learning from science

Case Studies of Science Offerings in Afterschool Programs

by Patrik Lundh, Ann House, Barbara Means, and Christopher J. Harris

Afterschool programs have increasingly gained attention as settings that can help enrich students' science learning (Halpern, 2004). Even though science is widely included in afterschool activities, sites often lack adequate materials and staff know-how to implement quality science. Moreover, not much guidance is available on how afterschool sites can offer quality science within the practical constraints of their work (Chi, Freeman, & Lee, 2008; Noam et al., 2010).

To address this need, this article examines afterschool science in light of the National Research Council's comprehensive synthesis report on promoting science learning in informal environments (NRC, 2009). We present the results of our analysis of qualitative case studies of nine state-funded afterschool sites in California, discussing the strengths of these programs against the background of three key site-based constraints—time available for science, staff's science backgrounds, and instructional materials—as well as the importance

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of partnerships with outside organizations to support sites in overcoming these obstacles.

Goals for Afterschool Science

Over the last two decades, experts have called for a shift in science education away from a focus primarily on knowledge acquisition and toward a focus on learning science by engaging in the *practices* of science (AAAS Project 2061, 1993; NRC, 1996, 2007, 2012). These practices include asking questions, developing and using models, conducting investigations, interpreting data, constructing explanations, engaging in scientific arguments, and communicating information and findings. This "science-as-practice" perspective (Duschl, 2008; Harris & Salinas, 2009; Lehrer & Schauble, 2006) has recently been applied to science learning in out-of-school settings, with added attention to cultivating students' science interests and science identities (NRC, 2009). Research in a variety of out-of-school settings that emphasize science as practice have shown promising outcomes in such areas as learning of science concepts (Bell, Blair, Crawford, & Lederman, 2003; Etkina, Matilsky, & Lawrence, 2003), collaboration and communication (Ritchie & Rigano, 1996), curiosity and interest in science (Barab & Hay, 2001; Bouillion & Gomez, 2001; Stake & Mares, 2005), science identity (Fadigan & Hammrich, 2004), and pursuit of science careers (Afterschool Alliance, 2011; Chi, Snow, Lee, & Lyon, 2011).

Over the last two decades, experts have called for a shift in science education away from a focus primarily on knowledge acquisition and toward a focus on learning science by engaging in the practices of science.

The NRC (2009) report proposes six strands of science learning that illustrate how informal learning environments can support meaningful participation in science:

1. Developing interest in science
2. Understanding science knowledge
3. Engaging in scientific reasoning
4. Reflecting on science
5. Engaging in scientific practices
6. Identifying with the scientific enterprise

Our case studies explore the extent to which afterschool science offerings are addressing the NRC strands and consider the factors that help or hinder their progress.

Case Studies of Afterschool Science

We conducted case studies at nine afterschool sites in different regions in California. In constructing our cases, we examined the goals and scope of science offerings and compared them with the NRC's (2009) six strands.

Selecting Cases

The case studies were part of a larger study in which we surveyed 406 sites in a state-funded network of afterschool programs throughout California. The purpose of the survey was to collect data on sites' partnership networks and how partner support influenced the depth and frequency of science offerings. We conducted case studies of nine sites from our survey sample to generate hypotheses about how various factors—in particular time, staff capacity, instructional materials, and support from other organizations—relate to one another and affect science offerings. We selected critical cases (Flyvbjerg, 2006) that would showcase science offerings under the most promising conditions, allowing the generation of explanatory patterns (Greene & David, 1984) of the critical factors associated with strong science offerings.

To find sites with frequent and broad science offerings, we followed a three-step process. First, we selected a sample of sites based on whether they had two or more sources of support, offered science at least once a week, and reported features that indicated high-quality science learning, such as inquiry-related activities. Our first-round selection resulted in 122 candidate sites. Second, we reviewed each of these 122 surveys holistically and in detail, looking at the broad picture of what sites reported about science activities, frequency of science offerings, instructional materials, and kinds of support for science, as well as open-ended descriptions of sites' science activities. We then conducted screening phone calls with 20 of the most promising sites. The results of these calls, along with geographical diversity, informed the final selection of nine sites.

