Being, Doing, Knowing, and Becoming:

Science and Opportunities for Learning in the Out-of-School-Time Setting

by

Bronwyn Bevan

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This manuscript has been read and accepted for the Graduate Faculty in Urban Education in satisfaction of the dissertation requirements for the degree of Doctor of Philosophy.

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Abstract

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This dissertation addresses the question of how structured out-of-school-time settings, such as afterschool programs and summer camps, are positioned to support children's engagement and learning in science. This study addresses a gap in the research literature that does not fully specify the nature of the out-of-school-time (OST) setting and that generally does not position learning and development in relationship to one another, instead focusing on one or the other. As a result of an incomplete conceptualization of the OST setting as a site for learning and development, the OST field is becoming increasingly academicized, and its developmental qualities and benefits for children are under siege.

A transformative activist stance (Stetsenko, 2008) guides my goals in undertaking this study – to produce knowledge that can inform the design and implementation of OST science programs – and it also guides my analysis of what constitutes learning in OST science. A transformative activist stance is a perspective on cultural-historical theory that understands individual development as occurring through agentive, goal-directed efforts to change one's self and

one's world. These goals and actions are always developed and enacted in cultural-historical context. Learning, which occurs through the appropriation of cultural tools and schema to achieve one's purposes, and which leads human development, is understood broadly, as entailing processes of being, doing, knowing and becoming (see Herrenkohl & Mertl, in press). I also draw on bioecological theory (Bronfenbrenner, 1979) to analyze the proximal processes that support and sustain children's participation in the OST setting.

In this study, I analyze the structural, developmental, and conceptual features of three different OST science programs to understand how they create opportunities for learning and engagement in science. The contributions of this study are to better specify the nature of the OST science program setting and to better conceptualize how learning and development relate to one another in the context of OST science. I draw on my analysis to make recommendations for ways in which OST science learning can be expanded and enriched for more children in more settings.

Dedication

To my kids, Aidan and Thalia,

for being constant reminders about why it all matters,

and for understanding and giving me space.

Acknowledgements

I decided to go to graduate school after reading Jean Anyon's *Ghetto Schooling*. Her book situated the ping-pong of educational reform in the larger socioeconomic context, and made me want to better understand how the out-of-school-time learning space was part of that larger context. My many classes with Jean were highlights of my graduate school experience. Early, in my second semester, I was lucky to enroll in Anna Stetsenko's Cultural Historical Activity Theory class. That course, and my conversations with Anna, opened up entirely new ways of knowing, doing, being, and becoming for me. It triggered a "mind quake" as Anna used to say, and shifted my worldview on learning (and development). I can't thank Anna enough for this new perspective and also for modeling what it means to take a strong theoretical stance to effect real change for real people. Throughout this process of writing my dissertation, Anna has constantly reminded me that it matters: we develop theory, we research, and we practice to make change in our selves and our world. Important to implementing this charge has been Ken Tobin's reminders to proceed with respect and generosity in one's examination of the world and the people in it. Ken's esteem for teachers, learners and learning have, especially as I began to analyze my data, helped me to reflect on the effects of categorization and evaluative stances. In writing and rewriting this document, his reminders have provided a moral compass.

I want to express my gratitude for the program leaders and children in the programs I observed for welcoming me in, and providing me views into their lives and learning. These children and adults were my inspiration for trying to make sense of what I was seeing, feeling, and thinking.

Just as I was beginning to write up my data, Leslie Herrenkohl at the University of Washington shared a draft of her forthcoming book with me. Her explication of “a broad view of learning” and of learning as “ways of being, doing, and knowing” ripple throughout this dissertation, starting with the cover page. Receiving that book at that time was a gift. I look forward to working with Leslie and the conceptual tools she is developing in the years to come.

Thanks to my colleague and friend Rob Semper at the Exploratorium whose encouragement and understanding made this all possible. I could write a dissertation about Rob’s generosity and insightful thinking, but one dissertation is enough for now. Thanks to my colleague and friend Vera Michalchik at SRI who reviewed early chapters of this document, was always encouraging, and whose deep thinking about children and learning have stopped me from many false starts in my thinking and writing. Thanks also to my graduate school colleague and friend Chris Siry, who read drafts, gave advice, encouraged, and inspired me to keep going. If Chris could do it with four kids I knew I had better be able to do it with two.

Finally, thanks to my family – my parents, sibs, and kids – for keeping the bar high and for always being supportive.

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Chapter One

Introduction: How This Project Came About

In 2006, colleagues and I received a grant to lead the research and evaluation efforts for a new federal program designed to support and study science in out-of-school-time settings. The program funded 16 different projects to develop sustained (one to two years) out-of-school-time experiences in science for about 100 middle school-aged children at each site. Projects were expected to provide 100 hours of programming for each child each year. The overall program aimed to learn how these programs contributed to students' interest in science and science-based career trajectories, including their school careers. Part of the work involved in the research and evaluation effort was to conduct site visits and observe programs at all 16 sites. This dissertation evolved out of my experiences in anticipating, encountering, and making sense of those projects.

1.1 Who Am I?

For almost 20 years, I have worked at a science museum dedicated to supporting awareness of the natural and social world around us. The Exploratorium, founded in 1969 by a humanist-scientist, conceptualizes science as a cultural practice that helps people to ask questions and make sense of the world around them. From the onset, artists have been part of the core museum staff, because the founder felt that artists, like scientists, were the official

noticers, questioners and sense-makers in our society (K.C. Cole, 2009). While art and science bring different lenses to the inquiry, the learning experiences designed at the museum (in exhibits or programs) are intended to provide opportunities for people to have direct interactions with natural phenomena, where they can develop, ask, and pursue their own questions about the phenomena. Like Dewey (1916), the Exploratorium's founder felt that such experiences were essential to helping people develop questions, agency, and rational approaches to meaning-making (encompassing intellectual, emotional, and aesthetic ways of thinking and doing) in the natural, social and political worlds we inhabit.

That is how I developed my understanding of what science is. I did not develop it in school, where I found science to be a tedious process of memorizing facts or procedures about mushy, invisible, or remote objects. In school I studied literature and history, which I experienced as people asking questions and making meaning of the lived world. But my views on science changed when I came to work at the Exploratorium and experienced the compelling perspectives museum scientists and artists gave me (and others) onto the natural world. Their work lifted a veil that

was masking science for me – I came to see that science was not just facts and procedures; rather it was a way of being, doing, and knowing that could open doors to wonder, understanding, and insight into the world around me.

These views on science, which inform the design of Exploratorium exhibits and exhibitions, also shape the ways in which children and adults experience science-learning activities conducted in the museum's programs offered to the public. For example, my 8th grade hands-on school experience of studying electricity involved a battery, a bulb, and two wires. The challenge was to hook up the wires to the correct terminals to turn on the light bulb. While there was some satisfaction in getting this to work, the relevance of knowing which wire to use was not apparent to me as a child (and I don't use this knowledge as an adult). At the Exploratorium, our circuits and batteries investigation involves a completely different set of materials and purposes. The purpose is to create wearable battery powered accessories, which we call *digital bling*. The circuitry becomes a means for powering the glowing, flashing, colorful belts, pins, scarves, hair bands, or other wearable objects invented by the learner. The

investigation takes place in a setting where learners are surrounded by the work of others to inspire and stimulate ideas. A wide range of materials, including unusual and aesthetically compelling materials such as mylar, feathers, miniature toys, etc. are on a table next to the batteries, wires, and small digital computing devices called *crickets*. Visitors are invited in (and supported by facilitators) to work with these materials to design wearable items that express their aesthetic, creativity, or whimsy. There is no template to follow, although there are ideas communicated by the materials themselves, as well as the examples that visitors find others already wearing or developing. In *digital bling*, there is no one pathway through the investigation, one can create multiple wearable pieces, one can decide to link several together, one can complexify the investigation as one's interests and goals expand through engaging in the investigation and through observing other learners/designers. The setting is physically organized with small group tables, benches, materials, and prior work to encourage learners to work alongside or with each other, gathering images and ideas from friends as well as strangers; thus the space and investigation is clearly marked as a social endeavor organized around creativity, exploration, and expression.

The scientific principles and phenomena in this investigation are the same as in my classroom experience; successful wiring of the circuits is essential to completing the investigation. But the purpose and process are entirely different: circuitry is mastered through pursuit of producing specific desired material ends (such as a new bracelet) and also in the service of creative self-expression. (Not all activities produce "material goods": another investigation produces a temporal

collaborative exhibit installation using light and reflection.) In this investigation, science is invoked as it was developed culturally and historically: as the best available means to meet desired purposes. These are the ways in which the views of science at the Exploratorium instantiate in learning activities, and this is what I came to view as “doing and learning science.”

1.2 What I Do

At the museum, over time, I grew into a position directing a center, funded by the National Science Foundation (NSF) that attended to the connections between in and out of school learning in science. My program work involved conducting small research studies, leading professional development for informal educators, and developing occasional position papers for the field.

One day, I found myself (after writing and winning a grant) co-leading an effort to make sense of an ~$18 million investment by a federal agency in a number of different out-of-school-time (OST) projects. To my surprise, most of the projects were led by universities. This was a surprise because I had assumed that it would be youth development organizations (which understood children) and informal science organizations (which understood science) that would be best positioned to provide compelling OST science experiences for students. (As I was to learn, the OST setting has become an important new naturalistic

learning lab for university researchers whose experiments have been squeezed out of the classroom thanks to the onslaught of testing mandated by the 2002 reauthorization of the Elementary and Secondary Education Act [ESEA].)

As part of our research plan, I, and others on the research team, went out in the field to observe the funded programs. Here is an excerpt from field notes taken in the spring of 2008 that is fairly representative of the programs that we observed:

> **Electricity and Magnetism After School**
>
> In a temporary classroom trailer behind a school building in a mid-Southern state, ten 5th grade children and two teachers have gathered for their weekly science afterschool program. Another 5 children who normally attend are absent, because they are receiving extra tutoring for the state tests that will be administered later in the week. The two-hour session begins at 2:30 with ice cream cones on this hot spring day. The children sit at desks in two rows facing the front, where the lead teacher lounges and chats informally with the children. The children speak quietly to one another, mostly absorbed by the ice cream. They seem happy. Another teacher sits at the side of the room at a computer where she is downloading the activity sheets for the session.
>
> At about 3pm, leaning back in her chair with her ice cream, the lead teacher begins to ask the children what they know about car engines. "How many of you came to school today in something that was motorized?" Many of the children raise their hands. The teacher asks: "What does motorized mean?" The children mumble and raise their hands. "How did you get to school Alexis?" the teacher asks. "By car." The teacher continues, "So, does a car have a motor in it? Are all motors the same? What does a motor use? Tell me what you know about motors, Lucas." Jerry replies, "Well I know that um I know how it works, a car motor? I know how a boat motor works." The teacher responds: "Tell Carter." She turns to Joe: "Joe, do you know how a motor works? Pat do you know how a motor works? Yes? Go over there and tell Isabel."
>
> Her friendly but rapid-fire questions (all addressed to the boys, note) signal that the class is moving from "social" time to "learning" time. For about 20 minutes, the group discuss what goes into a car (wiper fluid, gas, oil, air filters etc.), drawing mostly on their out-of-school knowledge) before the co-teacher steps forward, at about 3:30, and distributes step-by-step instructions for making a motor from a battery, two paper clips, a cardboard tube, a magnet, and a copper wire. She explains the activity

and points the children to the assembled materials at the front of the room.

The children come to the front of the room to collect their materials and then return to their desks to begin to work on the activity individually. The co-teacher reminds the children that copper is expensive and she wants to get the copper wires back. The children work assiduously for about 30 minutes. Though working individually, there is a low level of running chatter in the room and constant giggling from one part of the room. This level of interaction appears to be part of the group's social norms, as nobody is asked to be quiet. The children comment on each other's work throughout this time. The teachers work alongside the children, holding the tubes or batteries so that the children can construct the motor. But it soon becomes apparent that the activity is not working for anybody. It seems that the copper wire, no matter how tightly it is wound, keeps springing off the tubes; the paper clips keep slipping off the battery terminals. The teachers move among the children to try to help. After another few minutes, with not one motor working, the co-teacher asks the children: "If you have followed the directions, including the troubleshooting parts, and it still isn't working, then what could be wrong?" There is no response. The teacher looks back at the motor she is working on and the children keep working on their own motors. They are still cheerful but a few are beginning to groan at their lack of success.

Another 10 minutes go by, it's nearing 4:20pm. The teachers say aloud to each other that the materials they have assembled are probably not workable: the copper wire is probably the wrong size. They ask the kids to respond to this question in their journals: "Write what happened, or didn't. Why you think it went wrong? Could it be the tightness or the battery?" One girl retrieves her journal from her backpack and begins to write. The others leave their journals untouched and begin to collect their things. Parents start to show up at about 4:20 and, one by one, the children begin to leave the room.

1.3 Crisis!

I found myself in crisis. What I had seen was the antithesis of what I knew science could be in the OST setting. At almost all of the site visits I made I saw scenes like this one: Science presented as facts and procedures. The children put into positions of following directions rather than taking initiative. The activities not working as planned or described. No time for review or reflection. The

children[1] departed for home, oftentimes a little early because of other commitments, their work unfinished, their questions unarticulated or undeveloped. I was horrified. Where were the questions? Where was the agency? Where was the science? Moreover, what was all that giggling and smiling about? Should the teacher have been planning and preparing her lesson rather than eating that ice cream cone?

I spoke to two of my colleagues who were co-leading the project with me. One, a developmental psychologist, steeped in ethnomethodology, saw things in a completely different light. She saw children happily and deeply engaged in activities that involved the tools and phenomena of science. She saw these events unfolding within what she called supportive semiotic spaces (Lemke, 1990) that were signifying to the children the value, role, and embrace that science had and could have for them. When I pushed on the quality of the science experience, she argued back that yes, there *was* science happening. Children were encountering people, places, tools, and phenomena of science. Although it wasn't perfect, all of the time, at the very least these programs were doing the crucial job of "keeping the kids in the game." This phrase would come to haunt me.

My other colleague is a policy researcher whose real job is conducting massive citywide or multi-state evaluations and studies of various educational

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[1] In this dissertation I use the term "children" to connote both children and youth; that is, people under the age of 18.

interventions. His work is particularly concerned with children in urban communities, and mostly around literacy and mathematics. He was collaborating with me on this small out-of-school-time project mostly because he was too nice to say no when I asked him if he could help. When I described my dismay at the lack of agency, inquiry, and authenticity[2] I was finding in these programs, he responded, kindly but as if to a naïf, that the important thing for these communities was for the children to stay in school, stay alive, and get to college. I agreed with that, but questioned why, if that process was going to involve science learning, it had to be so boring, so lacking in agency, inquiry, and authenticity. His response to me was "They don't know what the Exploratorium knows about science." Now I had another image nagging at me. Was the kind of science that I had come to know through the Exploratorium only possible for some people some of the time? Was it simply unrealistic to assume that science in out-of-school settings could be presented and experienced as "a way of being, doing, and knowing that could open doors to wonder, understanding, and insight into the world around us" as I had come to understand it at the Exploratorium? Was it "good enough" – was it a start, a foundation, or even an essential building block – that children were happy to be in an out-of-school-time science program,

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[2] By "agency" I mean the capacity and capability to take initiative in matters of consequence to the self (see Holland et al., 1998). By "inquiry" I refer to processes of developing and pursuing questions ("Scientific inquiry" would incorporate scientific rules of evidence and argumentation) (see, Exploratorium, 1995). By "authentic" I mean genuine and meaningful (not imposed or arbitrary), which could refer to real, everyday issues, or to abstract or virtual concepts that have genuine meaning to children.

that they identified their activities, their peers, and even themselves as part of a science learning community, and that they were receiving positive feedback from the adults and children around them?

What was possible, feasible, and desirable for science in out-of-school settings?

1.4 Research Questions

This dissertation has been an exercise in trying to make sense of these three threads that pulled at me over the last few years. To recapitulate, the three threads that were pulling at me were:

1. I know what science looks like. Science is a cultural practice and endeavor, developed historically in authentic social contexts, that advances agency and inquiry in and about the world.
2. I know what learning looks like. Learning involves being invited in and supported to engage with cultural tools, practices, and endeavors, to express one's ideas and imagination, to work with others, in order to advance purposes and goals that have meaning and consequences. It is agentive, transformational action in the material world. It involves processes of doing, knowing, being, and becoming.
3. I know what urban communities look like and contend with. I know that all communities have to consider how to educate at scale. Many are struggling to keep children in school, to get them into college almost at any cost. For many communities, for parents whose children attend

> under-resourced schools, “more school” during after school hours seems like a good solution.

