Mapping Informal Science Institutions onto the Science Education Landscape

Bronwyn Bevan; Robert J Semper, PhD
– January 2006

Background

Informal science institutions are significant science learning resources in their communities. They house unique collections of science artifacts and experiences, and they are staffed by educators who excel at motivating interest and involvement with science. They are trusted and valued community resources that are designed to support learners of all ages and all levels of prior science experience and knowledge. The Center for Informal Learning and Schools (CILS) develops leaders and supports research to better understand the ways in which these institutions create and contribute to public engagement with science, including the pursuit of formal academic, informal leisure-time, and career-based paths in science.

In August 2005, a group of formal and informal practitioners and researchers met at the CILS *Bay Area Institute* in San Francisco to discuss what we know and need to know to better understand how informal science institutions can effectively inspire, augment, and reinforce science learning for school children. In particular, the group sought to identify systemic and institutional structures that impede or advance opportunities for informal science institutions to strengthen science in school and after-school programs.

The mission of most informal science institutions (ISIs) is to support public engagement with science, thus contributing to the development of a more scientifically literate public. While work with school and afterschool programs constitutes only a part of this broader mission, it is a critical part. First, ambivalent attitudes towards and perceptions of science are largely forged by school experiences with science. These pre-existing attitudes limit the reach of ISIs since a science-averse public is not likely to visit. By strengthening school science, ISIs contribute toward building a more interested and receptive audience for future and lifelong science learning. Second, and equally as important, work with school and afterschool programs is essential for reaching low-income and minority populations who are underrepresented in the sciences as well as in ISI audiences. Indeed, a recent CILS study (2005a) shows that a disproportionate number of schools that ISIs work with (40%) serve low-income and minority students. Work with school and afterschool programs is thus an essential part of ISI efforts to expand equity and access to science education, including to ISI resources.

Despite this reasoning, it is important to acknowledge that there is an active debate within the field as to how, and even if, ISIs should engage with the formal education system. As independent educational agencies, ISIs have the ability to be entrepreneurial, chart their own course, and avoid the bureaucracy and accountability that can constrain innovation within the formal educational system. Work with the formal system is thus seen by some as threatening a level of intellectual flexibility currently enjoyed by ISIs. At the same time, because of their independence, ISIs are not significantly supported by public education dollars, nor are they eligible for ongoing government funding or looked to as major educational players. They thus are subject to economics that may act to pull the field away from its educational roots to more entertainment driven approaches.

Given the above opportunities, imperatives, and constraints, we argue that working with the formal educational system is key for the ISI field to advance its mission to increase public engagement with science and to engage a more culturally and socio-economically diverse public than it currently engages. But it is important that this work build on the particular affordances of ISIs in response to the particular needs and opportunities in the formal sector. This paper will discuss some of the systemic and institutionalized opportunities and obstacles that impinge on such efforts.

Problem statement

There are many examples of excellent and systemic partnerships between informal science institutions and school or after-school programs. The American Museum of Natural History in New York City, for example, has partnered with six other informal science institutions and the NYC Department of Education to develop an integrated middle school teacher professional development, classroom resources and field trip program for schools throughout the city. In the Midwest, the St. Louis Science Center formed a partnership with the University of Missouri to develop an afterschool program as part of the St Louis GEAR UP program. In San Francisco, the Exploratorium Teacher Institute created the nation's first science-specific teacher induction program, which now supports new science teachers from districts throughout the Bay Area with content training, classroom coaching, and peer communities of experienced science teachers. Many smaller museums, such as the Fresno Metropolitan Museum or the Da Vinci Center in Bethlehem, Pennsylvania, have also established formal relationships with local school districts and universities to strengthen science programs for teachers and for students.

These programs bring an approach to science learning that builds on the importance of first-hand experiences with science phenomena and artifacts to engage the learners' curiosity and motivate further learning. As year-round, long-established community institutions, informal science centers offer a continuity of resources, support, and opportunities for strengthening science education efforts. They can serve as a place for teachers to come together around their love of science and the development of their professional practices as science educators within a neutral, and non-judgmental, science-centered setting.