Data Sources and Collection

Instruments—which included semi-structured interview protocols and structured observation debrief forms—and data collection were informed by a set of key categories intended to create rich descriptions of each case, to guide a detailed examination of individual cases, and to provide a framework for cross-case comparisons. These categories included site locations; program activities; number of staff members, their background and history in the program, and staff turnover; number of participating children and their ages, background, and demographic characteristics; history and purpose of science offerings;

instructional materials; staff background in, knowledge of, and interest in science; and external support for science education. We visited three of the sites twice, once in spring 2011 and again in fall 2011. Because data from the second site visits mostly confirmed data from the initial visits, we visited only one more site twice; the other five were visited once. During the visits, which took one or two days apiece, we interviewed science facilitators, site leaders or coordinators, and representatives of support organizations. We also observed science activities, taking detailed notes and writing up insights on a structured observation form.

Analysis

We began the analysis by examining the key categories described above in order to compare across cases. Comparisons highlighted substantive differences among sites. These differences served as the starting points for explanations of the relationships among science offerings and materials, unique and common circumstances, and supports. We profiled each case based on key factors and relationships between categories, highlighting the differing conditions under which science programs occurred. We then looked across cases to discern explanatory patterns in programming and support as well as to highlight notable program or support features using a grounded theory approach (Glaser, 1992).

Next we compared the science activities we observed to NRC's (2009) six strands of informal science learning. To generate a description of a site's science offerings that could be compared with the NRC strands, we considered several factors: the goals of science activities as reported by facilitators and site coordinators, the structures of the activities we observed and the engagement of children in the activities, and site staff reports of typical science activities. Each site was assigned a high, medium, or low score for each of the six NRC strands. A high score meant that at least one of the explicit science goals aligned with the strand and that the activities provided strong learning opportunities relating to that strand. A medium score meant that some aspects of science activities were aligned with the strand, but that these aspects were not made explicit to the children or the activities reflected the strand only moderately. A low score meant that few aspects of the activities were aligned with the strand and that these aspects were not highlighted. If the activity did not refer to or include any aspect of the strand, it received no score.

For example, an activity involving mixing borax, glue, and water to make "goo" would be scored high for strand 5, engaging in scientific practices, if children were encouraged to experiment with different proportions of ingredients, make predictions, and take observation notes about what these recipes created. It would be scored medium if the children merely made their own goo, following the same prescribed steps, and participated in a reflective group discussion after the activity. It would be scored low if the children just observed the teacher or followed directions without understanding the scientific purpose of the scripted acts, with the emphasis instead falling on the fun of playing with the goo.

Effects of Constraints and Support on Case Study Science Programs

Our findings revealed significant capacity constraints at these sites. The types and depth of science offerings were consistently explained by three site-based factors: time, staff capacity, and instructional materials. The support of other organizations, particularly with staff capacity and instructional materials, played a significant role.

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Below, we describe science activities observed at two of the nine case study sites. We then discuss our findings across all nine cases, considering the three key factors and external support in light of the NRC framework for science in informal settings. Finally, we discuss the implications of our findings for how afterschool programs can use their strengths to address the NRC strands within their practical constraints.

Two Case Studies

The Alhambra[1] site exemplified science activities and staff capacity constraints common among the nine sites. The case of Lockhart, one of two sites with the strongest science offerings, demonstrated how limited staff capacity can be improved through professional development from a partner organization.

Science at Alhambra

Alhambra is an elementary school serving grades 1–6 in a low-income neighborhood in a small urban area on California's north coast. The school operated the afterschool program, which, at the time of this study, offered science every Thursday for about one hour. In addition, undergraduates from the nearby university's community outreach program facilitated science activities for 45 minutes every Friday.

One of the activities we observed involved making rockets. When the two undergraduate volunteer facilitators told the children that the rockets would shoot up in the air, the children applauded. One facilitator explained that the children were to color and cut out rocket parts that were pre-drawn on paper. Participants were then to glue the rocket parts onto an empty film canister. The facilitator said, "After decorating and things like that, you will do some science stuff." The children began coloring and cutting out the pieces of paper. They were highly engaged in their coloring, chatting together as they worked. During the activity, about a quarter of the children left as their parents picked them up.

When most of the children had finished coloring and cutting, the facilitators demonstrated how to wrap the paper parts around the canister. This task was difficult for most children, so they ended up waiting for a facilitator to wrap and tape the parts onto their canisters. They sat and waited passively or chatted with other students.

When all the children had finished their rockets—which were quite attractive in various colors and patterns—they went outside. In the yard, the children lined up by a picnic table to have one of the facilitators pour a cola drink into the canister. Then they went to the other side of the table, where the other facilitator helped them add a mint tablet, quickly plug the canister, and place the rocket right side up on the table. The first few rockets fizzled. One jumped a few inches into the air. Some children started asking why the rockets did not "explode," and some suggested adding more mints or more cola. But no discussion ensued, and the remaining parents were arriving to get their children. After all the children had launched their rockets, the activity ended.