During the same time I happened to be taking courses in graduate school and immersing myself in theory, primarily schools of thought influenced by Vygotsky. I found, in my professional capacity as I reviewed the OST literature, that the learning space was drastically under-theorized. A large portion of the studies of learning in OST failed to take a principled theoretical stance in their analysis and argument. Instead they made grounded but disconnected assertions about the purpose, role, and impact or potential impact of the learning environment. The literature made competing claims, sometimes citing the same studies towards opposite conclusions.

The literature on science in the OST space was nascent but compelling; yet its many rich descriptions of children drawing on their funds of knowledge and cultural capital to exercise agency and inquiry in the authentic context of their local communities was not what I was seeing in the field. Much more typical was the scene I described above: Children sitting at tables or desks; following instructions to work with hands-on materials; more or less accomplishing what they were tasked by adults to do; leaving the room with unarticulated experiences with science phenomena, processes, and instruments. In common with the rich descriptions of science I found in the literature (and review in Chapter Two) were the low-stakes, supportive, and sociable contexts in which the activities took place. Missing were the tackling of matters of consequence,

the self-expression using the tools of science, and the reflective activities that helped children articulate their questions, understandings, and concerns. This contradiction between the understanding of OST science I developed at the Exploratorium, the correspondingly rich cases I found in the literature, and the reality I was finding in the field raised dilemmas for me as a person tasked with making sense of what I was seeing.

This is how my dissertation project developed for me as a personal project; but there is a political background that makes this project salient to others: At a national scale, through fiscal 2010, there has been growing investment in and expansion of OST programs. In 2009 OST programs served 15 per cent of American children; children from ethnic minority populations were more likely than children from majority populations to attend afterschool programs (Afterschool Alliance, 2009). The federal investment in afterschool soared from zero dollars 13 years ago, to $40 million in 1998, to over $1 billion today. Additionally, there is growing interest in expanding science in OST programs. Numerous new efforts at federal agencies such as the National Science Foundation, the U.S. Department of Education, NASA, NOAA, as well as private foundations such as Macarthur, Noyce, Moore, and Bechtel, are investing in science in afterschool. More than 90 percent of afterschool leaders report that they want to increase science programming for students (Chi, Freeman, & Lee, 2008).

But without agreement on the goals, strategies, and important contributions that OST can make to the lives of children and communities, the

question is what will that science look like, and what will it do for children? In the programs I studied, and in much of the OST science field, unstated (and untested) assumptions include a vision of the OST setting as providing children with inquiry-based, authentic science experiences that effectively increase their interest and excitement about science and translate to commitment and success in school science. This logic has led to a focus on school outcomes (grades, attainment, college readiness, career choices) as the ultimate measure of afterschool effectiveness. Many in the field are concerned that as federal investment has grown, OST programs have been forced to tie their fate to students' school test scores as the only acceptable evidence of their programs' contributions (Halpern, 2006; Nocon & Cole, 2006). For example, the current FY11 budget proposal for the main federal investment in out-of-school-time programs (21st Century Community Learning Centers, which are authorized under ESEA) would cut funding and shift the funds from state formula grants to a federally managed competitive program. This move parallels the *Race to the Top* initiative for federal funding for schools, and could mean that OST programs will be more beholden than ever to prove their efficacy through school test scores. The leading policy advocacy organization for afterschool, the Afterschool Alliance, while arguing against the proposed changes in funding mechanisms and levels, fully supports the notion that afterschool programs should align with school achievement and college readiness. At the same time, the Afterschool Alliance maintains that activities in afterschool hours "should do more than merely add time to the school day or year and should require community partners

and academically enriching, engaging, hands on learning opportunities that complement, but differ from school day instruction" (Afterschool Alliance, 2010). Logically, as described above, it appears reasonable to believe that afterschool programs can provide non-school like experiences that excite children about learning, and therefore support more active and successful participation in school activities that will translate to college readiness. However, there is in fact no evidence, or basis in theory, that suggests that non-school-like pedagogical approaches to teaching and learning can be effectively (or productively) aligned with the narrow focus of school-based goals and outcomes. To the extent that evidence of successful afterschool programming is tied to standardized tests, and funding is predicated on such evidence, it is inevitable that OST pedagogies will become more school-like in order to align with school measures of success.

Given this policy environment, my dissertation is an attempt to make sense of what I have studied and to develop a vision and recommendations for how science can be positioned in out-of-school-time settings, at scale, in ways that can support children's engagement and learning in science. In this process, I adopt a *transformative activist stance* (Stetsenko, 2008) towards my question and the analysis of my data. A transformative activist stance is a Vygotskian-informed view of development that sees the desire and process of actively transforming one's self and one's world as the mechanism for development at both the individual and sociocultural planes. Thus, development is not driven by a genetic unfolding in individuals in interaction with the physical world (as in Piaget), nor by induction of individuals into existing patterns of social interaction

and participation (e.g., see Rogoff, 2003; Lave & Wenger, 1991), nor purely through tool-mediated cultural-historical activity (e.g., see Engestrom, 1987). These accounts of development are important, but incomplete: in different ways each of them separates individual development from social and cultural development. Piagetian views see the individual developing more or less independently of the cultural-historical context (driven more by genetic unfolding, and in response to opportunities provided by the social and physical context). Scholars such as Lave, Wenger, Rogoff and Engestrom describe development as tool-mediated processes of enculturation into existing patterns of social interaction. Although they also stress the continually developing nature of sociocultural systems, they do not suggest mechanisms that relate the developing person to the developing sociocultural plane. A transformative activist stance posits a unifying mechanism that explains development of both individual and society, with one driving the other. It sees individual development as occurring through active, purposeful, directed efforts to change oneself and society. These goals and actions are always developed and enacted in cultural-historical context. Learning, which occurs through the taking up of cultural tools and schema to achieve one's purposes, and leads development, is understood broadly, as entailing processes of knowing, doing, being, and becoming. Thus knowledge, tools, self, and society are both producers and products of change at both the individual and social planes.

By "adopting a transformative activist stance" in this dissertation, I mean, first, that I undertake my study with the goal of effecting change. I seek to

develop knowledge that can be used by policymakers and program leaders to make a greater number of OST science programs more developmentally and conceptually rich for a greater number of children. Thus, I move beyond phenomenologically describing what I have found in three different OST programs, and instead present excerpted transcripts of different OST science program interactions that raise questions about the ways in which children's learning in science is supported and the ways in which it is not. I recount these efforts, some of which appear to be more canonically successful than others (e.g., some are more child-centered, more inquiry-oriented, more phenomenon-based) *not* to pass judgments, but to advocate for new ways of thinking about and positioning science teaching and learning for children in OST settings. Thus a transformative activist stance infuses the rationale for this study. Second, I adopt a transformative activist stance as my analytical lens for describing the kinds of learning and development I observed in the programs I studied. As such, I define learning as expanding one's capacities to use and transform cultural tools in order to achieve change in one's self and one's social world. Following Vygotsky (2004), I understand learning as leading development. That is, development is defined as a process of expanding one's capacities to act in and on the world; appropriating and transforming cultural tools (learning), which entails processes of doing, knowing, being, and becoming, is the means by which one changes and expands one's capacities to act in and upon the world. Increasing development, in turn, creates new opportunities for learning (for example, as a child develops the capacity to engage adults in logical arguments,

new conversations and activities, offering new opportunities for learning, are made accessible; on a more concrete level, as a child develops manual dexterity to manipulate a computer keyboard, new sources of information and experience can be accessed on a computer).

In this way, learning and development are deeply inter-related, one affording the other. A transformative activist stance guides my analysis of how the OST programs I study *provide opportunities* for children to develop goals for and enact plans to undertake efforts and actions aimed at transforming themselves and their social worlds. (My study was not designed to analyze changes in individual children. Rather, I analyze the programs as they create and support such opportunities for children, who may or may not take up these opportunities, and who may or may not create their own opportunities in the OST setting or elsewhere.)

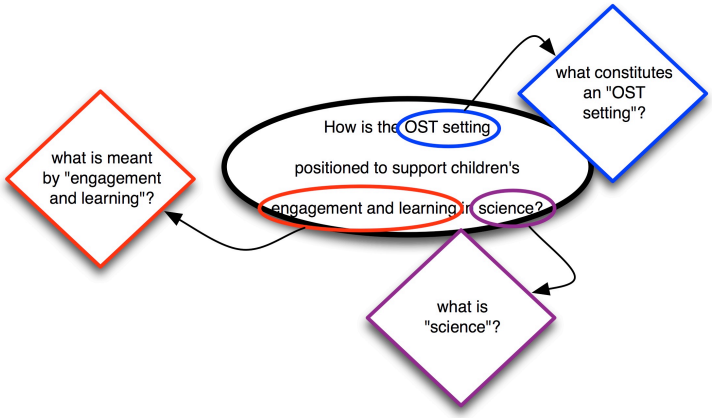
With this context and stance in mind, the central research question for my dissertation is:

How is the OST setting positioned to support children's engagement and learning in science?

To answer this question I need to do three things: (a) specify the nature of the OST setting, which is underspecified in the OST research literature, (b) specify what is meant by engagement and learning, and its relationship to development, which is a source of contention in the OST research literature, and

(c) specify what is meant by “science,” which is a subject largely unexplicated in the OST science literature. Better specifying the nature of the OST setting, especially in relation to opportunities for science learning, can potentially lead to more effective design and assessment of the contributions of OST science programs.

Figure 1. Parsing the Research Question



In Chapter Two of this dissertation I review the literature that relates to the nature of the OST setting. I thus provide a view of the educational and policy landscape in which the future of the OST field is being developed, showing why the question this dissertation addresses has consequences in practice and policy. In Chapter Three I develop the theoretical lens I will use to examine science and engagement and learning in the OST setting. Chapter Four describes my theory of inquiry, methods, and limitations. Chapter Five presents and begins to analyze the features of three different OST science programs. Chapter Five is organized around three sub-questions:

1. How do structural properties (setting; staffing; and attendance patterns) of the OST setting affect the program scope and stability?

2. How do the developmental conditions (the goals; participation structures; and relationships entailed in observed activities) affect children's patterns of interaction and social cohesion?
3. How does the conceptual positioning of science (as knowledge, inquiry, or cultural practice; and as a means for inquiry and agency) provide children opportunities for engagement and learning?

These questions are salient because the literature generally faults structural constraints for limiting teaching and learning, and touts developmental conditions as the promise of the OST setting for children's development. Frequently both of these arguments are made in the absence of subject-matter specificity, which is why I address the third sub-question. In Chapters Five and Six I use a transformative activist stance (Stetsenko, 2008), complemented by bioecological theory (Bronfenbrenner, 1979), to make sense of the structural, developmental, and conceptual features of the OST space; to address gaps in the literature regarding the specification of the OST setting and the relationship between learning and development in the OST setting; and to propose recommendations for how OST programs could be positioned to provide more developmentally supportive and more conceptually rich science learning opportunities for children.

Chapter Two

Rationale for This Study: The Educational Landscape

Out-of-school-time (OST) organized settings have been fixtures in urban communities for over a hundred years, dating back to the settlement houses at the turn of the 19th century (Halpern, 2002). But only recently have they begun to attract the attention of educational policymakers. By "OST setting" I mean organized out-of-school-time activities such as classes, clubs, and programs held during after-school, summer, and weekend hours that meet with some regularity, are not mandatory, and "are characterized by structure, adult-supervision, and an emphasis on skill-building" (Mahoney, Larson, Eccles, & Lord, 2005, p. 4). These programs are distinguished in the literature from unsupervised individual or peer group activities that may also occur during non-school hours.

Organized out-of-school-time programs include large national programs such as Girl Scouts, 4-H, or 21st Century Community Learning Centers; municipal or county programs, such as San Diego's *6-to-6* or Boston's *After School and Beyond*, which usually meet in school buildings during early morning and after-school hours; and a range of community-based programs that meet in church basements, museums, storefronts, community centers and other settings.

In the last dozen years, an infusion of funds from the U.S. Department of Education, as well as many other agencies and private foundations, has put the spotlight on OST programs with regard to student learning and development. In the context of the Elementary and Secondary Education Act under the Clinton

and Bush administrations, both of which stressed testing and accountability, many funding agencies have come to evaluate the effectiveness of OST programs not through their traditional emphasis on child and youth development outcomes but instead by looking at school achievement and attainment records.

This change in emphasis from funders has led to a bifurcation in the OST community as well as the literature documenting the effectiveness of OST programs: Programs either emphasize “development” or they emphasize “learning” usually through measures of academic achievement. Seldom do they seek to elucidate the connection between the two. But Vygotskian perspectives suggest that one does not exist in the absence of the other: learning leads development, and development creates opportunities for learning. Broadening views of learning to understand it as entailing processes of being, doing, knowing, and becoming (see Herrenkohl & Mertl, in press) highlights the relationship between what is commonly thought of as development (being and doing) and what is commonly thought of as learning (knowing and doing), and unites them through the construct of “becoming” – where purposes, tools, knowledge, and identities are resources drawn upon in purposeful, change-oriented activity (Stetsenko, 2008). A fundamental question driving this dissertation is how OST settings can be structured to build on the strong developmental qualities of the setting, take into account the structural constraints, while at the same time engaging children in learning in the discipline of science.

In this chapter, to provide the rationale for undertaking this study at this time, I first describe the OST field writ large, identifying what the literature claims are the strengths, weaknesses, and potentials for children's learning and development. I then review the literature on science education programs in the OST setting.

What I find is that there is disagreement about the potential of the OST as a learning space, and that the literature on science learning in the OST setting is limited in scope and size. Questions about the validity and limitations of the OST literature are not new; there are many who have noted this before (Bodilly & Becket, 2005; Honig & McDonald, 2005; Kane, 2004). But the most frequent explanation of this state of affairs has been to cite significant methodological challenges caused by the inherent variability of the setting in terms of the duration and consistency of treatment (Halpern, 2006; Kane, 2004). Others have argued that there is a lack of adequate theorization of the OST setting as a learning space (Barber, Stone, Hunt, & Eccles, 2005; Honig & McDonald, 2005; Larson, 2000). In addition to these two reasons, I argue that the literature suffers from weak conceptualizations of both *learning* and *science*. Too often, as I will show, science is conceptualized as "facts to be learned" and learning is conceptualized as the successful reproduction of such facts. I argue that these conceptualizations are partly responsible for the conundrum in which the OST field finds itself now. While children may indeed learn "facts" related to science, the setting is not positioned to provide evidence of such learning unless the setting is transformed into a school-like space. At the same time, the

developmental conditions which characterize the setting (which I detail below, but which include low-stakes, non-judgmental, and relationship-centered patterns of interaction), and set it apart from school settings, support kinds of learning that may elude traditional measurement strategies developed for classrooms. Thus, traditional approaches to conceptualizing learning (developed in the context of schools) fail to adequately account for the OST learning setting. On the other hand, a transformative activist conceptualization of science and of learning addresses this conundrum through clarifying a need to position both science and learning as acts of agency and inquiry, rooted in the learner's desires to transform his/herself and his/her world in authentic (meaningful) contexts. It builds on broad views of learning as encompassing being, doing, knowing, and becoming. I will show how this approach can account for learning that capitalizes on, and indeed may depend upon, the developmental qualities of the OST setting.

2.1 What Is the OST Setting?

The OST field traces its roots back to the settlement houses in turn-of-the-19th-century urban centers. Early youth programs located in settlement houses offered children and youth a mix of skills, experiences, lessons, and social opportunities; for example: sewing, diction, or dancing classes. Despite this early emphasis on what was seen as assimilationist-oriented "know-how" for first and second generation immigrant youth, historically the OST field has been conceptualized as a developmental space, distinct from schools, attending to

children's intellectual, emotional, physical, and social well-being (Addams, 1910; Honig & McDonald, 2005; National Academies of Science, 2002). These views and approaches in particular expanded during the 1960s and 1970s as views on childhood and adolescence began to change and emphasize "positive youth development" over the existing deficit models that conceptualized adolescence as a deviant stage in human development (Lerner, 2002). Programs oriented towards positive youth development stress the ways in which children and youth, from all communities, possess positive psychosocial, intellectual, and emotional assets that need to be nurtured through intentional community and adult efforts and structures, such as the organized OST program. Mahoney et al. (2005) note that within this framework the OST field is particularly interested in addressing youth assets and capacities that are neglected by schools, but upon which success in school and society depends; these assets include, for example, self-efficacy, high expectations, adaptive behavior, resilience, and persistence.