Despite these and many other strong examples of coordinated and systemic efforts to build on the strengths and affordances of informal science institutions to engage interest, develop content understanding, and support inquiry-based methodologies in schools, we know that these examples are the exception and not the rule.

A recent CILS study (2005a) surveyed some 500 informal science institutions from across the country—zoos, arboreta, natural history museums, science centers, and others—and found that despite the fact that about 75% reported that they offered structured programs for schools (beyond a standard field trip program), more than half of these programs were underutilized by their local school systems. For example, teacher workshops were not filled, curriculum kits were not checked out, classroom demonstrations remained unbooked. Furthermore, the data suggest that many of the programs designed for schools are not paid for by schools—they are paid for either by grants procured by the informal science institutions or through the general operating budget of the informal science institutions. This suggests that in many cases, despite the well-documented need to strengthen classroom science (see, for example, National Academy of Sciences, 2005), these local resources are not consistently prioritized or utilized by many school systems.

Further data analysis found that most informal science institutions do not assess their school programs in terms of how they impact school-based issues (such as teacher practice, curriculum implementation, or student experience). The most common means of assessment is the use of "feedback forms" by program participants—which seem not to be related to schools-based effects, but rather to ISI program design. (A current CILS study is examining this issue further with regard to ISI-based teacher professional development.)

However, where ISIs did indeed attend to the needs of schools—for example, through consulting schools on program design, by assessing program results by evaluating its contributions towards teacher practice or student achievement, or by sending informal education staff into teacher classrooms to coach or mentor teachers in science lessons—a secondary data analysis found correlations to institutional growth. That is, informal science institutions that designed programs for schools, in close connection with the needs and outcomes for schools, indicated that they had experienced institutional growth in budget, grants, or staffing.

Clearly, as suggested by the programmatic examples highlighted above, informal science institutions that work closely with schools can become highly valued by schools, and this integration into the larger science education infrastructure can in turn support the health of the informal science institution. Equally clearly, despite the beloved place that many informal science institutions hold in their communities' hearts and minds, most are not systematically contributing to their communities' definitions and vision for what students need to know and learn in science, as it has been encoded in the school curriculum.

Why not? What are the obstacles to greater coordination or integration? What would it take to accommodate or overcome them?

What CILS is learning

It is important to examine informal science institutions within a larger science educational landscape. Much of the existing research examines ISIs in an isolated fashion, without reference to what comes before or after a visit. This has been important as the field has defined and developed itself over the past 35 years. But still today, much does not commonly reference prior knowledge or acknowledge that the visitor lives in an environment of science including home, school, afterschool and media. (To be fair much of the existing research on schools does not either.) While we eschew the idea of developing a strictly interlocking system of educational experiences, we argue that greater coordination of some aspects of learning environments and opportunities may enhance opportunities for participation in science, perhaps particularly for low-income, minority, and female students who historically have been underrepresented in the sciences.

Jolly and colleagues argue that supporting children's participation in science requires opportunities in a trilogy of domains: engagement, capacity, and continuity (Jolly, Campbell, & Perlman, 2004). In short, they suggest that first students must become interested and enthusiastic about science (they must build their *engagement*), second they must develop an increasingly sophisticated body of knowledge, skills, and experiences that allow them to become more deeply immersed in doing and understanding science (they must build their *capacity* to know and do science), and third they must have ongoing and connected opportunities to develop their engagement and capacity (there must be *continuity* of opportunity within their social environments).

These three elements are not linked in a linear or chronological way, but instead are seen as essential ingredients for supporting children in pursuing science. While all are necessary, none is sufficient without the other two. For example, a child may develop great enthusiasm for science at a science museum or zoo, but if they have two or three years of dismal science experiences in school they can lose interest as well as fail to develop the necessary skills and knowledge to advance in science. Or, a child's engagement with science and her skill development may be proceeding apace in school, but if the school does not provide advanced coursework at a certain level, her chances of pursuing college or graduate school level science are significantly diminished. Jolly et al.'s report suggests that beyond schooling there is a broader educational landscape that can (and must) support science participation. ISIs excel in providing engagement. Through deliberate, structured efforts they can also provide support for the capacity and continuity parts of the trilogy.