Science at Lockhart

Lockhart is an elementary school in a predominantly Hispanic urban community in the Los Angeles metropolitan area. The afterschool site, which served 120 children, was operated by an afterschool organization with dozens of sites in the area. Science was offered to children in grades 3–5 two to four times a week, in addition to other activities including arts and crafts, gardening, dance, basketball, drill team, reading, chess, and keyboarding.

In one activity we observed at Lockhart, the facilitator began by asking the fourth- and fifth-grade children, "Can anybody give me an idea about how an airplane flies?" After the children shared their thoughts, the facilitator read from an activity sheet to inform them about the goals of the activity. Pulling polystyrene plates and a sheet of instructions from a large bag, he led the children through the process of making a plane.

The steps involved measuring, drawing, and cutting pieces of the plates. For each step, the facilitator waited for all the children to finish. When the planes were finished, the facilitator told the children to line up in the back of the room and throw their airplanes one at a time. "Did it glide?" he asked. When they responded "No," he told them to add a paper clip to the nose of their planes. One boy asked why a paper clip would help. The facilitator responded, "I don't know. We will discuss and see."

After the children tested their planes with paper clips, the facilitator led a discussion of what they observed. He related children's observations of their planes' flight to how a real plane flies. He asked questions such as, "Why do you think it flies in the air?" He explained how the wind carries the wings of a plane. He asked children what pulls a plane down and so shifted the discussion to gravity, asking them, for example, about the difference between how a crumpled piece of paper falls compared with a flat sheet of paper.

For the last 10 minutes of the session, the facilitator had the children explore and test their airplanes. The children continued to modify their planes; some competed to see how far their planes could fly. They exchanged ideas and techniques on the modifications they made to their planes. One girl excitedly told the facilitator, "Look! I took off the tail wing; it went so fast." One boy told the facilitator that he took off the bottom of the wing, saying: "It goes way better." One boy cried enthusiastically, "Dude! Did you see mine glide?" His friend asked what change he had made to the plane, and the two boys shared their ideas with a girl nearby. The activity ended with this exploration.

Comparing the Two Cases

The science activities at Alhambra and Lockhart shared some features. Both were partially scripted activities using simple materials. In both, the children followed step-by-step instructions to assemble vehicles that they later attempted to launch. In both, the amount of time allotted for science was about an hour. None of the facilitators had science backgrounds.

The two activities differed significantly, however, in the way they were facilitated. At Alhambra, even though a facilitator began the session by saying that participants would "do some science stuff," the children had no apparent reason to think that their rocket-building efforts amounted to anything scientific. The Alhambra children were engaged, but primarily when they were coloring and cutting their rocket pieces, an effort that in essence amounts to an arts activity. The scripted nature of the activity also did not leave much room for the children to explore or ask questions. At the end, when the mints were added to the cola to propel the rockets, the children began to express curiosity about why some rockets lifted and others did not. They made suggestions about how to change the outcome, but there was no time to explore the children's questions, and the facilitators did not attempt to discuss the phenomenon.

By contrast, the Lockhart facilitator framed the activity from the very beginning with a question about what makes airplanes fly. Although children spent significant time following prescribed procedures, once they had their planes built, the facilitator encouraged them to test the effect of adding the paper clip to the plane and to think about what happened. Then the children had time to play and explore with their planes without specific instructions. They collaborated and eagerly shared their discoveries with one another and with the facilitator. In the discussion, the facilitator did not lecture the children but asked open-ended questions. Rather than answering children's questions, he acknowledged that he did not know and said they might find answers during their experiments. He acknowledged the children's questions and suggestions. He also shaped the conversation by asking questions and by drawing his own comparisons with how other objects fall and how real planes behave.

A notable factor that distinguished the two sites was their access to support for science education. Alhambra had a partnership with a university whose undergraduates facilitated activities, both in the regular program and in the environmental science activities provided by the university's community outreach organization. None of the undergraduates studied science, however, or had science backgrounds. The students did their own online research to find activities. Lockhart similarly worked with undergraduate students with no science background. However, Lockhart's sponsoring afterschool organization provided access to extensive science training for facilitators—the most extensive of all our case study sites. In this training, facilitators engaged in hands-on activities themselves to develop an understanding of science inquiry. They also received training on the two afterschool science curricula used at the site. An additional training session specifically on science inquiry was provided by one of Lockhart's partners, a local science museum.

