of equity. There is evidence that access to outdoor classroom opportunities—and the advantages that are thereby bestowed—are skewed towards the independent (private) school sector.

Based on our experiences in CILS, and in recognition of the issues raised above, we have increasingly focused on providing opportunities for preservice students to benefit from and to appreciate the opportunities provided for learning beyond the classroom. All science education teacher candidates must, during their one-year course, take part in a range of formal/informal activities including a visit to the Center of the Cell (London's only true science center). Supplementing the preservice course is a book published by the Open University Press, *Becoming a Teacher*, which includes two chapters written by CILS staff that focus on learning in and out of the classroom (see, Dillon and Maguire, 2007).

King's has continued to recruit a number of highly motivated and high achieving doctoral students partly as a result of its profile in the informal sector. Recently, King's and the Natural History Museum announced a PhD studentship to undertake a PhD in an aspect of public engagement at the Natural History Museum's new Darwin Center. This collaborative studentship is unusual in the field of education and indicates the strength of the partnership and the mutual value placed on developing the links between museum educators and university researchers.

CILS work with informal educators also continues to focus on connecting informal and formal settings and opportunities. Much of this work is focused on mapping the landscape of current collaborations and analyzing the ways in which they are configured and supported. Published reports include a field landscape study (Phillips et al., 2006), a white paper created for the Center for the Advancement of Informal Science Education (Bevan et al., 2010), and a study to document features of informal learning activities to understand how they differ, reinforce, and relate to science learning in other settings (described in the next section). CILS participants continue to organize and convene conference sessions in the US and the EU that focus on relating research and practice and learning across settings.

SUSTAINING THE MOMENTUM TO BRIDGE ACROSS INSTITUTIONAL FIELDS

There is a well-known gap between research findings and their application in/to practice (Davis, 2007; Dolan, 2007). The gulf that divides education in formal and

informal contexts is less well recognized. Because of the almost ubiquitous use of field trips, many think little of the issue; it seems to work well enough, at least to a point. Yet, more substantial partnerships—ones that fundamentally change the nature of the science curriculum such that informal settings and resources are fully integrated into school subjects, or ones that provide teachers or school systems with new infrastructure—usually fade away when seed grants expire.

One reason for this phenomenon, we believe, is the lack of evidence of the impact of such partnerships, especially the impact on core infrastructure at either schools or museums. Even when individual leaders have a strong vision, it is difficult for them to secure institutional resources without such evidence. But to develop such evidence, it is necessary to understand the ways in which the different affordances of both schools and informal settings come together to create new possibilities for learning, and the further development of students' (and teachers') science interests and identities.

In 2008, with funding from The Noyce Foundation and The Institute for Museum and Library Services, CILS began a project with 13 different informal science institutions and youth development programs to begin to document [key design principles](#) underpinning high-quality out-of-school-time (OST) science learning activities. The study involves analysis of some six dozen videos of children engaged in science learning activities across the participating sites. The study, which is still underway, is examining the design of the environment, activity, and facilitation of the learning activities. Not surprisingly, we are finding that features of the informal learning environment are markedly different from many typical classrooms. For example, high-quality informal environments are often designed to inspire and model ideas (through, for example, a strategic level of materials and “mess” that represents an archaeology of ideas, as well as the creation of physical thresholds within a space that allow for different modes and levels of engagement). They also support learner initiative and autonomy (through placement of and access to materials and tools) and allow for cross-pollination of ideas as well as collaboration (through the organization of space to allow for fluid sight lines).

Features of the informal science learning activities themselves include elements such as positioning science as a means to achieve a desired purpose, rather than as an end unto itself; the creation of multiple pathways to account for varying levels of prior knowledge and experience; the use of materials and phenomena that invite inquiry and exploration; the establishment of connections with relevant real-world problems or settings. These features share much in common with high-quality school science activities.

Interestingly, in our study of facilitation strategies we see almost no difference between high-quality teaching in formal and informal settings. Our analysis focuses on how informal educators spark, sustain, and develop student engagement in the activities. Strategies include modeling or engaging in parallel play to spark engagement; providing just-in-time tools or ideas to scaffold learners past frustrating

or premature stopping points to sustain their participation; using analogs as well as reflection strategies to help deepen student participation. However, in the context of environments that support autonomy and cross-pollination, and different aged learners working on different projects and at different paces, facilitation may become more logistically complex even while it is less high-stakes.

As we begin to understand critical features that underpin different kinds of informal learning settings—from science museum to nature center to youth development programs held in school cafeterias—we can begin to analyze the ways in which these programs support the development of science understanding, interest, and identities through engaging learners in science concepts and processes. The value of efforts like these, in addition to providing knowledge for informal educators to strengthen their work, is to begin to develop models for how informal and formal educators and institutions can work together to support the developing interests and capacities of teachers and students to engage in science. Documenting the ways in which the different settings provide different opportunities, and how these opportunities relate to outcomes that are valued by both sets of institutional actors, is critical to sustain collaborations across settings. Otherwise, it is too easy for educators and institutions to maintain business as usual. Looking to the learner, as the person who in real life is constantly moving across different institutional fields or boundaries, and understanding how her or his interests, identities, and capacities are developed and relate across settings, is critical to the creation of the new educator in both formal and informal settings.