Barton & Yang's (2000) profile of Miguel is an example of how a lack of coordination between in and out of school learning is a missed opportunity. Miguel is a NYC Puerto Rican man whose strong interest in science, and specifically in nature and reptiles, went unnoticed by his formal schooling. His family did not consider science as a viable employment option. Consequently, he failed to pursue science, academically or professionally. As the authors point out, it is critical for school science to value the dispositions, skills, and knowledge developed in out-of-school settings, and vice versa. Recently, Pugh & Bergin (2005) argued that, similarly, little is known about how school learning influences out-of-school learning.

Clearly science interest, skills, and knowledge develop in many places, at many times, and through many mechanisms—including home, afterschool programs, the internet, television, and community-based settings. What are children learning, experiencing, needing to know in and across these settings and how can these experiences be supported, amplified, or expanded at different times and in different places? What is the role of the ISI, both as an entity in itself and as a partner with other educational organizations? There is a need for knowledge, derived from both practice and research, about how these different settings work together.

To better situate themselves in the broader landscape of science education, ISIs need to reach beyond their traditional professional communities to interact with communities of researchers, natural scientists, and formal educators from both K-12 and Higher Education. One structural barrier to this effort is the relative isolation of the field. Outside of most mainstream educational funding, and curiously cordoned off by many funding agencies as "informal", ISIs also face economic barriers to integration. Of course, most ISIs can point to some kinds of formal partnerships and relationships with other educational entities, or with scientific or commercial entities. Nevertheless, at annual AAAS meetings, where the latest in science knowledge is discussed, one will find few informal educators present. Similarly, at conferences such as NARST and AERA, where new knowledge from science education research is shared, or ASCD or NCTE where school policies and practices are discussed, the numbers of informal science educators attending is surprisingly small.

One of the major contributions of CILS, as documented through our external evaluation, has been to bring together disparate professional communities and to build new communities with overlapping areas of interest and expertise. After two years of such CILS programs, an external reviewer remarked that it was difficult to tell, at a CILS conference, who were the researchers and who were the practitioners. The ISI field needs to create more opportunities to interact with other fields engaged in science education practice and research. These interactions will strengthen insight and work on all sides.

In the high stakes accountability environment of schooling, it is important that informal science institutions articulate how their contributions support, and can be held accountable for supporting, schools, teachers, and students. We do not suggest that the K-12 system of standards and assessments be applied to informal science institutions. Such a step would be highly inappropriate for many reasons. For one, ISIs exist within an entirely different framework for conceptualizing and designing science learning experiences and interactions. However, there is an increasing recognition that if we claim to support our colleagues in the K-12 system, and if these colleagues are being held accountable for results for students, then we cannot ignore what accountability means for our work with schools. This suggests that ISIs need to think carefully about, and accrue evidence for, how their work with formal systems strengthens or expands the ability of school and afterschool programs to meet their goals for students. In some cases ISI work may involve increasing student motivation and readiness to learn science. In other cases it may directly support the development of conceptual understanding found in state standards, or the development of science process skills that will be tested in performance evaluations. In some cases it may support the development of highly qualified teachers, or advanced level science students. Whatever it is, as the CILS *Landscape* study (2005a) showed, it is important for ISIs to attend to and address the school-based needs of their school partners and audiences.

In a second CILS study (2005b), museum-based teacher educators participating in a CILS professional development program, the *Informal Learning Certificate* Program, reported that they wanted to learn more about school policies and theories of science learning and of schooling that inform classroom decisions. This study, and conversations at the Bay Area Institute and elsewhere, suggests that informal educators have remained somewhat insulated from the political and policy pressures that define the formal education landscape in which they work. Additionally, a lack of familiarity with the research literature on science learning, especially classroom science, means that many informal educators who work with schools may not be attending to key features of science learning—such as the role of evidence and argumentation or formative assessment.

There are many systemic barriers that work to divide research and practice. There is a need for better mechanisms for translating research findings into implications for practice. While CILS practitioners—through their exposure to many research communities and efforts—are no longer waiting for the silver bullet from the research community, there is still a need (and a thirst) for access to research that can inform practice. What is needed are synthesis papers or pamphlets that can draw on a body of theoretical or applied research and articulate implications for program and for further research. Such a body of work, written for the practitioner, would provide ISI staff access to current knowledge, language, and ideas—and would stimulate more innovation and experimentation in the field. Such work would have to be written within the context of policy and practice—i.e., it would have to show how ideas relate to constraints imposed by policies.