Site-Based Factors Shaping Afterschool Science Activities

Findings from all nine case studies show considerable variation in the way sites dealt with the three main constraints of time, staff capacity, and instructional materials. The support of partner organizations was one of the main factors in sites' ability to transcend their constraints in order to provide high-quality afterschool science experiences.

Time

Time was the most obvious limit, imposed both on individual activities and on opportunities to connect and build on activities across days and weeks. Most of the case study sites offered science at least once a week; the frequency ranged from a couple of times a month to every day, although daily programs were offered only periodically. In all nine programs, science was one of several activities offered. In all but one site, no more than an hour at a time was dedicated to science. Because science was usually scheduled as the last activity of the day, after homework or other activities, parents often picked up their children in the middle of science activities. Between time spent setting up, getting organized, and cleaning up at the end, children would spend about half an hour on actual science activities. This limited time made it difficult to conduct in-depth investigations or discuss children's observations. Facilitators intentionally selected activities that they felt would engage children who might be tired after a long day and that could be implemented in a short time and with minimal setup.

Staff Capacity

Only two of the nine sites, including Lockhart, provided science-focused professional development. Of the 26 facilitators and 10 site coordinators interviewed, only one was formally studying science in college and only one had a teaching credential. Facilitators often had experience or training in youth development; most sites provided professional development on youth work in general but not specifically on science. Facilitators' limited science backgrounds were reflected in the way they enacted activities. For example, they mostly stayed on script, following directions in the instructional materials. Discussions were limited in time and scope; facilitators asked fact-based questions and responded to students' questions rather than facilitating open-ended and exploratory discussions. Furthermore, the learning experiences they generated were mostly procedural, with the entire group working in unison through prescribed steps. In the few cases where facilitators had received some training in science content and inquiry practices—and had acquired some confidence in implementing inquiry-based activities—their science activities were more open ended, allowing children to explore on their own and engage in reflective discussions. The comparison between the rocket activity at Alhambra and the plane activity at Lockhart exemplifies this critical difference.

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Instructional Materials

Across all sites, facilitators reported that they selected, or influenced the selection of, activities based on what they thought children would enjoy and would be able to engage with at the end of a long day. Facilitators also reported taking into account what they themselves would enjoy, were already familiar with, or felt comfortable implementing. All nine sites had scarce resources, so facilitators often used whatever they had on hand, frequently mixing and matching materials. Staff at all sites searched for science activities on the Internet to some degree.

Support Through External Partnerships

All of the sites received varying degrees of support for science learning from the organizations operating the program, which included afterschool organizations, school districts, and individual schools. Other partners included a university, a museum, a government agency, and a nonprofit organization. The most common kinds of support were instructional materials, professional development, sending facilitators to lead science activities, and, in the case of educational institutions, providing undergraduate or high school students to work in the science program. We grouped sites into three categories based on the level of support they received for science activities. In the first category, "most support," we placed sites with consistent science-specific support from one or more organizations. Two sites fell into this category, including Lockhart.

Four sites, including Alhambra, had "some support" for science, meaning that the operating entity or other partner organizations provided general resources, such as professional development and materials focused on youth development. These organizations also emphasized making science a part of regular programming but did not provide consistent science-specific support. The three sites in the last category had no external support for science and little support for other programming.

Scope and Depth of Science

The science offerings at the nine sites, though often well facilitated and engaging from a youth development perspective, varied considerably in the degree to which they realized the NRC framework.

All nine sites focused on making science fun and interesting to children, a goal that corresponds to NRC framework strand 1: "Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world." This aspect was perhaps most emphasized in statements by site staff about the goals and purposes of their science offerings. One site coordinator, for example, said that she aimed "to make sure the children feel positive about science and have fun while learning."

All sites also tried to address science concepts and ideas in their activities, an effort that corresponds to strand 2: "Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science." However, facilitators' limited knowledge of science meant that they often did not address content in any depth beyond the information provided in kits, worksheets, or other materials.

At four of the nine case study sites, we observed activities where children had opportunities to explore and perhaps wonder about science phenomena—for example, digging with their hands inside pumpkins, creating models of erosion, and observing chemical reactions or models of what happens during earthquakes. But children's opportunities to ask questions about such phenomena and to engage in more open-ended testing and exploration to support sense-making, as expressed in NRC strand 3, were few. This finding again may be explained by facilitators' limited knowledge of the phenomena.