Over the past decade, as the testing and accountability environment has begun to drastically affect the organization and experience of school life (Achinstein & Ogawa, 2006; Anyon, 2005), there has been a growing interest in the potential of organized OST programs to more directly support children's academic achievement. The federal investment in OST programs grew tenfold in the early 90s. With funding came not only increased scrutiny but a slate of expectations that children's school performances would improve if OST programs were effective. These developments have dramatically affected the OST field and

indeed are seen by many as a threat to its fundamental developmental power and potential (Halpern, 2006; Hull & Greeno, 2006; Nocon & Cole, 2006).

2.1.1 Developmental and Structural Properties of the OST Setting

The opportunities and challenges within the OST setting as a *developmental* environment have been well documented; they have been shown to build children's capacities to act in and upon the world (Halpern, 1999, 2002; Mahoney et al., 2005). Among the opportunities are: more flexible uses of time; socially supportive adult-child relationships; positive peer groups and role models; and low-stakes, intellectually safe contexts that encourage children to take on new roles and stances with respect to a wide variety of domains. These qualities of the OST setting can support an openness, readiness, and willingness in children to try new things, work with peers, and come to participate in social learning communities, using the cultural tools of particular disciplines (such as science) to participate, contribute, and realize the group's particular purposes. Thus, they can provide children with opportunities to develop new stances with respect to different subject matter or contexts.

In 2002, a consensus report was issued by the National Research Council and Institute for Medicine that asserted that community-based youth development programs expanded opportunities for youth "to acquire personal and social assets and to experience the broad range of features of positive developmental settings" (National Research Council and Institute for Medicine, 2002). This report called for both an expansion of such programs and an

increase in research and evaluation of program designs and effects for participants.

There are also well-documented *structural* constraints in the OST setting (Bodilly & Becket, 2005; Davis, 2002; Halpern, 1999, 2006). By “structural” I refer to the features of institutions that make them recognizably of the same field, including the institutional goals, settings, stakeholders, funding sources, timeframes, staffing, regulations, and other forms of underlying resources and schema that operate to shape the field and its member organizations (see DiMaggio & Powell, 1993 for a discussion of structures at the level of institutions and institutional fields; cf. Tyack & Cuban, 1995 for a discussion of school structures). OST programs have historically suffered from unstable funding, which limits their abilities to plan and build their infrastructure. They therefore frequently operate out of borrowed spaces, such as school cafeterias or classrooms, church basements, or libraries. This means that much time must be spent in gathering and transporting materials, setting up learning activities, unpacking, using and repacking materials. Thus the borrowed spaces can constrain the ability of OST programs to undertake long-term projects that require time and space for incubation of ideas or projects.

A second structural constraint involves staffing. Because the hours of operation are limited to a few hours per day after school and sometimes during weekend or summer hours, the job does not offer full time professional employment, and the positions tend to offer low wages. Low levels of staff training and high rates of staff turnover have been cited as problems that

challenge stable, experienced, and professional staffing of OST programs (Halpern, 2006; Sandel & Dobbins-Harper, 2007). There is no mandated credentialing of OST workers and opportunities for professional development are few (Coalition for Science After School, 2007).

A third constraint concerns regularity of attendance (see Nicolopoulou & Cole, 1993). Because the OST hours are also the hours when schools schedule sports events, parents schedule doctors appointments, children seek part-time employment, and all manner of activities take place that can not occur when school is meeting, attendance in OST programs tends to fluctuate significantly. Attendance is also affected by the voluntary nature of these programs. Parents are not obliged to send their children to OST programs, and children may have the option to attend or not based on their interests and other competing activities.

These structural characteristics of the OST setting affect the relative "stability" of these programs. This stability, or lack thereof, ranges from the (in)ability to undertake long-term planning at the organizational level to the (in)ability to maintain order and focus among the children within the activity setting itself. For this reason, programs are sometimes evaluated on their ability to resist "chaos." The NRC/Institute of Medicine consensus volume on OST programs specifically calls out "appropriate structure" as a feature of positive developmental settings. They define such structure as "limit setting; clear and consistent rules and expectations; firm-enough control; continuity and predictability; clear boundaries; and age-appropriate monitoring" (NRC, 2002, p. 9). The opposite characterization is defined as "chaotic; disorganized; laissez-

faire; rigid; overcontrolled; and autocratic" (NRC, 2002, p. 9). A lack of stable conditions can make it difficult to document teaching and learning. OST programs may be led by adults with limited subject-matter expertise, attended by children irregularly, and programmed in short episodic events. Even "high-end" OST programs that may specialize in particular subject matter, such as science camps at science museums or zoos, are subject to fluctuations in attendance that force programming decisions that may not be an issue in other more stable learning environments.

In summary, in general, the OST space is commonly acknowledged to be a highly supportive developmental space, at the same time it is subject to various structural constraints that threaten its stability affecting its capacity to plan and realize its goals with regularity and consistency. These qualities are both credited and blamed for the evidence or lack of evidence about the relationships between OST experiences and learning and development.

2.1.2 Learning and Development in the OST Setting

A number of studies of OST programs have been conducted over the past ten years to document children's learning and development in the OST setting, but the results have been deemed equivocal (Bodilly & Beckett, 2005; Honig & McDonald, 2005; National Research Council, 2009). There are two somewhat distinct bodies of research on the impact of the OST setting on participating children: one on "development" and the other on "learning." This bifurcation reflects not only who is conducting the research (psychologists or evaluators) but

also the two different directions in which the OST field is heading. Indeed, these different directions have led some to sub-categorize OST learning programs along lines such as “school aged care,” “youth development,” “extended day,” and “extra-curricular activities,” with extended day programs being more focused on academic outcomes than the other three (Miller, 2003).

2.1.2.1 “Developmental” Outcomes for Children in OST Settings

I define “development” as a dynamic and lifelong process of continuity and change with respect to one’s capacities (intellectual, emotional, physical, and social) to act in and upon the world. In their research compendium, Mahoney et al. (2005) cite evidence that participation in OST programs supports children’s negotiation of “the salient developmental tasks of childhood and adolescence” including reduced problem behaviors, heightened psychosocial competencies (such as self-esteem, collaboration, conflict avoidance, civic engagement), and educational attainment and achievement. Results are notably strong for children and youth from high-poverty and non-dominant cultural communities, who are disproportionately served by such programs (Heath & McLaughlin, 1993).

Many scholars in the OST field, particularly before the significant expansion of the federal investment in the OST field, have worked from sociocultural perspectives to study the ways in which OST programs help students develop psychosocial skills such as initiative, motivation, and persistence. Through efforts to bridge cultures between home and school, to offer leadership opportunities, to provide experiences with new materials, issues,

and contexts, OST programs have been shown to build children's resiliency (Benard, 1991), leadership (Heath & McLaughlin, 1993), and belonging (Pittman, 1991). Heath, for example, showed how participation in a theatre-based afterschool program led to expanded agency as exemplified by new forms of discursive practices, new approaches to problem-solving and the taking up of multiple roles within an authentic work (theater) context (Heath, 2000). She found that afterschool settings that provided students opportunities to take risks, contribute to joint efforts, take on new roles, and work side by side with adult role models expanded students' horizons while building their sense of accomplishment and value. McLaughlin (2001) found that underserved youth who had participated in OST programs developed life skills, such as self-efficacy, agency, and hopefulness that they brought with them into young adulthood. Notably, she found that youth who had high levels of attendance were twice as likely as others attending OST programs, and 15% more likely than youth not attending such programs, to "strongly agree" that they were persons of worth. She also found correlations between participation in OST programs and expectations about high school graduation and college enrollment. Additionally, the youth they surveyed were "significantly more likely to 'strongly disagree' with the statement that 'chance and luck' are 'very important' to getting ahead" than students not attending such programs (McLaughlin, 2001, p. 5). Larson (2000) studied OST programs to determine if and how they supported children's development of initiative, which he defined as constituted by high levels of intrinsic motivation along with high levels of "deep attention." Initiative, he noted,

drops off markedly as children go through the middle school years. According to Larson, initiative is associated with agency whereas a lack of initiative is associated with malaise. His study found that schoolwork correlated with low levels of intrinsic motivation, whereas “hanging out” correlated with low levels of “deep attention.” Structured voluntary settings, on the other hand, were associated with high levels of both of these facets of initiative. Larson’s study concluded that OST settings could be highly supportive of development, but that more rigorous research methods were needed to test models and outcomes. For more than two decades, Cole and colleagues have conducted a large number of studies of the Fifth Dimension, a computer-based collaborative learning program, underpinned by Vygotskian theories of learning and development, implemented in a wide array of afterschool settings (Cole, 2006; Nicolopoulou & Cole, 1993). Using a cultural historical framework, they have found, among other things, that students were able to complexify their problem solving and strategizing when their participation rates were high, consistent, and collaborative in nature.

In the field of identity development, scholars have examined how youth identities develop in activities and contexts supported by OST programs. The research of Barber et al. has found that OST activities allow children to "negotiate and formalize their identities" through both refining and publicly expressing them (Barber et al., 2005, p. 205). Following children in and beyond high school age, they found that these patterns carried forward and provided validation of social identities established during adolescence. Nasir and Hand (2008) have identified ways in which some non-school settings are designed to support the

development of what they call practice-linked identities (by which they mean identities related to and emerging in activity, rather than what they differentiate as more global or stable identities). Specifically, they note how a basketball program provided participants (a) access to the domain, (b) opportunities to take on integral roles, and (c) opportunities for self-expression in the practice. Polman (2006) investigated the relationship of youth identities and OST learning opportunities. He found that OST programs that intentionally built on identity resources that children brought with them to the program were successful in developing and expanding children's repertoires of practice. In particular, he documents the case of a youth with a "gamer" identity that is parlayed, through the OST experience, to expand to include identities and skills related to historical inquiry. (He also has a counter example where the program did not take into account a youth's existing identity resources.) Hull and Greeno (2006) looked specifically at the role that OST settings could play in supporting children's development of mathematics identities through providing experiences that employ mathematical practices and tools. Rahm (2007) followed three girls in two different science afterschool programs and found that their positive experiences in the OST programs reinforced their particular (and different) interests, identities, and life trajectories. Interestingly, this case showed how the OST programs could provide different meanings to different students; in this case, validating, for the three students, academic capacity, career ambition, and sense of self-worth, respectively.

Additionally, some developmental scholars draw on bioecological or ecological systems theory to investigate the ways in which OST programs support children's development across time and setting. Lerner and others have investigated the ways in which student engagement with community and civic issues develops a sense of values and individual power to effect change that translates to a "thriving adolescence" which he defines as being on the path to an "adult status marked by making culturally valued contributions to self, others, and institutions" (Lerner et al., 2003, p. 173).

In summary, the developmental literature is extremely promising in its examination and documentation of how powerful and supportive contexts can support children's overall well-being and development. However, the OST developmental literature falls short of directly addressing the issue of learning per se, especially subject matter learning. For example, the identity studies cited above are each grounded in different subject-matter experiences (physical education, history, mathematics, and science, respectively), yet none of them draw clear and theoretically guided connections between the documentation of identity development and engagement and learning in and through subject matter. Returning to the reciprocal relationship between learning and development – with development defined as the increasing capacity to act in and upon the world, and learning defined as a process of appropriating, using, and transforming cultural tools, and with each arising from and also creating conditions for the other – I posit that the development described in the studies named above emerged through children's engagement with and appropriation of

cultural tools (i.e., “learning”) associated with one discipline or another. Indeed, McLaughlin has noted (quoted in an interview found in Hutchins, 2009) that developmental activities always entail subject matter learning: For example, planning and creating an historical mural involves not only design, collaboration, and self-expression (which may lead to developmental outcomes such as a greater sense of self, community, and self-efficacy) but also entails pursuing, learning about, and ascribing meaning and values to the reading of history (encompassing cultural tools associated with the subject-matter discipline of history). Learning understood broadly, as processes of doing, knowing, being, and becoming, places the developing self at the center of learning. But to date, most studies have measured and documented effects such as (for instance) self-efficacy without relating it to the material grounding in learning about history. In a compendium of the OST research presenting recent “conceptual, empirical, and policy-relevant advances” (Mahoney et al, 2005) not a single chapter addresses subject matter learning. Nor does the National Research Council consensus report (2002) on community-based youth development programs address subject matter learning per se in any of its chapters.

It is more than reasonable to argue that OST programs should not use school test scores or even school outcomes to assess the contributions of non-school settings. However, the failure to establish, from a theoretical as well as practical perspective, the connection between learning and development, and to reconcile the two bodies of OST research, has, I posit, fueled the incursion of the

school agenda into the OST space. This becomes problematic for children whose developmental spaces are coming under siege.

2.1.2.2 "Learning" Outcomes for Children in OST Settings

Pressured by policymakers and funders, a separate body of research is being generated that looks almost exclusively at "learning," usually as defined by performance on standardized tests. This literature does not typically take into account the developmental goals and structures of the OST setting and, to date, the results of these studies are mixed. While many overview papers cite the existence of "a growing body of evidence" supporting positive learning correlations or results (Afterschool Alliance, 2006; National Institute of Out-of-School-Time, 2003), others have found no connection between OST programs and student learning (e.g., Huang et al., 2004; James-Burdumy, Dynarski, Moore, Deke, & Mansfield, 2005; Kane, 2004). A multi-year study of the LA's Best program has been cited by Kane (2004) and Bodilly & Becket (2005) as an example of a failure to find learning, and cited by Miller (2003) as an example of links that have been made between OST participation and learning.

A recent National Research Council (2009) consensus panel volume on learning science in informal environments cites more than two dozen afterschool/OST youth programs that have documented learning outcomes in the six areas that the volume considers: interest development, conceptual understanding, scientific reasoning, reflecting on science, scientific practices, and identifying with science. These studies, all of which were published after 1998,

vary in their methodologies ranging from use of observations and focus groups to quasi-experimental methods involving comparison groups. In general these studies show positive outcomes for children (Huang et al., 2004; McLaughlin, 2001; Miller, 2003); some of them have shown that interest and commitment to science persists over time (Gibson & Chase, 2002). However the report also acknowledges that there is a lack of a synthesized literature that can make strong claims about the contributions of OST settings to science learning (NRC, 2009, p. 175).

This finding mirrors the earlier, 2002, finding from a different National Research Council consensus panel on youth programs (which was not specific to science learning). This volume specifically cited the lack of experimental studies in its finding that there is insufficient evidence of impacts of OST programs on children. Against this background, and with the expansion of the U.S. Department of Education investment in the OST field during the 1990s, a number of large-scale, quasi-experimental studies were undertaken in the early 2000s. These studies sought to establish links between OST participation and school performance, and relied on school-based standardized tests as the main measures of such impacts. A number of them also looked at developmental outcomes, such as conflict resolution or self-efficacy. For example, a study of a municipal Los Angeles afterschool program, LA's Best, found correlations between regular and sustained attendance in the program and higher attendance at school, which correlated with lower drop-out rates as well as drops in juvenile crime (Huang, 2005, 2009). A study of the national 21st Century Learning

Community Center program, that randomly assigned students to participate in federally funded OST programs or in no programs found no differences in students' academic performances, and indeed found treatment groups were more likely to engage in negative behavior (James-Burdumy et al., 2005). Kane (2004) in a meta-analysis of four OST program evaluations (Beacon in San Francisco, The After School Corporation in New York, 21st CCLC, and Extended-Service Schools Initiative) found that none of them could claim statistically significant impacts on academic achievement.

A RAND Corporation study, in a review of the literature, asserted that the quality of the evaluations was thin, that causal claims could not be made based on the research methodologies used, and that the claims of the field were overreaching (Bodilly & Becket, 2005). This report found that even the programs with the most rigorous (controlled) evaluation designs showed "at best modest positive impacts on academic achievement, academic attainment, and social behaviors such as reduced drug use or pregnancy" (RAND Corporation, 2005).