In general, the ISI field has not placed adequate emphasis on staff professional development. There are significant fiscal and institutional barriers to providing adequate professional development, including participation in the professional activities or conferences of other communities discussed above. In particular for ISI staff who work with outside agencies, a level of currency (theoretical, political, programmatic) is critical for success. There is thus a vital need for increased professional development for informal educators who work with schools. This professional development can lead to stronger, more salient program designs, which in turn, as suggested by the CILS *Landscape* study (2005a) is correlated with institutional growth.

It is important to leverage resources in areas where informal science institutions can have the greatest impact for formal science. The diversity of informal science institutions—ranging from aquaria and zoos to botanical gardens and science centers, to name a few—is immense. Not only in type, but also in collections, in emphasis, in pedagogical approach, ISIs are extremely varied. Therefore, where and how informal science institutions choose to leverage their resources to support and connect with formal science education will always depend on the specific context, needs, and resources. However, we believe that three areas in particular hold great promise for investing time, effort, and resources to link formal and informal educational systems. These areas build on ISI strengths in designing learning experiences that are social in nature, build on and develop agency in the learner, and take playful and engaging approaches to the content. We are exploring theoretical links between these features of ISI work and research in youth development, teacher professional development, and issues of motivation. There is a need for more knowledge in this regard.

Working with Students in Structured Ways

While demographics indicate that classroom science engages only a small percentage of US students, it appears to be even less successful for low-income, female, or minority students (Atwater Wiggins & Gardner, 1995; Brickhouse, 1994; Kahle & Meece, 1994). As Tobin (2005) points out, school science is imbued with middle-class and Western European styles of discourse and argumentation which may make it alien and difficult for minority urban youth. Afterschool programs, alternatively, are environments that celebrate youths' family and community identity (Honig & McDonald, 2005; National Academy of Sciences, 2002; Noam, Biancarosa, & Dechausay, 2003). They can create the kind of "intentional figured communities" seen as essential in Teresa Perry's theory of African-American achievement (Perry, 2003). As such, they may prove to be more generative places of learning for minority and low-income students, as well as girls.

With afterschool programs coming under increasing pressure to support the academic achievement of participating students (Noam et al., 2003), and with NCLB-mandated state science tests beginning in the 2006-2007 school year, afterschool settings have significant potential for becoming a powerful site for science learning for urban students. Yet in typical afterschool programs, the staff have little science or science education experience. This may represent an opportunity for informal science institutions. A recent report by the James Irvine Foundation (Museums After School, 2005) notes the strong potential that museums have for contributing to afterschool programs. What might this mean for science?

Inquiry-based science, called for in the National Science Education Standards (National Research Council, 1996), refers to learning science through a process of investigation and also learning that science *is* a process of investigation—the kind of science that many informal science centers excel at. Good inquiry-based science consists of opportunities for children to raise questions, design investigations, consider evidence, and construct explanations (Duschl, 2003). Children thus develop their abilities to do science while they develop their understanding of science. A central issue implicit in this vision of science education is that the inquiry must be driven by a question that has meaning to the inquirer. Like afterschool/youth development organizations, inquiry-based science thus stresses the agency of the learner in defining or appropriating a question that drives their curiosity and defines their scope of work or their task. There may be highly generative theoretical and structural connections in bringing these two fields together. CILS is co-leading a three-year study, with colleagues from Harvard, Lawrence Hall of Science, and Reginald Clark & Associates, to investigate these connections.

There is a significant opportunity for informal science institutions, most of which are located urban or metro areas, to bring their science expertise, materials, and educational leaders to partner with afterschool programs. In such settings, science programs may be able to build on the practices and theory of youth development in afterschool programs, while bringing to bear strong learner-driven, inquiry-based science strategies to create new science learning opportunities. These programs, which have grown significantly in size and number over the past decade, serve high numbers of low-income and minority youth (Afterschool Alliance, 2005; National Academy of Sciences, 2002; National Institute of Out-of-School Time, 2003; Walker, Wahl, & Rivas, 2005). They offer students a supportive, learner-centered environment for learning and building their capacities to know and do science. But there are organizational barriers to this work as well. Working with afterschool programs will require ISI educators to learn more about youth development and working with minority and low-income youth. It will involve establishing shared goals, across very different organizational structures, that meet needs and priorities of both youth development and science education. It will require renewed and sustained institutional commitments to supporting and diversifying ISI education staff.