At one site—one of the two with the most external support—we saw very limited evidence in one activity of strand 4: "Reflecting on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena." Among the instructions the facilitator had posted on the wall was the text, “I can use the scientific method to compare different materials and to examine insulating properties.” However, the facilitator did not actually lead the children in this kind of reflective discussion.

In six of the nine sites, we observed children engaging in science inquiry corresponding to strand 5: “Participate in scientific activities and learning practices with others, using scientific language and tools.” The two sites with the most external support stood out in this regard; at these sites, children had opportunities to conduct (but not design) experiments, collect and interpret data, collaborate, make predictions and state hypotheses, and present their observations. Activities at other sites also involved some steps of scientific inquiry, but in these cases the steps were prescribed and not driven by the children themselves.

Opportunities for children to identify with science practice, as in strand 6, were limited to the two sites with the most partner support. The site coordinators from these two sites mentioned goals of helping children connect to science and see themselves as persons doing science. One facilitator also said that site staff “want to give [children] a vision of there being other things out there, to open their eyes, and dream and perhaps become a scientist.” In an activity at one site, the facilitator gave the children explicit roles as “chief scientists.” However, we did not see widespread evidence at any of the sites of explicit, sequenced, or sustained practices that might help children relate to science as a practice, take on roles relevant to different aspects of science, or envision themselves as scientists.

When we compared sites’ level of implementation of the NRC informal science strands to the level of support they received from external partners (Figure 1), we found that the two sites with the most support implemented five or more of the six strands in at least some of the observed science activities. The four sites with some support scored in the middle in terms of the NRC strands: Their science activities covered fewer of the NRC strands than those at the best-supported sites, but they engaged children in fun ways. Activities at these sites gave children opportunities to find science interesting, to encounter some scientific phenomena, and to learn limited science ideas and vocabulary.

The three sites with no support for science activities implemented the NRC strands least fully. At two of these sites, in comparison with other sites, science activities were characterized by more behavior problems, more superficial exposure to science ideas and practices, and more failure to engage children in questioning and wondering. In the third site with no support, children

■■■ Explicit goal with likely learning opportunities ■■ Part of activities, but with few learning opportunities ■ Part of activities, but no learning opportunities Not part of activities		1 Developing Interest in Science	2 Understanding Science Knowledge	3 Engaging in Scientific Reasoning	4 Reflecting on Science	5 Engaging in Scientific Practices	6 Identifying with the Scientific Enterprise
Most external support for science	Site A	■■■	■■■	■■	■	■■■	■■
	Lockhart	■■■	■■■	■■		■■■	■
Some external support for science	Alhambra	■■■	■■			■	
	Site D	■■■	■■	■■			
	Site E	■■■	■■■	■■		■■	
	Site F	■■■	■■			■	
Little or no external support for science	Site G		■■				
	Site H	■■■	■				
	Site I	■	■			■	

Figure 1. Comparison of Sites’ External Support for Science and Their Scores for NRC Strands

had some exposure to science phenomena, but, as in the other two sites in this category, they had no opportunities to discuss, ask questions, or delve into the science behind the activity in any depth.

Implications for Afterschool Science

Creating engaging experiences that build on children's interests and that incorporate science learning is a tall order. The task becomes even more difficult when afterschool science sessions happen infrequently, for about an hour at a time at the end of long school days, and when they are led by facilitators who have little background—or sometimes even interest—in science.

Although achieving the ambitious goals in the NRC framework within these constraints is challenging, our case studies offer evidence that, with the right support, youth development professionals can create powerful science experiences for children. At various moments in our site observations, we saw science activities that engaged children in exploring phenomena, collecting and analyzing data, asking questions, and discussing scientific concepts. These observations provide "existence proofs" that afterschool settings can deliver effective science learning experiences. This finding is especially important in light of the reduced time being spent on science during the elementary school day (see, for example, Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011; Marx & Harris, 2006). However, our cases also show that the challenges programs face in providing science experiences prevent sites from pulling these experiences together into sustained and complete science learning. Having partnerships with other organizations is one way for programs to build their capacity for offering science. Of the three main constraints on afterschool science programming, only time is not often affected by external supports. By contrast, quality instructional materials and science-focused professional development are areas in which external partners can intervene to help programs strengthen their science offerings.

Acknowledgement

This material is based on work supported by the National Science Foundation under Grant No.0917536.

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Note

[1] Alhambra and Lockhart are pseudonyms for the sites.