A recently published study found statistically significant links between afterschool participation and improved student test scores in mathematics (Vandell, Reisner, & Pierce, 2007). But in an editorial exchange in *Education Week*, when they were challenged about the lack of change in literacy scores (DiPaolo, 2008), the authors responded that they would not expect to see academic gains from the incremental time spent in afterschool programs, and instead attributed the changes in mathematics test scores to changes in student study habits and social behaviors encouraged by their OST participation (Vandell

& Reisner, 2008). This point had been mentioned but downplayed in both the study's executive summary and the professional journal that reported about it. The editorial exchange points to the dichotomies that have solidified around development and learning in the OST setting: Academic learning is privileged by the policy community, developmental goals are undervalued, and the connection between the two is usually ignored.

In summary, the literature on "learning" in the OST setting is limited, largely because "learning" has been narrowly defined, by both the research and policy communities, as academic achievement documented by standardized tests scores, rather than more broadly as entailing processes of doing, knowing, being, and becoming. The latter view is necessary to conceptualize and investigate the relationship of learning and development in the OST setting.

Summary: A Need to Synthesize Development and Learning in OST Settings

Honig & McDonald (2005) have ascribed the equivocal nature of the OST learning research to weak conceptualizations of the relationship between afterschool programs and learning. With respect to the development literature, Larson (2000) and Eccles (2005) have also called for the need to better theorize the OST space.

There is a need to synthesize, from a principled theoretical stance, learning and development in the OST setting. This dissertation adopts a transformative activist perspective on learning and development that understands them to be fully implicated with one another, in order to investigate how science

can be positioned in the OST setting to support both. Learning leads development. Learning is grounded in the material world of which the academic disciplines are constituted. What is needed is a theoretically principled analysis of the OST setting that reveals how practices of the discipline are positioned such that the well-documented developmental outcomes are made possible, at the same time revealing how the developmental and structural conditions position science in the OST setting. Better theorization of these relationships can inform design, implementation, and assessment of OST programs. In this dissertation, I seek to lay the groundwork for such studies by noting and relating, from a transformative activist stance, the different features of the OST setting that must be accounted for in efforts to document and test connections between development and learning in subject matter areas such as science.

A transformative activist stance understands learning and development to be fundamentally activist projects of making change in one's self and one's world. I, myself, seek to take an activist position through the work of this dissertation with respect to how we as educators, funders, and policymakers can make OST settings more developmentally and conceptually powerful for children. A transformative activist stance conceptualizes a powerful OST setting as a site where children are provided the opportunities and tools to make change in themselves and their world. Science, understood as a cultural practice that has been developed historically for humans to take action in and on the world, may offer particularly rich opportunities to advance this vision of a powerful OST space for children's development and learning. Conversely, OST settings may be

particularly rich sites for engaging children with science, given the common grounding of inquiry and agency that one finds both in science as a cultural and historical practice and in the OST setting as a developmental space. It is this theoretically principled stance that I will take towards the problem, the setting, and the data discussed in this dissertation.

2.2 What Does Science Look Like in the OST Setting?

The expansion of OST programs has occurred at a time of renewed attention to science education. A series of policy papers linking economic workforce issues with science education has propelled new investment in science education, including in the OST setting (Business Roundtable, 2005; National Academies of Sciences, 2005). [3] As noted above, in the last five years, several major new national funding initiatives, numerous private foundation efforts, and a range of professional associations have begun to advocate for increased science learning activities in OST settings (Coalition for Science After School, 2007).

Science in OST settings takes many shapes and sizes (Bevan & Michalchik, in press). Some programs are offered by science-rich cultural institutions like zoos and science museums – these programs may range from

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[2] Workforce arguments dominate the policy literature, but there are other reasons to support expanding access to science education ranging from Deweyan ideas about supporting a democratic society to conceptions of science as a critical part of the Western humanist legacy as well as the modern technological society (Osborne, 2000).

specialized afterschool classes to intensive summer camps. Other science programming is offered as part of existing youth development programs such as Girl Scouts, and may constitute a special 6- or 10-week unit. Others are multi-year sustained immersive science programs, such as Project Exploration in Chicago or the Youth Exploring Science program in St Louis. OST programs have been shown to be productive and supportive for science learning. In an overview, Hussar et al. note that "after-school science programs can improve students' attitudes towards science; increase their scientific knowledge and skills; and, in some cases, raise grades, test scores, and college attendance. Participation in science after-school and summer programs has also been correlated with increased likelihood of selecting science-related college majors" (Hussar, Schwartz, Boiselle, & Noam, 2008, p. 8).

There is no meta-analysis of existing OST science programs, and surprisingly little about them has been published in mainstream education journals like *Educational Researcher, Science Education,* or *Journal of Research in Science Teaching*.[4] While there is an extant and slowly growing body of peer-reviewed literature on learning in museums (e.g., Hooper-Greenhill, 2007; Leinhardt, 2002), most of this is concerned with either families or children engaged with exhibits during unstructured visits, or with school field trips, which

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[4] In 2009, a national database of such programs was created by the Coalition for Science After School and within weeks over 5,000 programs had been registered. In 2007, NASA commissioned a report that involved a scan of the field, and identified several dozen science based youth programs (Walker, Wahl, & Rivas, 2005). These lists, however, have not been subjected to analysis.

are extensions of the school day and classroom. Little of it addresses organized OST programs – afterschool, weekend and summer classes and camps – such as are considered in this dissertation. The NRC (2009) *Learning Science in Informal Environments* volume therefore drew mostly on evaluation reports to note documented outcomes of student learning. In general, these outcomes can be broken down into three different sets of constructs, one dispositional (including interest, motivation, and career interests), one developmental (mostly through the prism of identity), and the other more specific to the subject matter of science (including inquiry process skills, concepts, and the nature of science).

Development of Science Interest and Motivation. Many programs have documented changes in children's interests, attitudes, and senses of self (particularly vis a vis career interest) with respect to science (Gibson & Chase, 2002; National Research Council, 2009). These studies are almost always done through self-reports in interviews or surveys. For example, an evaluation study of the Girls, Inc. program Operation Smart, in which girls work with scientists to engage in a wide range of hands-on science investigations, found that participating girls "demonstrated an increase in their confidence, competence, and comfort in science, math, and technology" (Allen, 2001). Fadigan and Hammrich (2004) found that high school girls participating in an afterschool science program, Women in Natural Sciences (WINS), were more likely to choose careers in health, medical and science related fields than other career choices. Markowitz (2004) found that a summer camp for high school students had long-term impacts on participating youth, who reported that their participation

had led to their taking advanced science classes in high school and their pursuit of science degrees in college. Few of these evaluations approach their data from an explicit theoretical stance, but instead note features of the programs, such as access to laboratory equipment, hands-on investigations, in some cases family involvement, or access to scientists, which they credit as shaping the experiences. Such features repeatedly emerge in the literature on OST science, and may reflect the power of authenticity of purpose and setting (including the cultural and historical trajectories of the professional and academic fields to which students are exposed) in sparking and sustaining student participation in science; however, unguided by theory, the data collected in these studies do not specifically assess for these connections.

Conceptual Development in Science. Fewer programs have documented ways in which students have developed conceptual understanding in science. The NRC (2009) volume on informal environments notes that those that do generally refer to standardized test scores and also often involve integrated efforts with school programs. Unpublished evaluations of some programs have tested for content knowledge, generally using pre and post surveys attuned to the program treatments. For example, an NSF-funded year-long middle-school engineering program, called SPARK!, based at the University of Pennsylvania, found that participating children developed their conceptual understanding of the design-engineering process, based on comparison of pre and post concept maps and short answer tests (Bevan, 2010). A U.S. Department of Education-funded Upward Bound project based at the Miami

Science Center, engaging low-income, first-generation, immigrant students in four years of science activities with local scientific research agencies, found that 91% of its graduates continued on to college, and 59% of these students majored in STEM (science, technology, engineering, and mathematics) fields; 95% of the students persisted through college (Juarez, 2009, personal communication).

Most of these programs are science-intensive, many based at informal science institutions (like zoos or museums), or funded through research grants. Less is known, because less has been done, about science in the typical OST setting, where staffing and resources may be thin. Moreover, most of these studies fail to specify the theoretical grounding for the program design, the nature of the participants, and the details of the treatment. They therefore indicate that learning science in OST settings is possible, but they do not provide the basis for more systematic or generalizable investigations of how and when and for whom OST science learning opportunities can be made more accessible and impactful.

Youth Development of Identity and Agency in OST Science. There are a small number of studies that have taken strong theoretical perspectives to frame their inquiries into the OST science program as a context for development. For example, one study used a transactional-cultural historical activity theory (CHAT) framework to examine a group of middle school children in a zoo-based OST program (Douglas & Katz, 2009). Students learned about animals in the zoo and then worked together to create a website called *Animal Rescuers* which highlighted four different animal species and the environmental conditions that were impacting their well-being. The authors of this study found that the agentive

affordances of the OST setting (such as participation structures that included multiple communication channels and mixtures of web-based and first-hand research) and the authenticity of the tasks, including the collaborative nature of the activities, encouraged students' commitment to the project, development of understanding and affiliation with animals, and their development of efficacy particularly with regard to issues around environmental stewardship. Another study by Furman and Barton (2006) used a sociocultural perspective emphasizing student voice as a process and product of identity formation, as well as theories of funds of knowledge and social capital, to study how students developed and activated their voices through the process of creating short video documentaries on science. Children were allowed to choose any topic they desired, as long as they could explain how it related to science. The two boys who were the subject of the published research chose to create a video on animals. This study found that afterschool programs that provided room for children's voices to develop and emerge through creative productions in the context of science gave them access to new forms of human, material, and social capital. This newly acquired capital helped the children "to reposition themselves within the school context as knowledgeable, capable, and popular" (Furman & Barton, 2006, pp. 686-687). Thus the study positioned science as a context for identity formation, and suggested that positioning science in this way made it more accessible and engaging to children who might otherwise have been disaffected from science. A study by Dana Fusco (2001), using sociocultural perspectives on learning and action research, found that an afterschool project

that was designed to involve children in transforming a vacant city lot into a garden was successful in engaging the participants in the content and processes of science due to the relevance and authentic nature of the purpose and product related to their effort. Specifically, she found that the project's relevance emerged because the project "(a) was created from participants' concerns, interests, and experiences in and outside science, (b) was an ongoing process of researching and then enacting ideas, and (c) was situated within the broader community." (Fusco, 2001, p. 873).

Although none of these studies make strong claims about "learning" (i.e., relating their findings about development to children's expanded subject matter experiences), they come to common conclusions that effective OST programs are rooted in meaningful and personalized purposes and participation structures that support children's inquiries, agency, and identity development. Each of these scholars has their own particular way of approaching constructs like agency, identity, and inquiry, but they share a common grounding in sociocultural and even cultural-historical perspectives, viewing identity as a dynamic, context-dependent representation of self; and agency as the capacity and capability to take initiative in matters of consequence to the self. In each of the cases, children were provided opportunities to exercise agency and inquiry in the service of making change in contexts of consequence to themselves.

However, the richness of the learning experiences described in these studies, while compelling, and important for contributing to understanding about learning and science learning, is not what I encountered in the course of

collecting data for this study (nor does it match my prior experiences in many other OST science programs: much of what I have seen in non-National Science Foundation funded projects is much more recipe-like and pro forma that what is described in these OST studies). Importantly, none of the studies I have found and cited here address or acknowledge the structural constraints that typically affect and shape OST programs as documented in the literature cited earlier. They provide accounts of learning that extend theory developed for the classrooms to the OST setting, such as “funds of knowledge” or “third space” or other frameworks. They thus show that, when the conditions are right, powerful agentive learning can happen in the OST setting as well as in the classroom setting. But without taking into account the structures and conditions common to the OST setting, I believe that these studies provide important but incomplete accounts of learning and development. They are important for the insights they provide on children and on learning. They are incomplete for what they omit as to the larger political and educational landscape that is organized or not to provide such experiences to children at a larger scale.

In contrast, Cole and colleagues, who have been testing a CHAT-based afterschool (non-science-specific) program called the Fifth Dimension for over two decades, have written about the ways in which the structural constraints of the institutional settings of afterschool directly impinge on the learning activities and their learning and developmental outcomes. For example, they have noted that attendance patterns (regularity and duration), patterns of interaction, and organizational culture all operate to shape children’s experiences of the exact

same learning activities across different settings (Brown & Cole, 2002; Nicolopoulou & Cole, 1993). Invoking CHAT, they have found that varying organizational cultures (for example, comparing a library's afterschool program to a youth development organization's afterschool program) create different systems of meaning for children participating in identical activities in different settings. These different meaning systems lead to different learning outcomes.

In summary, there are different approaches to documenting science in the OST setting, reflecting different conceptions of both learning and of science. The dispositional literature generally relies on methods such as interviews and self-reports, or retrospective accounts of science experiences in OST settings. The conceptual development literature generally relies on test scores. The developmental literature generally fails to make explicit links between conceptual learning and development. And few of these studies include complete analyses of the structures and conditions that are inherent or common to OST programs and that may affect or organize the possibilities for learning activities.

2.3 Summary: Need to Better Theorize and Specify Science Learning in OST

The literature on OST and on STEM in OST is largely split between development and learning. The measures of learning are inadequate, relying mostly on test scores designed for K12 schooling. In the face of growing interest and investment, the OST field is pressed to articulate its value as a learning space and as a site for learning of science. But the field remains underspecified.

While certain things are assumed (such as the rich developmental conditions and the obstructive structural constraints) they have not been systematically linked to learning and development in these settings. In the absence of clarity of purpose for both learning and science in the OST setting, the field may well be pushed towards the existing school model of science curriculum, instruction, and assessment. This is already the case in the field of reading literacy, and increasingly it is the case for mathematics.

This situation is troubling for three reasons. First, as noted above, organized OST programs serve high numbers of students from high-poverty and non-dominant cultural communities, children for whom school science has manifestly failed. There is no reason to suppose that moving more school-like science into OST settings will not have similar results. Second, the developmental power of the OST setting — in such areas as self-esteem, self-efficacy, peer relationships, and academic achievement — emerges in settings that have explicitly adopted non-school-like strategies. Yet few of the assessment models take these structural differences into account beyond superficial adjustments to curriculum reflecting more fragmented uses of time or the lack of storage space, etc. Third, the growing literature that shows the possibilities for learning in the OST setting, apparently when the structures, conditions, and pedagogies are aligned to do so, is tantalizing but not necessarily representative of common realities for most children.

There is a pressing need to better conceptualize, theorize, and document the OST setting in ways that take into account the structural and developmental

properties, and show how they create conditions that work for or against science learning. This dissertation is an attempt to show how learning and development are implicated with one another in the OST setting, and how the power and potential of OST science programs emerge from a confluence of the structural, developmental, and conceptual affordances of the setting.