Working with Teachers in Structured Ways

There is a common consensus that teachers are the linchpin of school reform (see, e.g., National Commission on Teaching and America's Future, 2003; The Center for Teaching Quality, 2005). *No Child Left Behind* legislation states that all classrooms must be led by "qualified teachers." Yet concomitant with these reports are the alarming figures related to preparing and retaining qualified science teachers in the classroom. Along with increasing enrollments, reduction of class sizes, and implementation of standards have come rising retirement rates and what has been characterized as a revolving door for new teachers who come into the profession and leave, in up to 50% of the cases in urban schools, within the first three to five years. One result of this shortage is that roughly a third of the teacher force is new each year; and high poverty schools are hit the hardest by this phenomenon (NCTAF, 2003). Moreover, science and mathematics have the greatest shortages of qualified teachers. As a result, many teachers in these subject areas are new teachers, that is though they may have appropriate levels of subject matter knowledge, they may be just starting to develop their teaching skills.

Darling-Hammond and others (see, for example, Ball & Cohen, 2005, Darling-Hammond, 2000) have shown that teacher's knowledge as well as their knowledge of how to teach their subject matter is correlated with classroom performance as well as with student achievement. Thus there is a strong need for professional communities to support teachers in the development, consideration, and refinement of their teaching strategies (NCTAF, 2003). ISIs may be well-suited to support such communities. ISIs are perceived as politically neutral and friendly places for teachers—a place where teachers can feel free to ask questions and to make mistakes. Devoted to science, and filled with people actively learning science, ISIs can serve to rejuvenate a teacher's passion for science education. Besides working to shore up teacher content knowledge, professional development programs at ISIs can help teachers to develop methodologies to engage students interest and to motivate further learning. They are also places where teachers can build professional communities, around science teaching, and they serve as year-round resources and support.

But again there are systemic and organizational barriers to effectively implement this work. CILS found that about 40% of ISIs provide professional workshops to teachers, but the majority target elementary teachers. Under NCLB, most elementary schools are focused on reading and mathematics, unfortunately sometimes to the exclusion of other subject matter—this may at least partly explain why many of these teacher development programs are undersubscribed. Schools may have little professional development time and few resources to devote to elementary science. There is of course an opportunity for ISIs to seek funding outside of the district to provide elementary science professional development, and perhaps to fill a niche, and many do this. But what is striking is the paucity of programs targeting middle and secondary science teachers. Given NCLB qualified teacher mandates, this may represent a need that ISIs could meet. There are several ISI programs across the country that do offer middle and high school teacher professional development. But ISI educators will need support to become familiar with the material teachers are teaching and the content their students are being tested on. They will have to adjust their traditional offerings for teachers who themselves are adjusting to new demands. Again this requires ISIs to reach into the formal science education community—its research, knowledge, practices, and policies—to better understand the context that teachers are working in.

These efforts also suggest the need for further research that uses organizational and institutional theory to understand how these different forms of institutions and systems of education are structured to work together (Ogawa, Crain, Loomis, Ball, & Kim, 2005).

Working with Teaching Materials in Structured Ways

Another way in which ISIs work directly with schools is through the creation of learning materials such as exhibits, programs, study guides, curriculum, and on-line materials.

ISI science materials typically provide students direct experiences with the natural world. Through unexpected or counterintuitive encounters with phenomena, exhibits, for example, are designed to arouse curiosity and motivate further learning. They are also designed to engage the aesthetic or playful side of people to draw them into investigations. Many ISIs have online materials, activity kits, and workshop materials that they have designed building on these principles. Davis & Krajcik note that good curriculum materials must contain "good representation of the content, a clear purpose for learning it, and multiple opportunities for students to explain their ideas" (Davis & Krajcik, 2005, p. 3) In some cases ISIs work with curriculum design principles to develop materials specifically for the classroom. For example, the Lawrence Hall of Science at Berkeley has been one of the pioneers of classroom kit-based science with FOSS and GEMS. The Museum of Science in Boston is developing an entire K-12 engineering curriculum. These examples show how ISI experience in content, pedagogy and design can translate into rich science education materials for children in classrooms.