CONCLUSION

In exploring the terrain of bridging formal and informal settings, the CILS program seeks to develop a new breed of educational researcher and practitioner who approaches science education with broad perspectives on learning, and who seeks to design and support science learning by drawing on a variety of resources and settings, spanning multiple timeframes and institutional settings. The result of this effort has been a large number of informal educators, representing over 100 informal science institutions, who have not only a vision of but also a growing fluency with how to design programs that span formal and informal settings. For example, ILC graduates have designed teacher preparation programs in collaboration with local universities, have designed youth development programs spanning school coursework and summer field experiences, and have begun to work with state systemic efforts to support teacher development. Many of the doctoral students have gone on to positions of leadership within informal science institutions, prepared with deep study of learning research and theory, now leading educational and public programs that allow them to draw on broad conceptions of learning to more strategically position their institutions within the broader educational landscape. Many of the postdoctoral students have taken on academic positions

where their research continues to examine the ways in which children draw on their cultural and community resources to engage in science learning in and out of the classroom.

Such views of science—as emerging from learning across settings and timeframes—are important and have long standing in the research literature. CILS adds an institutional overlay to this question: How can educational institutions and organizations organize and position themselves in ways to provide maximally engaging and effective science learning opportunities for children and their teachers? In efforts to improve science education for all children, it is essential that communities examine the full range of educational resources. Informal settings have been shown to be effective at exciting interest and curiosity. They provide students with views about how science is situated in the everyday world, including how science professionals engage with their communities. They thus bring resources to the sustained effort of schooling that can be critical in making science more appealing and addressing the dwindling levels of interest and participation that typically set in during the middle school years.

But to truly envision and enact such a program that spans resources, we need more educators who have firsthand experiences in seeing the power and thinking through the institutional constraints of such programs. Professional preparation programs, of both formal and informal educators, need to take more consistent approaches, drawing on the research as well as theories of learning, to develop understandings of the following:

- how science learning develops across time and settings;
- the ways in which different institutional settings provide particular learning affordances within a broader educational landscape that also includes the home and community resources that children access;
- how institutional settings can strategically connect, interweaving resources, expertise, and times of exposure;
- how different methods of assessment and evaluation can be used in different settings to support an understanding of progress towards shared goals for student or teacher learning.

We close with a recommendation, based on what we have learned so far through CILS, that leaders of training programs for both formal and informal educators need to develop more opportunities for conversations and concrete collaborative projects, that span the goals and expertise of both formal and informal educators. Taking such broad views of learning will help to strengthen science programs to make them more engaging and meaningful to learners, and thus ensure greater equity and access to science learning for children in schools.

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REFERENCES

- Bevan, B., et al. (2010). *Making science matter: Collaborations between informal science education organizations and schools: A CAISE inquiry group report*. Washington D.C.: Center for Advancement of Informal Science Education (CAISE).
- Davis, S. H. (2007). Bridging the gap between research and practice: What's good, what's bad, and how can one be sure? *The Phi Delta Kappan*, 88(8), 568–578.
- DeWitt, J. (2007). Supporting teachers on science-focused school trips: Towards an integrated framework of theory and practice. <http://cils.exploratorium.edu/cils/resource.php?resourceID=1273>. Unpublished dissertation. London: King's College London.
- Dillon, J., & Maguire, M. (eds.) (2007). *Becoming a teacher* (3rd ed.). Milton Keynes: Open University Press.
- Dolan, E. L. (2007). Grappling with the literature of education research and practice. *CBE Life Sciences Education*, 6(4), 289–296.
- Herrenkohl, L. R., & Mertl, V. (2010). *How students come to be, know, and do: A case for a broad view of learning*. New York: Cambridge University Press.
- Meisner, R. (2007). Encounters with exhibits: A study of children's activity at interactive exhibits in three museums. <http://cils.exploratorium.edu/cils/resource.php?resourceID=1303>. Unpublished dissertation. London: King's College London.
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- Phillips, M., Finkelstein, D., & Wever-Frerichs, S. (2007). School site to museum floor: How informal science institutions work with schools. *International Journal of Science Education*, 29(12), 1489–1507.
- Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M. Y., Sanders, D. and Benefield, P. (2004). *A review of research on outdoor learning*, Preston Montford, Shropshire: Field Studies Council.
- Sjøberg, S., and Schreiner, C. (2006). How do students perceive science and technology? *Science in School*, 1, 66–69.
- Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*, 312(5777), 1143–1144.
- Wever-Frerichs, S. (2008). The role of museums in the on-going professional development of teachers. <http://cils.exploratorium.edu/cils/resource.php?resourceID=1302>. Unpublished dissertation. London: King's College London.