Chapter Three

Theory: Science, Learning, and Learning Science

In this chapter I discuss the theoretical lenses I bring to my work. I do this by addressing three issues salient to my central research question – How is the OST setting positioned to support children's engagement and learning in science? The issues are: (1) What is *science?* (2) What is *learning*? (3) What, then, does learning science look like? I first provide some historical perspective on how different scholars and theoretical schools have approached these questions, showing how a transformative activist stance, the lens I will use in my analysis, emerges from, responds to, and differs from this work. Specifically, I show how this lens focuses my analytical eye on instantiations of learning as goal-driven acts of agency and inquiry undertaken in authentic contexts to achieve matters of consequence to learners. In other words, using this lens means that I do not identify learning as (1) the proficient reproduction of knowledge (which I might do if I were adopting traditional behaviorist views of learning), nor do I identify it as (2) the proficient participation in existing cultural patterns of interaction (as I might if I were adopting traditional cultural-historical views of learning, particularly as they have been developed in the American academy). Rather, I view learning as including proficient uses of knowledge and participation in cultural practices but always driven by the development and pursuit of subjective, and socially-situated, acts of agency undertaken for consequential purposes. I then discuss what the use of such a transformative

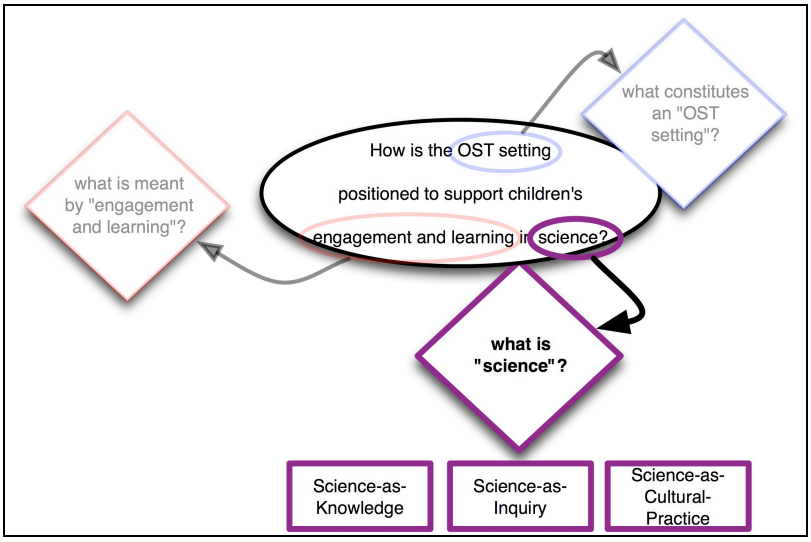
activist lens suggests will serve as evidence of learning in the context of OST science programs. The purpose of this review is to situate the transformative activist lens, which is a developing theoretical perspective, in the established sociocultural theoretical literature, highlighting what new elements are essential to analyzing learning in OST settings, in the context of science. In Chapter Three, I also explicate, and later draw on, bioecological theory as a useful complement to a transformative activist stance, because of its emphasis on the choices and actions of adults in supporting children's learning and development. This theoretical view is incorporated into my identification and analysis of particular constructs relevant to design and implementation of educational programming in the OST setting, as I will describe in Chapter Four.

3.1 What is Science?

Much has been written about the ways in which traditional science education presents science as a series of fragmented, decontextualized, and stable truths (DeBoer, 1992; Lemke, 2001; Roth & Barton, 2004). The "scientific method" which portrays science as an orderly, rational, fixed sequence of actions and analysis is an apt model for this version of science. In 1962, this model of science was effectively upended with the publication of Kuhn's *The Structure of Scientific Revolutions* (1962/1996) which revealed both the iterative and imaginative sides of science, as well as the ways in which scientific paradigms are historically bound and operate to filter both observation and understanding. A raft of critical and postmodern critiques of science followed (e.g., Haraway, 1988;

Harding, 1998; Latour & Woolgar, 1986). However, despite this expansive body of work, science-as-fact, or science-as-knowledge, remains the dominant way science is taught and tested in the U.S.

Figure 2. What is Science?



Science-as-knowledge perspectives are concerned with how children can most efficiently and effectively acquire facts or conceptual knowledge structures. “Transfer” of these facts – using them in different contexts – is seen as proof that knowledge acquisition, or learning, has occurred (Anderson, Reder, & Simon, 1996). Science educators in this tradition, which includes cognitivism and behaviorism, and associationism before that, design and test opportunities for individuals to exercise, master, and refine different tasks or responses. These tasks are usually undertaken in isolation from the larger societal or real world context in which they might later be deployed, and often in isolation from other

learners. Educators working from a science-as-knowledge perspective might argue that the OST setting provides additional time for children to exercise specific tasks related to the acquisition of science facts or conceptual knowledge structures that are part of the school science curriculum.

This view of science education has come under a stinging critique from many scholars working from a sociocultural perspective. Alternative views to science-as-knowledge, harkening back to Dewey (1916), might be described as science-as-ways-of-knowing, or science-as-inquiry. Educators working from this perspective design inquiry-based science learning activities around processes of working with children to generate questions, devise experiments, collect data, develop effective means to represent and communicate the data, analyze, draw conclusions, and subject results to peer review. Science-as-inquiry has rippled through U.S. science classrooms for over a hundred years, ebbing and flowing but never firmly taking hold. Reform efforts in the 1990s attempted to reposition classroom science as processes and products of inquiry (American Association for the Advancement of Science, 1993; National Research Council, 1996; Olson & Loucks-Horsley, 2002), but this effort was undermined by concomitant developments in the high-stakes assessment and accountability movement, which stressed factual recall across the curriculum. Nevertheless, work in science-as-inquiry has continued. Research oriented to science-as-inquiry, which encompasses both cognitivist and culturalist approaches, investigates the ways in which instruction can support children's understanding of how scientists use models or inscriptions to understand science (e.g., Lehrer, Schauble, Strom, &

Pligge, 2001), how they build arguments from evidence (e.g., Reiser et al., 2001), and how to support conceptual change through processes of inquiry (e.g., Kalchman, Moss, & Case, 2001; Vosniadou, 2008).

Yet as Eisenhart and others have shown, underpinning reform-based science-as-inquiry efforts are assumptions about science that still isolate it from its cultural and historical context (Eisenhart, Finkel, & Marion, 1996; Roth & Barton, 2004). Inquiry becomes a set of processes used to construct understanding about natural phenomena, but the meaning and value of the phenomena – in other words, the fundamental social purposes of undertaking inquiry – are not addressed.

Working from traditions of critical theory, activity theory, and critical pedagogy, a third school of researchers emphasizes science as a set of situated practices that are shaped by institutional, social, and cultural norms. As such, these views position science as cultural and embodied ways of knowing, doing, and being (Herrenkohl & Mertl, in press; Roth & Barton, 2004; Tobin, 2006). Mirroring the historical development of scientific inquiry, classroom inquiry does not happen independent of a meaningful and authentic context. Research undertaken within this model starts with grounding scientific inquiries in authentic contexts of consequence to children, such that inquiry is undertaken with purpose and agency. This research includes exploring the everyday nature of science (Bouillion & Gomez, 2001; Fusco, 2001), the gendered and classed nature of science (Brickhouse, 1994), and the socially and culturally mediated science classroom (Lemke, 1990; Tobin, 2005). These researchers examine the

ways in which science can be made more meaningful through the deployment of children's cultural resources and schemata. Such perspectives can lead to the design of science learning activities that are embedded in larger complex problems that children address over time (see, e.g., A.L. Brown & Campione, 1998).

In summary, there are competing models of what science is (or can be in the classroom): one is fact-based, another is inquiry-based, and another is cultural practice. In a sense these models are nested. Fact-based science focuses on key concepts. Inquiry processes focus on the use of key concepts. Cultural practices focus on the purposes and contexts for the uses of key concepts. But the representations of science are not simply nested. They also span a continuum of static versus dynamic, of universal versus contextual conceptions of the nature of knowledge and knowing.

A transformative activist stance would position science as a cultural tool, developed historically to achieve meaningful purposes, and introduced to children as a tool for them to achieve transformations of themselves and their worlds. Such a perspective positions science as always dynamically changing in relationship to cultural and historical contexts. This view would take into account the ways in which science might be introduced and perceived as a tool to advance (transform) a child's academic or socio-economic status (through pursuit of careers in science) as well as a tool that can be used to make changes in one's world (such as through investigating patterns of water quality and disease in a community). Thus, it is not whether science is fact, process, or

practice – it is all of these things – but how it is meaningfully presented as a human endeavor and employed, in a particular context for particular children, for consequential purposes; that is the question that a transformative activist stance would ask.

3.2 What is Learning?

In contrast to transmission models of teaching and learning – where learning is understood to be the acquisition of knowledge, independent of context – I focus here on learning as a sociocultural process. I adopt a transformative activist stance in my analysis, which means that I attend to how programs are designed to support student agency and inquiry into matters of consequence, because it is through such agentive acts that learning (and development) are supported. It is important to note that a transformative activist stance, developed by Stetsenko (2008, 2009, 2010), operates not simply as an analytical construct for explaining a given event or sequence of events, but rather proposes a psychological mechanism that explains individual ontogenetic development and how it relates to (is forged in and also transforms) sociocultural development (that is, development of culture and of society). It is an elaboration of Vygotskian views of how the appropriation and mastery of cultural practices drive development, explaining how individuals are drawn to, partake in, and expand such practices without denying individuals their subjectivity, or without glossing over the open-source and dynamic nature of the sociocultural plane, which have

been critiques of cultural-historical theory from both within and without the school of thought (see for example Holland et al, 1998).

Following Vygotsky, in this dissertation I define learning as a process of appropriation, use, and transformation of cultural tools and practices. According to scholars working in the traditions of Vygostky, learning is the central mechanism for human development. In this view, children are inducted into historical and cultural endeavors and practices of a society, introduced to a variety of cultural tools entailed in those endeavors and practices, and challenged to take up, master, and ultimately adapt and transform these tools, endeavors, and practices. This process advances the child's ontogenetic development, and in turn, through participation (cultural reproduction) and contribution (cultural production), sustains, advances and transforms social and cultural practices in their communities.

A critical element of this conception of development and learning is that activity is always driven by goals and motives. The cultural and historical goals within a given social group create a framework for different cultural practices. The individual goals and purposes that drive the learner to engage in and take up these practices are culturally, socially, and historically situated and shaped; they both propel individuals' participation and learning and operate to transform societal goals over time. Such a view of learning is fundamentally change-oriented, or transformative. Tools, practices, and endeavors are taken up as the means by which individuals and social groups can achieve the transformations they seek. Although this transformative aspect of development, spanning

individual and sociocultural, was always embedded in the theoretical contributions of Vygotsky, it has not been fully appreciated or explored in the context of the American academy's work with Vygostkian theory, and does not therefore show up in much of the research and writing that invokes Vygotsky and the cultural-historical school.

Cultural-historical views of learning were introduced into the American academy with early translations of Vygotsky's *Thought and Language* in the 1960s, and began to develop critical mass in educational research in the 1980s and 1990s as the works of Vygotsky and of the activity theorists who were his heirs, such as Luria and Leontiev, became widely disseminated (see Forman, Minick, & Stone, 1993; Gallimore & Tharp, 1990, Moll, 1990). Seminal works by American cultural-historical activity scholars focused on issues of participation in tool-mediated cultural and social activities (e.g., Cole & Wertsch, 1997); the movement from novice-to-expert practice (e.g., Lave & Wenger, 1991); and the social contexts, especially through person-to-person interactions, in which learning and development occurred (e.g., Wertsch, 1991). These views did not attend as much to issues of agency, purpose, or meaning, as they did to notions of collectivity and social interaction, stressing the cultural and social nature of human development and learning. These scholars made an important and radical break with cognitivist and other learning scholars who continued to conceptualize knowledge, the mind, and learning as occurring largely independent of context, including the social contexts involving interactions with others. As such, the emphasis on interdependence and collaboration in this first wave of cultural-

historical scholarship in America reflected values and concerns of an academic generation that came of age during the social upheavals of the 1960s; much as the historical revolutionary era in which they were first developed in the USSR fundamentally shaped Vygotsky's work, ideas, and purposes (Stetsenko & Arievitch, 2004). But this first wave omitted developing particular lines of argument, such as the critical role of agency in learning and development.

From within sociocultural perspectives, critics argue that early American cultural-historical theory scholarship, in stressing the social nature of development, failed to fully account for subjectivity (e.g., Holland, Lachicotte Jr., Skinner & Cain, 1998; Roth et al., 2004).[5] Additionally, and related, it has been argued that early cultural-historical theory scholars did not fully account for the role of agency, power and resistance as drivers of both individual and sociocultural development (Diamondstone, 2002; Litowitz, 1993).[6]

Within an educational context, cultural-historical theory traditions generated important accounts of sociocultural activity, but they explained neither

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[5] For example, many of the early studies in the U.S. focused on studies of collective, distributed, and situated cognition. These studies showed how reasoning, mathematics, and cognition emerged from the practical and material contexts of activity, such as the quantities and forms in which milk bottles were crated or candy was bundled. Others of these studies showed how individuals came to participate, over time, in adult social practices such as tailoring or weaving, through the gradual appropriation of tools and moving in from the peripheries towards the center of social life and production (e.g., Lave & Wenger, 1991; Rogoff & Lave, 1984; Saxe, 1988).

[6] An exception is Marshall's account of butchers, which revealed, at a communal but not at a subjective level, how power could operate to privilege and sequester expertise and thus impede learning, as in the case where the apprentice butchers were not given visual or physical access to more advanced butchering tools and practices (Marshall, 1972, cited in Lave & Wenger, 1991).

the subjectivity of experience in classrooms nor the ways in which social governing bodies responsible for those experiences could track progress at the level at which they were accountable to their constituencies, i.e., the individual child. This may be due to a fundamental tension between the education policy context of schools, which are ultimately accountable for an individual child's achievement, and theoretical perspectives that reject a conceptualization of knowledge as a property of the mind, and of learning as a process of the individual, and of education occurring independent of context. But, at any rate, this gap made it difficult for educational systems to incorporate cultural-historical theory, as a developmental theory, into much of its day-to-day practices. Few studies were done that tracked individual development and learning (in social context), and little was done in the domain of assessment (with work on dynamic assessment being a notable exception)[7]. Instead much of the early educational cultural-historical theory literature focused on language and literacy development, classroom discourse, the concept of the zone of proximal development (see, e.g., Forman et al., 1993; Moll, 1990), and in explicitly locating individual agency in the context of social configurations (Palincsar & Brown, 1984; Wertsch, Tulviste, & Hagstrom, 1993). As such, this early scholarship did not fully address a lingering theoretical gap between individual development (or ontology) and social and cultural development. This gap was particularly troublesome in the U.S., where

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[7] In the last decade there has been more work done on assessment from sociocultural and situated perspectives, but little of this has yet translated to classroom or policy settings (Lidz & Gindis, 2003; Moss, Pullin, Gee, Haertel, & Young, 2008).

prevalent ideologies (reflected in schooling, testing, as well as other aspects of society) emphasized individual development and achievement over social development. Stetsenko (2008) has argued that this gap allowed neo-nativist and cognitivist conceptions of human development to continue to hold sway in classroom and educational discourse despite the major accomplishments of the first wave of cultural-historical theory scholarship.

Building from a conceptualization of development and learning as rooted firmly in goal-oriented, tool-mediated activity, and incorporating critical and feminist perspectives into cultural-historical theory, Stetsenko (2008) argues that the ontological gap between the individual and the sociocultural is closed when one understands that the driving force behind taking action in the world is not merely to participate in social and cultural activities, but to make change in one's self and one's world. Such a *transformative activist stance* predicts development of both person and society through the agency of the person-in-society. A transformative activist stance sees development occurring not merely through "participation" (which can be undertaken in many modalities, including resistant, rote, or coerced) but through acts and activities involving "contribution." Thus, a transformative activist stance understands learning and development to always entail directionality and meaning, as well as subjectivity and collectivity (Stetsenko, 2008, 2009, 2010). This view of learning and development is consistent with the writings of Vygotsky and his colleagues, and brings to the fore a critical dimension of learning that has been overshadowed by much of the American cultural-historical theory work: namely subjective experience in social

contexts. In short, the individual is forged in society, and society is forged through the agency of individuals. Cultural-historical tools are the means through which individuals engage in social-cultural activities, and also the products of this engagement. Agency becomes a central driver of development, of both individual and society, in this cultural, historical, and social context.

3.2.1 Subjectivity: Being, Doing, Knowing, and Becoming

How does situating the individual within the social, and understanding how individual agency arises from and also contributes to development of the social plane shed light on educational program design and research? A move towards a transformative activist stance requires that attention be paid to the ways in which learners are invited, engaged, and supported to find and create meaning in the work that they do. In the context of science education, this means moving beyond knowing and doing science, to including ways of being and becoming in the context of science.

To put this into historical perspective, it's important to note that the relationship between *knowing* and *doing* science has been well detailed in the constructivist literature (see, e.g., Fosnot, 2005; Minstrell, 2000). While doing science is seldom tested in school, and therefore is easily marginalized in the classroom, in principle it is commonly accepted that doing science (investigating, testing, etc.) is important. As noted above, such constructivist inquiry-based approaches are found throughout the major science education policy documents (e.g., American Association for the Advancement of Science, 1993; National

Research Council, 1996; Olson & Loucks-Horsley, 2002). What is less acknowledged in the mainstream science education research and policy is the way in which *being* and *becoming* are also equally implicated in science learning. The critique of the Standards movement by Eisenhart and colleagues (1996) made this point quite forcefully. Other scholars make the same point more obliquely as they explore science learning processes and activities through the lens of identity and subjectivity (Basu & Barton, 2007; Furman & Barton, 2006; Fusco, 2001) drawing on a robust body of literature that examines learning and thinking as a complex of cognition, affect, and social and cultural resources and activity (see Ageyev, 2003; Vygotsky, 1962).