However, in many other cases, materials developed by ISIs are less sweeping in scope, and may not connect clearly or completely with the K12 curriculum. For example, although the Exploratorium Snackbook, a collection of classroom activities to make table-top versions of exhibits, is used in classrooms all over the country, it was designed with reference to the museum's exhibit collection and not to the curriculum. Because the table-top "recipes" were created by teachers it generally connects with the science into the curriculum. Further, it's worth noting that the original set of Exploratorium exhibits, many of which are replicated in the Snackbook, were inspired by the Elementary Science Study (ESS) and high school curriculum. However, the Snackbook does not include ways to introduce activities, or to incorporate them into core K12 curriculum. It does not include assessment strategies to track what students are understanding and what is eluding them. Similarly, may of the materials produced by science museums appear to be somewhat ad hoc from a curricular point of view. Sometimes they are based on exhibit collections, which may or may not be connected to standards-based curriculum. Sometimes they are pieces of an overall classroom curriculum. Sometimes they are derivatives of special exhibitions.

While the ability to produce entire curricula, as Lawrence Hall or Museum of Science have done may be rare, it is highly possible that ISIs can serve as curriculum advisors or consultants to science education publishers. They can bring their sense of whimsy, their skill at engaging learners, their variety of low-cost hands-on techniques for having children do science, and contribute to an array of other materials being developed by science curriculum experts for the classroom. As educational designers, ISIs have particular sets of skills that may help to bring science content alive in text form. Systemic barriers that work against such collaboration mainly pertain to the lack of awareness of classroom curriculum issues on the ISI side, and a lack of awareness of the richness of the ISI resource on the publishing side.

Conclusions

CILS discussions at the August 2005 roundtable and elsewhere have led to three main conclusions. First, it is important, as a part of meeting their institutional missions to support lifelong science literacy for all, for ISIs to support and connect with formal science education institutions. Second, to do this well, ISIs must invest in sustained professional development for their staffs, and significantly expand their communities of colleagues and practice beyond the confines of cultural institutions and informal science. Third, ISIs must be a part of creating and utilizing new knowledge that can guide investments of resources into programs and structures that support links between informal and formal science education.

We realize that this is a broad agenda, but we have also learned that to move from the particular examples of strong programmatic collaborations, such as those highlighted at the beginning of this document, to implement, at a national scale, systemic and systematic collaborations that can strengthen the way science is taught in schools, and therefore how it is pursued through lifelong learning, requires more than a call for "best practices" or a set of design principles. Instead, it requires deep-seated shifts in the way that ISI professional practices are oriented and supported. This shift, we believe, starts with reconceptualziing our place and role within the broader educational landscape, and connecting with communities with shared concerns for broadening access and equity in science education.

Roundtable Participants

Participants in the CILS Bay Area Roundtable who contributed to conversations and thinking represented in this paper include: Catherine Aldridge (@-Bristol Science Center, UK); Bronwyn Bevan (Exploratorium); Kathleen Boyle (Georgia State Department of Education); Julie Cross-Steele (Ft Worth Museum of Science and History); Jennifer DeWitt (King's College London); Kerry Davidson (Louisiana Board of Regents); Rena Dorph (Lawrence Hall of Science); Janice Earle (National Science Foundation); Teri Eastburn (National Center for Atmospheric Research); Auntaneshia Garry (King's College London); Erin Graves (The Imaginarium); Ling Hsiao (Museum of Science, Boston); Cheryl Iani Juarez (Miami Museum of Science); Lesley Kennedy (Museum of Science, Boston); Ruth Kim (UC Santa Cruz); Kristin Leigh (Explora); Claire LeMoine (Explor@dome, Paris); Sue McWilliams (Central Oregon Community College); Diane Miller (St. Louis Science Center); Nicole Peisker (Children's Discovery Museum of San Jose); Gil Noam (Harvard University); Wayne Ransom (Franklin Institute); Nora Sabelli (SRI International); Dawn Sanders (King's College London); Marcella Saoud (Taylor Elementary School); Dennis Schatz (Pacific Science Discovery Center); Rob Semper (Exploratorium); Laura Shaffalo (Children's Museum of Pittsburgh); Patrick Shields (SRI International); David Smith (Da Vinci Discovery Center); Elizabeth Stage (Lawrence Hall of Science); and Sonnet Takahisa (New Visions, Inc.).