A forthcoming book by Herrenkohl and Mertl documents a 4th grade classroom, showing how children's changing capacities to know and do science develops in conjunction with children's changing capacities to "be" science learners, and science knowers and doers (Herrenkohl & Mertl, in press). By this the authors mean at least two things: On the one hand they show that as the 4th grade children are asked to take on roles that require them to develop, articulate and test theories, and to examine the relationships between hypotheses and evidence – that is, as they *do* science – they develop their capacities to *be* scientists as well as their capacities to *know* science. This is in line with much of the literature on inquiry-based or constructivist theory. They also show, however, that the ways in which children approach classroom scientific practices and acts of *doing* and *knowing* is deeply shaped by who the children are (intellectually, emotionally, physically, and socially) and how they exist in relationship to one

another. For example, engaging in scientific argumentation poses different challenges to different children. The more argumentative children need to learn to listen and consider other forms of reasoning and explanation. The more shy or reticent children need to learn how to articulate their thinking and present it in relationship to (as contradiction or support) the ideas or theories of their peers. Listening and communicating are not just markers of child development. They are also fundamental practices in the field of scientific inquiry. Thus, children's ongoing *acts of being,* that include but transcend being in the classroom, influence their engagements with science, and influence each other's engagements as well (if the argumentative children can't learn to listen, then the reticent children have a harder time learning to speak, and vice versa; similarly, if scientists do not listen and communicate with one another then science as a field does not advance). This broad view of learning stresses the social dynamics of the classroom as contexts where self, collective, subject matter, teaching, learning, and development come together in the context of science.

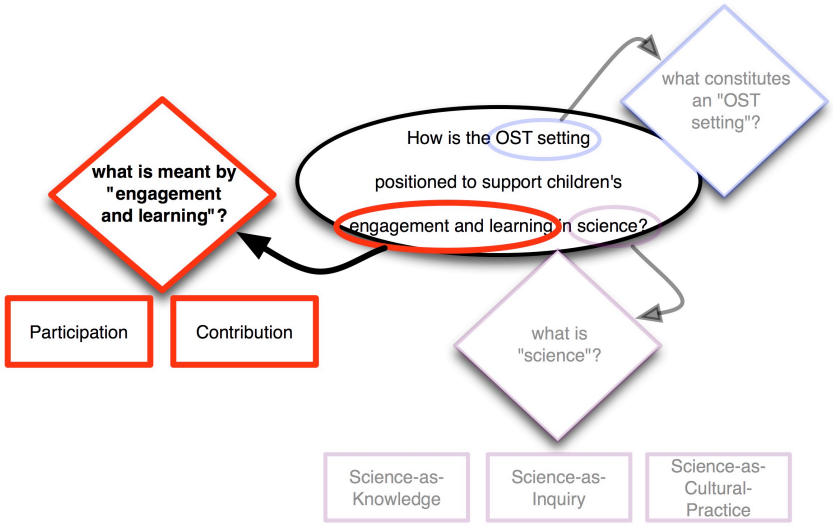
A transformative activist stance on CHAT sheds additional light on this relationship between knowing, doing, and being, and adds the process of *becoming*. This view, as described above, posits *contribution* to purposeful and valued activity as fundamentally transformational of both self and society and as the driver and context for learning and development. As such, engaging in and expanding both inquiry and agency are placed firmly at the heart of learning and development. In this way, the disciplinary practices of science, which are equally grounded in inquiry and in agency, are shown to be the very practices which can

drive learning and development, just as learning and development, instantiated in expanded agency and inquiry, can support deepening engagement in science. In this way *being*, and moreover *becoming*, are shown to be inseparable from knowing and doing at a sociocultural as well as an ontological level. The conditions, therefore, in which inquiry and agency can be exercised, and knowing, doing, being, and becoming can develop, become critical.

3.2.2 Conditions for Learning Science: From Participation to Contribution

The need for a theoretical move that clearly relates learning and development as well as the sociocultural and the individual is an especially important issue for the OST field, where there is little doubt in the field and the research literature that children are "engaged," but there is less certainty that children are "learning." This is because, first, much of the learning activity in OST settings is done as a collective, yet questions persist about efficacy of such programs at the individual level. Second, because OST programs often do not consist of extended or consistent

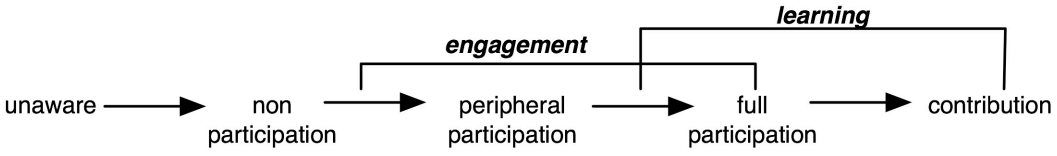
Figure 3. What is Meant by Engagement and Learning?



periods of time in which learning can be carefully observed, documented, and tracked, ways of conceptualizing phases of engagement can serve as important markers for understanding when and how children are progressing in their levels of development with respect to the activities. Third, a fundamental concern in the OST field is that written assessments, and even formal interviews or focus groups, common to school settings are inappropriate to, and can "spoil" the experience of, the OST program (NRC, 2009). Theorizing and documenting the interdependence of engagement and learning, how one sets the stage for the other, and how these stages relate would help to advance the field's capacity to design, articulate, and document learning and development in OST settings.

Operationalizing movement from engagement to learning (as represented in Figure 4) would require distinguishing between the *appropriation* of cultural tools, practices, and endeavors (i.e., movement from peripheral to full participation) to the agentive and purposeful *transformation* of relevant cultural tools, practices, and endeavors (i.e., movement from full participation to contribution). Although transformation of cultural tools and practices has long been noted as part of learning and development (e.g., Rogoff, 2003), the

Figure 4. Trajectory of Learning and Development: Participation to Contribution



development of a transformative activist stance, as a new theoretical tool, points specifically to constructs of authenticity, inquiry, and agency at the heart of purposeful human tool-mediated activity as drivers of development. It thus provides a tool for operationalizing the design and study of such learning and development by distinguishing between participation and contribution.

In the context of OST science education, for example, taking a transformative activist stance would suggest that educators design (or document) learning contexts and purposes that are both authentic and of consequence for participating children, wherein their participation in such activities leads to (supports and propels) the agentive generation and use of knowledge, products, or ideas that are valued (meaningful or useful) to students both individually and as a social group. In other words, the goals, roles, inquiry processes, contributions, and consequences of the activities would be undertaken agentively and for authentic and valued purposes.

In advanced science classes, it may be that traditional science education, which values science for science's sake (including the important cultural contributions science has made), can effectively engage students who have chosen to enroll in advanced classes. Such students have already ascribed value to the process of science learning. However, in cases where students may be disaffected from or new to science education, scholars have noted the power of activities that use science as a tool to achieve authentic (real world) purposes for sparking and sustaining student engagement and learning (Bouillion & Gomez, 2001; Fusco, 2001). For example, Rahm (2007) showed in her study that

students attending the same outdoor gardening summer programs found and made meanings that had value to them (confirming self-concepts as good students or as scientifically-minded). Douglas and Katz (2008) showed that the creation of a website to communicate their authentic concerns about what they had learned about animal and environmental stewardship provided a structure for children to exercise both inquiry and agency.

Examples of science-as-cultural-practices in the OST setting have found that such programs can develop students' interest and engagement in science when it includes or is organized around the following features:

Table 1. Comparison of Science-as-Cultural-Practice Approaches

Fusco (2001)	***Roth & Lee (2004)***	***Basu & Barton (2007)***
(1a) created from participants' concerns, interests, and experiences in and outside science	(2a) the potential for scientific literacy to emerge from collective praxis	(3a) science experiences connect with how students envision their own futures
(1b) entails an ongoing process of researching and then enacting ideas	(2b) science is but one strand of more encompassing democratic forms of life	(3b) learning environments support the kinds of social relationships students value
(1c) situated within the broader community	(2c) students engage in everyday community-oriented activity	(3c) science activities support students' sense of agency for enacting their views on the purpose of science

What is missing in these accounts is not the design and implementation of meaningful science learning opportunities, but a theoretical explanation that can account for why these experiences are meaningful and powerful beyond simply engaging children or youth in science activities, an account that explains both individual and sociocultural planes of development, as both are implicated in the

programs and analyses. A transformative activist stance posits a developmental mechanism for explaining *why* these program designs are engaging and transformative. At a large grain size, common to all three models is an emphasis on subjectivity and *agency* (items 1a, 3a, and 3c in Table 1); collaborative *inquiry* (items 1b, 2a, and 3b in Table 1); and situating the endeavors in *authentic* contexts and communities (items 1c, 2b, and 2c in Table 1). As such, these perspectives position science as cultural tool, practice, and human endeavor, to be taken up and pursued to achieve meaningful purposes. Facts, concepts, and conceptual knowledge structures, are part of the repertoire of practice, along with ways of questioning, exploring, explaining, and understanding. Science becomes a cultural means and modality for exercising agency in the world: for finding out, for solving problems and for arguing ideas that matter to the learner. Thus, both scientific concepts and the disciplinary practices of science (inquiry and argumentation, for example), including its historical trajectory, purpose, and meaning as a human endeavor, become integrated as tools and means in the purposeful actions of children.

Inquiry, agency, and authenticity, then, become characterizations of science-as-cultural-practice that will guide my analysis of science in OST settings as I examine the ways in which goals, roles, processes, and consequences are structured to support student engagement and movement towards learning.

3.3 Designing for Learning and Development

While a transformative activist stance focuses on the driving purpose that engages and transforms (and is transformed by) participants, it does not directly address the ways in which societies can organize opportunities for children to come to value and participate in transformative activities. Indeed, there may be a broader socioeconomic and political reality that actively widens this gap, deterring many students, particularly from cultural minority and female populations, to see themselves as aligned with “the contours of practices” associated with science (Nasir & Hand, 2008).

In my study, I draw on bioecological theory as a useful complement to a transformative activist stance because of its explicit call for adults (or more capable peers) to create the developmental (cognitive, affective, physical, and social) conditions that can invite in and support children’s engagement in cultural and historical activities. While similar to Vygotsky’s construct of the zone of proximal development (Vygotsky, 1962; Werstch & Tulviste, 1992), and the related concept of scaffolding (Bruner, 1985; Stone, 1993), bioecological theory is more explicit about the reciprocity and co-creation of the conditions for engagement. Bioecological theory emphasizes the dynamic and bi-directional relationship between the developing person and his or her environment, where the environment is constituted by people, objects, interactions and multi-layered contexts (Bronfenbrenner, 1979). Although bioecological theory was developed separately from the cultural-historical scholars in the U.S., like cultural-historical theory it is deeply relational, conceptualizing the individual as both a product of

and producer of his/her developmental context. In this section of my dissertation I describe what bioecological theory is, and why it is an important additional tool for my analysis of OST programs.

Bronfenbrenner and colleagues posit what they call “proximal processes,” meaning immediate interactions between people and other people or between people and cultural artifacts (such as books or computer programs), as the “engines of development” (Bronfenbrenner & Morris, 1998). Proximal processes are the social interactions through which the developing person is invited, welcomed, supported, and challenged, by the complexification of interactions over time, through reciprocal relationships in which “the balance of power gradually shifts in favor of the developing person” (Bronfenbrenner, 1979, p. 60). Bronfenbrenner et al. conducted several secondary analyses of different quasi-experimental studies that controlled for proximal processes to test for differentiated outcomes. For example, they took data collected by Drillien which sought to document the relationship between maternal responsiveness at age 2 and problem behaviors at age 4, analyzing for differences in social class (defined by income, education, and the neighborhood in which the family lived) and birth weight (normal, underweight by up to one pound, underweight by more than one pound). “Maternal responsiveness” constitutes a form of proximal process. The results of the study showed that low rates of maternal responsiveness to children at age 2 correlated with problem behaviors for children at age 4, across variations in social class and birth weight. The study also found that proximal processes also varied by the controlled conditions – children with the lowest

social class, or the lowest birth weight showed greater negative effects from maternal unresponsiveness. That is, the proximal processes, environmental conditions (social class), and properties of the developing person (birth weight) operate as multipliers. In another study, they took data collected by Risken-Walraven that involved three treatment groups with directions to mothers on how much guidance (in terms of proximal processes such as noticing, pointing, naming, and speaking to) they should provide their nine-month old babies. The results again showed greater cognitive growth for the infants who benefited from higher levels of proximal processes.[8]

In the context of science learning activities, proximal processes would include the ways in which teachers or other adults or more capable peers

- make science or scientific phenomena interesting and accessible to children;
- relate the phenomena to everyday and prior experiences so that children can recognize and value them as meaningful to their greater lifeworlds, and those of people they care about, such as their family and friends;
- invite children to reflect upon their prior observations of and experiences with the phenomena, valuing them as relevant

[8] Both of these studies, and many others, are described in Bronfenbrenner, 2005, and cited in many of his other papers and publications.

contributions to group discussions and understanding of the phenomena;

- support the development of children's questions and observations;
- facilitate the introduction and taking up of scientific language and instruments relevant to understanding the phenomena;
- provide time for children to mess about, experiment, retest, make mistakes, learn from mistakes, and find success in working with/understanding the phenomena;
- value and make use of the children's contributions to the group understanding or product.

It is this attention to the shifting balance of authority that introduces notions of invitation on the part of the adult and agency on the part of the learner. As Foucault has argued, power is not a static force that resides in one person or place. Rather it emerges through "a substrate of force relations," which means that it is always moving and unstable (Foucault, 1990, p. 93). I conceptualize this substrate as moving water through which waves of energy ripple, forming apexes and troughs, emerging, standing, and subsiding. As learners move from invitation, to participation, to contribution (a process which would not be sequential or linear, but rather constantly ebbing and flowing), they exercise, resist, and also relinquish power and agency at different moments. The salient point that bioecological theory stresses for the study of OST science is the understanding that developmental conditions include spaces in which power *can*

shift, and indeed educational leaders must create spaces in which power *must* shift, as the learner finds and creates meaning (and therefore desire) to take up cultural tools and exercise her or his agency in the world. Teachers who hold onto knowledge as power, it is theorized by Bronfenbrenner and colleagues, fail to create conditions for agentive learning.

3.3.1 The Role of Settings in Shaping Possibilities for Learning

My dissertation draws on a transformative activist stance to conceptualize learning and development, and bioecological theory to study how conditions are created to engage learning and development. Using these lenses, in Chapter Five I analyze the structural settings of the OST program in relationship to science, especially understanding how the OST setting draws on its developmental and structural features and affordances (as discussed in Chapter Two) to invite and sustain learning. The contribution of this dissertation is an analysis that takes into account these features as it considers, from a principled theoretical stance, the opportunities for learning that are made possible.

Nicolopoulou and Cole (1993) note a lack of attention in the sociocultural literature to the ways in which institutional settings shape learning. In their study of the Fifth Dimension program conducted in a youth program and in a library, they note the ways in which institutional cultures, characterized by modes of interaction, shape the meaning and impact of interactions within those contexts. The library they studied was more rule-bound and had more consistent rates of participation, this led to richer and more sustained interactions, characterized as

greater forms of “social cohesion,” as children participated in the learning activities following the norms established and understood by the institutional setting. Children from the same schools and socioeconomic backgrounds who participated in the same learning activities in a youth program, where the institutional culture was less rule-bound and attendance patterns were more variable, had different and less rich learning outcomes. Nicolopoulou and Cole cite more consistent attendance patterns as one form of evidence that the “social cohesion” (characterized by interactional density, continuity of interaction, and commitment, which mutually reinforced one another) was stronger at the library, where learning outcomes were also stronger. Indeed the point of their paper is that the cultural context of the setting is constituted by resources and schema which must be aligned with the resources and schema implicit or integrated in the learning activities in order to achieve robust developmental and learning outcomes.

To summarize my theoretical toolkit, in the context of this dissertation, a transformative activist stance helps me to analyze how programs are designed (or not) to support children’s movement from engagement (which I define as attentive and active participation) to learning (which I define as entailing processes of being, doing, knowing, and becoming that involve taking up and transforming cultural tools in the agentive pursuit of meaningful goals). Bioecological theory sheds light, at the micro-level, on the ways in which adults shape the social cohesion of the setting by welcoming in and supporting children’s engagement, and moving children, through a shift in power, towards

contribution in meaningful activity. These deeply relational theoretical lenses on learning, combined with the ways in which science is positioned as a cultural practice or as knowledge or as inquiry, serve as critical tools for examining how:

1. the structures of the OST setting,
2. the developmental conditions of the OST setting, and
3. the conceptual positioning of science in the OST settings

create opportunities for engagement and learning in science in the OST setting.

Table 2. Research Questions and Constructs

How is the OST setting positioned to support children's engagement and learning in science?					
	Rationale in the Literature				
Sub-Questions	**OST Research**	**Developmental Theory**	**Theoretical Lens**	**Constructs**	**Method and Instrumentation**
How do **structural** properties of the OST setting affect program scope and stability?	Structures impede scope and coherence	Structural features shape organizational culture	Transformative Activist Stance on CHAT	Setting	observations
				Staffing	observations
				Attendance patterns	Background interviews with program leaders
How do the **developmental** conditions affect children's patterns of interaction and social cohesion?	Develop-mental conditions support children's "voice and choice"	Purposeful, reciprocal (shifting balance of power), relationships needed to support development	Transformative Activist Stance on CHAT	Activity goals	observations
				Participation structures	observations
			Bioecological	Relationships -reciprocal -complexifying -low-stakes	observations
How does the **conceptual positioning of science** provide children opportunities for engagement and learning?	Learning activities are hands-on and inquiry-based, project-based	Learning and development occur through transformative, agentive inquiry in authentic, meaningful activities/contexts	Transformative Activist Stance on CHAT	Science as cultural tools and practices; inquiry and agency in authentic (meaningful) contexts	observations

Chapter Four

Methodology: Design, Methods, and Limitations

The data I use in this study was collected as part of a larger federally-funded study I co-lead at the Exploratorium. The design of the data collection was developed jointly with my colleagues at another research institution. The larger study uses both quantitative and qualitative methodologies, includes a comparison group, and contains, in general, a large quantity of data not referenced in this dissertation. In this chapter I describe – purely apropos the data that I draw on here, and not apropos the larger study – my questions, theory of inquiry, methods, and the limitations of my study design.

4.1 Research Questions

My research question is:

How is the OST setting positioned to support children's engagement and learning in science?

To answer this question I first address three sub-questions that reflect the existing literature on OST settings and science learning in OST settings:

1. How do structural properties (setting; staffing; and attendance patterns) of the OST setting affect the program scope and stability?
2. How do the developmental conditions (the goals; participation structures; and relationships entailed in observed activities) affect children's patterns of interaction and social cohesion?

3. How does the conceptual positioning of science (as knowledge, inquiry, or cultural practice; and as a means for inquiry and agency) provide children opportunities for engagement and learning?

4.2 Theory of Inquiry[9]

The qualitative data analyzed in this study were collected over a period of two years. The theory of inquiry guiding my data collection was informed by naturalistic perspectives on qualitative inquiry (Lincoln & Guba, 1985). Naturalistic perspectives take a post-positivistic view of the nature of knowledge, science, and inquiry – asserting that all three are always bound by context and history, and that all three are always tentative and subjective. Lincoln and Guba discuss 14 features of naturalistic inquiry, which include: a natural (non-laboratory) setting, the researcher as a human instrument, the utilization of tacit knowledge, the use of qualitative methods, purposive sampling, use of grounded theory, emergent design, negotiated outcomes, case study methods, ideographic interpretations, tentative application, focus-determined boundaries, and special criteria for trustworthiness.

Thirteen of these fourteen criteria are reflected in my study. My approach to the inquiry did not, however, adopt a strict interpretation of grounded theory in which researchers approach settings without pre-identified coding categories and

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[9] This study was designed in collaboration with my colleagues; however, I use the singular "I" when describing choices related to the methods to reflect the fact that I alone am responsible for the framing and analysis described in this dissertation.

instead allow constructs and categories to emerge from the data (see Glaser & Strauss, 1967). Rather, I approached the setting with theoretical perspectives (discussed in Chapter Three) that by definition drew my eye to particular constructs – such as adult-child interactions or the positioning of science as a cultural tool.

Adopting a particular theoretical perspective was important to me because, as noted above, the OST setting is largely under-theorized (Barber et al., 2005; Honig & McDonald; 2005; Larson, 2000) with much of the research and evaluation literature failing to systematically approach the setting, the activity, and the trajectory with a coherent framework that can guide meaning-making. Indeed, it has been noted that much of the literature documenting outcomes for students fails to specify the treatment, much less detail the context or interpret the treatment within a theoretical framework. Thus, a potential contribution of this dissertation is to take a principled, theoretically-grounded perspective on science activity and learning in the OST setting that can lay the groundwork for future investigations.

As part of the design for this dissertation I selected three of the 16 programs that we observed in the larger study, I refer to these programs in this study as Urban Engineers (hereafter "*Engineers"*), Energy Explorers (hereafter "*Explorers"*) and Environmental Researchers (hereafter "*Researchers"*). These programs took place in two Midwestern and one Southern community. This purposive sampling was taken in order to highlight different types of OST science programming. Although all three are highly structured, they are structured along

a continuum of school-like to lab-like. They also work with different populations, encompassing minority and majority populations, high and low income schools, and urban and suburban settings. The goals of the programs, the structures employed, and the ways in which the activities unfolded also differed across these three programs, which will be shown in the next chapter. This purposive sampling helps to illuminate interesting patterns as well as different developmental pathways for both programs and the participating children.

Table 3. Program Characteristics

	Urban Engineers	***Energy Explorers***	***Environmental Researchers***
Setting	Midwest: Large Urban	South: Suburban/ Small City	Midwest: Mid-Sized Urban
Majority population	African-American	White, High-Poverty	White, Middle-Class
Leadership	CBO	University	University
Subject-Matter	Engineering	Physics	Enviro Sciences
Duration of participation	Two to Three Years, and beyond	Two Years maximum	One Year maximum

4.3 Instrumentation

To guide my observations in the programs, I used an observation instrument developed by Vandell and colleagues for use in the afterschool setting (Vandell et al., 2005). Vandell et al. used the tool as an observation protocol to observe and rate the quality of dozens of afterschool programs, using criteria that closely align with the characteristics of high quality community programs discussed in the NRC (2002) volume on youth programs. I chose this particular

tool because it considered a combination of structural, developmental, and learning features.

I did not use the tool to rate programs but rather to focus my eye on features acknowledged in the literature (NRC, 2002) that were associated with structural, developmental, and learning properties of the OST setting. The tool was already tested and validated. The protocol was, however, not specific to science, so I added sections that addressed (1) the nature of science in the observed activities, for which I drew upon transformative activist perspectives and (2) the nature of the proximal processes, for which I drew upon bioecological perspectives. (The additional questions and constructs are detailed below.) I refer to this modified protocol as the Adapted Vandell Science Protocol (found in Appendix A of this dissertation).

For Vandell et al.'s study, observers were instructed to make six activity ("investigation") observations, lasting 15 minutes each. I defined an "investigation" as a discrete set of goal-driven tasks that had an identifiable beginning, middle, and end. In some programs, investigations were part of a larger trajectory (such as a data collection investigation that was part of an ongoing research study of a pond). In other cases, investigations were more discrete or "one-time" investigations that would not be repeated (such as building a battery operated motor). I conducted at least six investigation observations at each site, but, deviating from Vandell's 15-minute observation limit, I observed for the duration of the investigation, which sometimes lasted several hours.

Typically I would visit a site for one to two days at a time, observing as many different program investigations as were occurring. (*Engineers* met once a week, therefore my visits were limited to one day each time. The other programs met several days in the week, as well as running camps during the summer, which allowed me to attend two days at a time.) I frequently scheduled my trips so that I could also attend one of the projects' scheduled professional development sessions or family events. Altogether, data were collected at the three sites over the course of about 60 total hours of observations.[10]

I took extensive field notes; time stamping these notes at transition points in the activities. Later I coded the field notes using the Adapted Vandell Science Protocol. In addition, I conducted semi-structured interviews with adult project leaders (teachers and also project directors) to gather background information about the history, context, leadership, staffing, and goals of the programs.

4.3.1 Observation Constructs

The Vandell protocol included an introductory data sheet to note features such as physical setting, numbers and genders of participating children and adults, materials, and the nature and purpose of the observed activity. In addition, the tool included rating sheets for the following constructs (I have reordered and grouped the constructs into categories aligning with my study):

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[10] One set of observations and interviews, at the Explorers project, was conducted by colleagues on my research team. All other data were collected directly by me.

Structural Features

(1) Chaos/Lack of Chaos

(2) Appropriate Structure

Developmental Features

(3) Adult-Child Relationships

(4) Peer Relationships

(5) Over-Control/Autonomy

Conceptual Features

(6) Engagement

(7) Opportunities for Cognitive Growth

(8) Mastery Orientation

Vandell et al. developed a rubric containing indicators (see Table 4) of what each of these constructs looked like in both high and low frequencies, and with descriptors for each (see Table 5 for samples of descriptors). For example, the guide to rating “appropriate structure” had five different indicators, including:

Table 4. Sample Vandell Indicators

High	Low
Transitions are orderly and efficient	Transitions are chaotic
Instructions for activities are clear and appropriate	Instructions are unclear and not easily followed
Staff members support each other	Staff members work at cross-purposes or give conflicting information
There are no obvious safety hazards	Activity area is cluttered and materials are broken
External distractions are minimized	Distractions outside the observed activity interfere with students’ participation/experience

For the second indicator, “instructions for activities are clear/unclear,” the descriptors were as follows:

Table 5. Sample Vandell Descriptors

Instructions for activities are clear and appropriate	**Instructions are unclear and not easily followed**
➢ Staff understand and are prepared to support students in the activity	➢ Students may not know what they are supposed to be doing
➢ Explain reasons for rules and structure of the activity	
➢ Instructions are easily understandable and easy to follow	
➢ Students understand and follow instructions	
➢ Students understand their responsibilities	
➢ Students know what is expected of them	

Each of the eight categories had different numbers of indicators; each of the indicators had different numbers of descriptors. These rubrics and indicators were useful for providing concrete views into what constructs such as “appropriate structure” might mean. However, as noted above, I used this instrument as a guide and not as an instruction sheet. That is, I did not note the presence or absence or level of frequency of each and every indicator, but rather used these indicators as ways of understanding how to think about and observe for aspects of structural or developmental features in the OST context. For example, the presence or absence of safety hazards is important in the OST literature; transitions being orderly or chaotic is also an issue for these settings. Features such as these would not have been top of mind for me without reference to this protocol.

4.3.2 Adapted Vandell Science Protocol: Changes to the Instrument

Drawing on bioecological theory, I added the following three questions that aimed to document ways in which the programs were implemented to invite and support children's engagement and learning:

1. Did you see evidence that the activities are growing or have grown in complexity, such that children's thinking and skills are being challenged and developed?
2. To what extent is this activity a part of a coherent set of learning experiences, before during and after? Does it reflect sustained work in a particular area? Is it something that children return to with regularity?
3. In what ways are the activities reciprocally designed so that children are able to influence the activity (the leaders, the activity, the materials or tools) as much as these elements structure their experiences?

Additionally, drawing on transformative activist perspectives on science-as-a-cultural-practice, I added the following constructs, with respect to how science was positioned in the programs, that asked how the programs:

1. related science to everyday experiences
2. related science to school STEM
3. presented science as accessible, historical human endeavor (for example, illuminating career or academic pathways)
4. engaged children's imaginations
5. used STEM tools, language, activities
6. built on children's social capital

7. built on children's prior knowledge
8. allowed children time/mental space for engaging, taking risks, and making mistakes
9. structured activities in social rather than individual tasks (and how)
10. provided dimensionality/tactility
11. provided intellectual safety

Field notes for each activity observation were typed up as narratives unto themselves. When possible I audio recorded activities and appended taped transcripts of dialogue between and among adults and children to the narratives. Excerpts of these transcripts are included in Chapter Five.

4.4 Limitations

Because the data were collected in cities across the country, my access to the sites was limited by time and resources. Therefore, although we spent between 6 and 12 days at each site, these visits were episodic in nature. At the same time, I was able to observe the programs evolve over time, and through discussions with program leaders over the two years to come to understand issues and concerns that they had about the programs. Nevertheless, a limitation of these data is that they are discontinuous. It is therefore not possible to make definitive evaluative statements about the totality of these programs based on my observations alone. (For this reason, the larger study is augmented by other data.) For the purposes of this dissertation, these observations allow me to

analyze the conditions and evolving interactions that create opportunities for learning, if not their overall net impact on participants.

Related, because these three programs were situated in cities where I have never lived, I cannot profess to have a deep understanding of the social dynamics in the communities that helped to shape the program designs and the subjective experience of them. Through extensive discussions with program leaders over the years, I did hear their own stated beliefs about the needs and dynamics of the cities, but my personal understanding was mostly developed through my interactions with these program leaders and staff. It's possible that I missed relevant undercurrents in the social interactions, for example socioeconomic tensions or anxieties among students.

I struggled significantly with a desire to follow and track individual children over time, to observe their own personal trajectories as they engaged in the program, taking on or avoiding more activist stances, and developed understanding of science and the subjects they were investigating. The larger study design, and our IRB approval, did not allow for the collection of these kinds of data. This is a limitation insofar as I cannot make claims about any one child. However, the purpose of both the larger study and my dissertation is to theorize the OST setting as a site for science learning. As such, my eye is focused on the structural and development conditions, as well as the ways in which science is positioned within those settings and programs to create opportunities for learning. My study, I believe, sets the stage for both microgenetic and longitudinal designs attending to the trajectories of students within these settings.

Such studies of individuals in OST have been done (e.g., Furman & Barton, 2006; Fusco, 2001; Rahm, 2002) but not in ways that fully take into account the conditions of the setting which my study has been designed to illuminate and document.

I visited all of the programs as an outside evaluator of the overall federally-funded program. My work was funded by a grant, I was not working for or representing the federal agency (as with a contract); but, nevertheless, I represented a group that was looking at the programs to draw conclusions about the entire effort. At each visit, I talked with program leaders and teachers about my goals, making clear that I was not visiting to evaluate the programs per se, but rather to get an on-the-ground perspective of the ways in which programs were being implemented (all of the data I collected would be reported to the federal agency in aggregate form, without naming any particular programs). Nevertheless, because of the episodic nature of my visits, and the fact that I was recognized as the leader of an external evaluation effort, I cannot be certain that my presence did not affect the actions of adults or children. In some cases when I reviewed the transcripts I wasn't sure if certain statements were made for my benefit or not. At the same time, as a program leader myself, who has had external federal agency grantee reviewers just like me come and visit my program, I know that when you are in the middle of teaching and learning you cannot really tune into both the needs of your participants and what you might want to convey to the visitors. Therefore, I tend to trust the data as representing the programs more or less as they would have been with or without my presence.

Because I was a part of a research team investigating these sites, I had the benefit of being able to check my assumptions and understandings with my colleagues. As noted in Chapter One it was two of these interactions that in many ways set me on the path that this dissertation takes. In my many moments of doubt, it was through exchanges with my colleagues on this project and on others – discussions about tensions, gaps, opportunities and recurrent themes that they were seeing in other similar sites – that helped me both through confusing or confounding moments, and gave me confidence in the ecological and face validity of the findings that were emerging from my analysis of the data.