References

Afterschool Alliance. (2005, 12/20/05). *Afterschool Issue Overview*, http://www.afterschoolalliance.org/after_over.cfm

Barton, A. C., & Yang, K. (2000). The Culture of Power and Science Education: Learning from Miguel. *Journal of Research in Science Teaching, 37*(8), 871-889.

Center for Informal Learning and Schools. (2005a). *Informal Science Institutions Landscape Study*

Center for Informal Learning and Schools. (2005b). *Professional Practices and Beliefs of Museum-Based Teacher Educators*

Darling-Hammond, L. (2000). *Solving the Dilemmas of Teacher Supply, Demand, and Standards: How We Can Ensure a Competent, Caring, and Qualified Teacher for Every Child*. New York: National Commission on Teaching and America's Future.

Davis, E. A., & Krajcik, J. S. (2005). Designing Educative Curriculum Materials to Promote Teacher Learning. *Educational Researcher, 34*(3), 3-14.

Delpit, L. (1995). *Other People's Children.* New York: The New Press.

Duschl, R. (2003). Assessment of Inquiry. In J. M. Atkin & J. E. Coffey (Eds.), *Everyday Assessment in the Science Classroom*. Arlington, Virginia: NSTA Press.

Honig, M., & McDonald, M. (2005). *From Promise to Participation: Afterschool Programs through the Lens of Socio-Cultural Learning Theory.*

James Irvine Foundation. (2005). *Museums After School: How Museums are Reaching Kids, Partnering with Schools, and Making a Difference*.

Jolly, E., Campbell, P., & Perlman, L. (2004). *Engagement, Capacity and Continuity: A Trilogy for Student Success*.

National Academy of Sciences. (2002). *Community Programs to Promote Youth Development*. Washington, DC: National Academy Press.

National Academy of Sciences. (2005). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

National Commission on Teaching and America's Future. (2003). *No Dream Denied*. Washington, DC: National Commission on Teaching and America's Future.

National Institute of Out-of-School Time. (2003). *How Afterschool Programs Can Most Effectively Promote Positive Youth Development as a Support to Academic Achievement*.

National Research Council. (1996). *National Science Education Standards*. Washington DC: National Academy Press.

Noam, G. G., Biancarosa, G., & Dechausay, N. (2003). *Afterschool Education: Approaches to an Emerging Field*. Cambridge: Harvard Education Press.

Ogawa, R. T., Crain, R., Loomis, M., Ball, T., & Kim, R. (2005). *Linking Socio-Cultural Theories of Learning with an Institutional Theory of Organizations: Impliacations for Theory, Practice and Collaboration*.Unpublished manuscript.

Perry, T. (2003). Up From the Parched Earth: Toward a Theory of African-American Achievement. In *Young, Gifted, and Black: Promoting High Achievement Among African-American Students*. Boston: Beacon Press.

Pugh, K. J., & Bergin, D. A. (2005). The Effect of Schooling on Students' Out-of-School Experience. *Educational Researcher, 34*(9), 15-23.

The Center for Teaching Quality. (2005). *Why Teaching Quality Matters: What We Know*. Retrieved January 10, 2006, from http://www.teachingquality.org/whytqmatters/whatweknow.htm

Tobin, K. (2005, September). *Using Science Education to Expand the Agency of Urban Youth, Keynote Address.* Paper presented at the Second Annual Symposium on Optimizing Science Achievement for All Students, University of Maryland Institute for Minority Achievement and Urban Education.

Walker, G., Wahl, E., & Rivas, L. M. (2005). *NASA and Afterschool Programs: Connecting to the Future.*