Finally, I have struggled with a critique of an earlier draft of this paper that the voice was too judgmental. My purpose in undertaking this study, as described above, was to make sense of contradictions I was finding in the field – because any schema I had for evaluating the merits of the programs (such as too much or not enough structure, or too open or too closed science investigations) were confounded by the enthusiasm or dedication I saw in the children as they participated in the programs. But I took the criticism to heart. I re-examined my language and changed some of it; I tried to ensure that I did not analyze any one program or program moment along a single dimension (such as inquiry present or absent) but instead tried to show how inquiry (for example) was both present and absent, when and how. Through this most recent struggle, I have come to see that my method of analysis – of describing three different programs along the same dimensions – unavoidably creates the conditions for comparison, and in so doing, inexorably leads any reader (or writer) to a sense of order or ranking. This

is problematic because any sort of straightforward ranking of programs (along lines of evidence of inquiry, active student participation, coherence of curriculum, etc.) oversimplifies the situation, confounds the purpose of my study, and distorts the validity of the findings. But I fear it is a major limitation of this document that reconciling my desire to generate useful analysis – useful to people who design and lead OST programs – has meant that I have taken the position at times about what is *not* present (such as time for children's reflection on their investigations) as much as I have tried to describe what is present (such as the development of social cohesion in the context of science learning activities), and these descriptions of what is and what isn't I find necessary in order to pose "what ifs." The field of OST science is developing and being defined as I write this dissertation. It is being developed by educators who are experimenting with different approaches, goals, and contexts. It is being defined by federal, state, and private agencies and foundations that are setting requirements for funding. My goal in this dissertation is to introduce new elements for consideration, and to make recommendations for both parties, so that what ifs can be pursued to benefit children through the expansion of opportunities for rich and agentive science learning.

Table 6. Research Questions and Instrumentation

How is the OST setting positioned to support children's engagement and learning in science?		
Sub-Questions	**Constructs**	**Questions from Adapted Vandell Science Protocol**
How do **structural** properties of the OST setting affect program scope and stability?	Setting	Cover Sheet "C. Activity Setting"
	Staffing	Cover Sheet "E. Total Adults/Staff"
	Attendance patterns	[from attendance database, supplemented by interviews with program leaders]
How do the **developmental** conditions affect children's patterns of interaction and social cohesion?	Activity goals	Activity Descriptions
	Participation structures	Activity Descriptions
	Relationships -reciprocal -complexifying -low-stakes	Q 1 Program Design and Implementation
How does the **conceptual positioning of science** provide children opportunities for engagement and learning?	Science as cultural tools and practices; inquiry and agency in authentic (meaningful) contexts	Q 2 Student Experience of STEM Learning

Chapter Five

Data: Three OST Science Programs

In this chapter I draw from qualitative observations of three OST science programs to explore the different ways in which the properties and affordances of the settings create opportunities for children's science learning, as seen through a transformative activist lens, which understands learning as subjective and social processes of being, doing, knowing, and becoming that occur in the context of goal-driven, tool-mediated activities undertaken to effect change in one's self and one's world. In this view, learning is an activist project, emerging through opportunities to express agency and inquiry in matters of consequence.

How are OST science programs positioned to provide such opportunities? I begin with a premise, based in the literature, that OST programs – with their historical focus on child development, and their structural lack of constraints to "cover a particular curriculum" and test a particular set of concepts – are promising settings for engaging children's intellectual, emotional, physical, and social selves in science. I analyze the OST settings by examining three different programs to understand how it is (or might be) positioned to provide such opportunities for children to engage with science and science learning. This analysis consists of three parts:

I first describe the structural features of each program. As noted in Chapter Two, structural constraints are largely credited with obstructing children's opportunities for learning in the OST setting. My analysis finds that,

while some structural features do indeed hinder consistent and coherent educational experiences, the literature overlooks a perhaps even more profound effect, which is that structural features can also operate to shape how science itself is positioned in the programs. I find that structural features also shape the nature of the developmental conditions: for example, while fluctuating attendance, due to the voluntary nature of participation, may operate to preclude long-term investigations (and thus affect the program's capacity to provide opportunities for children to engage with science as inquiry), the voluntary nature of participation may also operate to build social cohesion among participating children, thus potentiallu creating more supportive learning spaces for processes of doing, knowing, being, and becoming in the context of science.

Second, I describe the developmental conditions of these programs. As described in Chapter Two, developmental conditions of the OST setting have been well documented and are a primary reason that OST programs are seen as potentially powerful learning spaces. In the three programs I describe I find evidence of strong developmental conditions; however, as noted above, I also find that these conditions are sometimes inadvertently affected by structural design decisions (such as staffing with classroom teachers leading to more adult-centered instruction). In general, the developmental conditions that I found were more adult-centered than much of the OST literature describes or assumes; as such, they affect participation structures which in turn shapes children's abilities to exercise inquiry and agency in the context of science.

Finally, I describe how science has been positioned in each of the three programs. I note the ways in which the design decisions relating to structural and developmental conditions affect how science is positioned and experienced. There is a common assumption in much of the literature that, because OST science investigations tend to be materials-based (instead of text-based), that science is positioned as inquiry or even cultural practices. My study finds that how science is positioned is far more complicated and varied, both within as well as across programs, than the literature and advocacy rhetoric might suggest.

In investigating and describing the programs in this way, I seek to show variation across the programs, and also how these variations (which are results of decisions by program leaders) come together as a whole to shape opportunities for learning. I undertake the description and analysis of particular dimensions not to conduct a reductionist comparison, rating, or ranking of these elements. (A reductionist approach is not consonant with my theoretical line of inquiry, described in Chapter Three.) Rather, I conduct this analysis to highlight important elements that must be attended to – and are often overlooked in the OST science literature – that operate dynamically with one another to create the opportunities for learning. This analysis reflects my goals to contribute to a better specification of the OST field, which can guide program design, implementation, and funding.

In comparison to research on classroom learning, little research has been done to specify, document, and explore the features and nature of the OST learning environment. A premise of my dissertation is that identifying the range of

relevant issues, constructs, and design decisions is essential for the ultimate development of a coherent and valid way of conceptualizing (and evaluating) the OST setting as a site for learning. This dissertation represents a step in that direction. A transformative activist stance both guides my work (undertaking this inquiry with the goal of contributing to a larger political discussion about the role of the OST program in supporting learning in science) and guides my analysis (understanding how the structural, developmental, and conceptual features of OST settings create opportunities for children to develop meaningful goals and to agentively take up the tools of science in pursuit of these goals). Using this particular lens – which is especially well suited to the study of a field that, historically, from the developmental perspective described in Chapter Two, is premised on the notion of empowering children and youth to take action in their lives – is critically important for developing a more coherent and valid approach to conceptualizing the OST setting. Positivist, reductionist investigations, analyses, and interpretations would (and perhaps have) develop(ed) knowledge and understanding of the OST field that is not, as I tried to show in Chapters Two and Three, sufficiently coherent or ecologically valid to guide development of the field. It is in this context that the field is currently struggling to develop its identity and direction, under the scrutiny of policymakers who see these extra hours and settings as opportunities to expand student engagement and learning in science, but who tend to measure (and therefore direct) that learning using traditional school accountability measures such as improved standardized test scores and increased uptake of postsecondary science degrees.

5.1 Parsing the Data

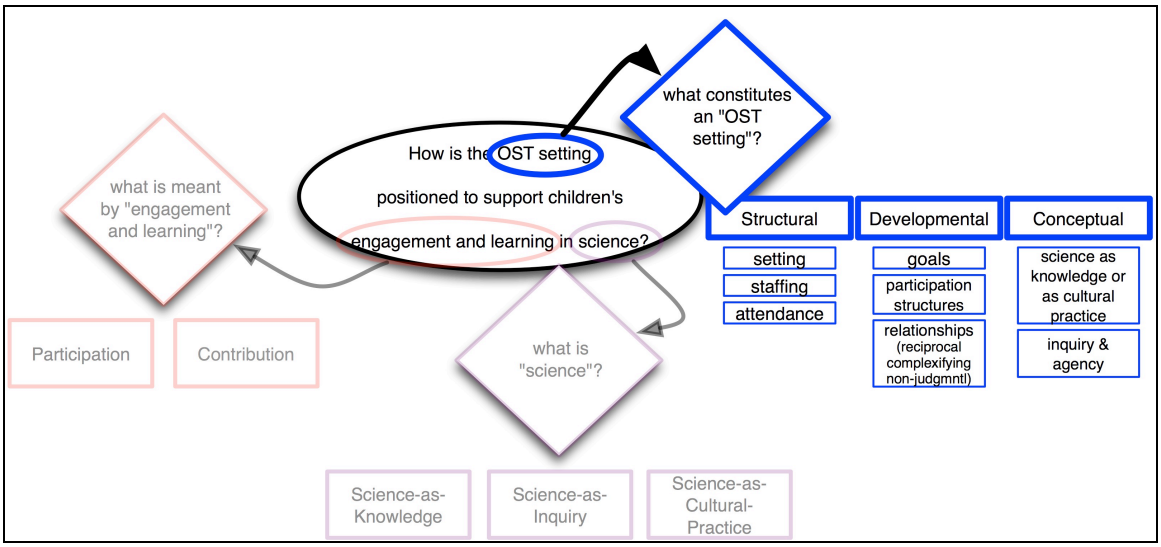
In this chapter, for each of the three programs I discuss I highlight:

1. The structural properties that shape the program, including the dimensions of (a) setting, (b) staffing, and (c) attendance patterns; asking: *How do the structural properties affect program scope and stability?*
2. The developmental conditions, including the dimensions of (a) goals and expectations for learning, (b) activity participation structures, and (c) relationships among children and adults; asking: *How do the developmental conditions support children's patterns of interaction and social cohesion?*
3. The ways in which science is conceptualized and positioned in the learning investigations, including the dimensions of (a) how the cultural tools and disciplinary practices of science are introduced and taken up in authentic contexts and (b) how science learning investigations are structured to advance students' inquiry and agency; asking: *How does the positioning of science provide children opportunities for engagement and learning?*

These dimensions emerge from the literature described in Chapters Two and Three as critical features of the OST setting or of learning. Structural conditions have been shown to affect the possibilities for learning by creating

irregularity and instability in programs at both an organizational (funding, staffing) and experiential (attendance, coherence) level. Some have argued that OST settings are simply too unstable to afford “learning” (e.g., Halpern, 2006). Developmental conditions and results are touted in the literature on OST programs but the ways in which such features create conditions for learning, as defined by a transformative activist lens, have not been explored (see Mahoney et al., 2005 for examples of studies of developmental conditions with no links to learning). The ways in which science is positioned remains largely unexamined, with exceptions being the science-as-cultural-practice literature (e.g., Fusco, 2002). Yet, as I noted earlier, such program examples as are found in this literature are not necessarily illustrative of common practices in OST programs, which tend to be less sustained over time, more fragmented in approach, and less connected with community settings. I examine programs that are perhaps more typical in some ways than those programs described through the important research of scholars such as Fusco, Roth, and Barton. My goal is to add to their contributions, using a transformative activist lens that I posit provides powerful explanatory power to studying science in OST programs, including the studies that these other scholars have already conducted.

Figure 5. Features of the OST Setting



Although, for reasons described above, my analysis focuses, in turn, on structural, developmental, and conceptual features, my data reveal how deeply the three are inter-related. Chapter Six will further discuss the reciprocal nature of these relationships.

5.2 Background on the Programs

The programs I observed, during the calendar years of 2007 and 2008, had each received three-year ~$750,000 awards from a federal agency to support their activities. Thus, the programs by definition had relatively stable sources of funding during the two years of data collection. (For this reason, funding, which is normally a major structural constraint in afterschool programs, will not be considered in my analysis.) Additionally, the programs were designed to focus on science. In this sense, these were not typical afterschool programs,

but instead could be characterized as science-rich, and even resource-rich, OST programs. Nevertheless, by virtue of being both voluntary and held during after-school hours, they were subject to many of the same structural constraints that are typical of OST programs, as will be shown below.

As noted in Chapter Four, I selected the three programs discussed in this study from a larger group of sixteen based on observed variations in their structural features, their developmental conditions, and how science was positioned in the investigations. I will briefly describe the projects here before beginning a more detailed analysis using the three sets of features described above as my analytical framework. (All of the names of people, places, and programs have been changed.)

Program One: Urban Engineers

Urban Engineers ("*Engineers"*) was located in a large Midwestern manufacturing-based city with a majority (>80%) African-American population. The *Engineers* program for middle school children was created by a non-profit educational organization, Midwest Young Engineers, which has been in operation for over 30 years. Midwest Young Engineers serves an average of 4,000 students each year, through in-class science and engineering programs, as well as through intensive semester-long weekend and summer programs. The federal award allowed Midwest Young Engineers to expand its weekend offerings to middle school-aged children in the *Engineers* program. The parent program, Midwest Young Engineers, is strongly valued by the local community, especially

among African-American families, which make up more than 90% of the participants. There is typically a waiting list of students who wish to enroll in the program. Once enrolled, students are expected to, and typically do, stay in the program for a period of several years. Siblings frequently also enroll and participate. *Engineers* took place Saturday mornings, from 9 am until noon, usually in classrooms in local universities. Parents were responsible for getting their children to the program; for the most part public transportation was either not available or difficult to access. The program was advertised through the usual channels, which include notifications through the school systems and word of mouth. Students were selected based on a minimum GPA of 2.5 and strong school attendance. The program also sought to achieve 50% female participation. Classes were taught by middle school science and mathematics teachers from local school districts. The program focused on the topics of sound and music, with children designing their own instruments, and on forces and motion, with children designing and racing mechanically powered cars. Both music and automobiles are strong elements in the local history and economy, and the program incorporated several field trips and family events to partner institutions that included corporations associated with the music or automobile industries. The parent organization, Midwest Young Engineers, boasts a 95% high school graduation rate of its students, as compared to the city average of below 50 percent.

Program Two: Energy Explorers

Energy Explorers ("*Explorers"*) was a two-year program based at a state college located about 30 miles from a medium sized city in a southern state. Led by a professor who also led the university's P-16 community outreach program, the program was developed in response to the state's new emphasis on attracting science-based industries. As a consequence, the state was also developing K-12 science standards and assessments for the first time in its history. The program served approximately 60 middle school aged children, mostly White, often from low-income households. *Explorers* was developed in partnership with local schools and afterschool organizations, which served as the sites for the programs. Students were recruited through flyers that were sent to the parents of children attending the partner schools or afterschool programs. No children were denied enrollment. Parents had to arrange car transportation for the students to get to the program. In addition to a one-week summer camp, the program met weekly after school for 16 weeks during the school year. The program focused on a range of topics related directly or indirectly to the theme of energy, including topics such as cell structures, photosynthesis, and forces and motion. The program was taught by middle school teachers with varying degrees of science expertise and interests.

Program Three: Environmental Researchers

Environmental Researchers ("*Researchers"*) was a one-year program located in a mid-sized Midwestern city that is the home to a growing biotech

industry. The program was based at a local private college. All of the activities took place at the college, using a science lab as the primary classroom, and a nature center classroom in an adjacent, college-affiliated nature preserve, as an occasional classroom. Its partnerships with local industries and science education organizations (such as nature preserves etc.) provided sites for field trips and career exposure. *Researchers* worked with about 80 students per year, over a two-year period. The children attended the program in cohorts of about 15-20, each cohort met on a different day in the week. Each year, all four cohorts participated together in the two-week summer institute. Students were predominantly White and not on free lunch programs. Students were recruited through teachers and principals at local school districts. In most cases teachers suggested to children or their parents that they might enjoy the camp based on their understanding of the children's interests, dispositions, or activities. None of the children who applied to the program were turned away. Parents had to arrange car transportation for the students to get to the program. The program was led by a high school science teacher. Approximately six pre-service teachers from the college's education department were enlisted as "coaches." The focus of the program was on developing understanding of the nature of scientific experimentation through the activities of small research teams, coached by a pre-service teacher, which conducted investigations of local environmental conditions. At the end of the year students participated in an assessment that tested their understanding of experimental design.

5.3 Structural Features and Affordances

In this section I focus on *structural* features that define, organize, and underpin the physical and social setting in which the programs take place. By "structural features" I mean the elements that effectively define and make recognizable members of a given institutional field (see DiMaggio & Powell, 1993 for a discussion of institutional fields and structures). For example, structural features of schools include mandatory attendance, state standards and assessments, annual budgets tied to tax revenue, and required certification of teachers. These structural features create the context in which developmental interactions and disciplinary practices play out in the school classroom. In other words, curricular reforms designed to shape modes of interaction (such as inclusion of the reading rug in elementary classrooms or science kits as opposed to text books) are implemented within a setting that has particular structural features or constants (see, e.g., Tyack and Cuban, 1995, for a discussion of the structural features of schooling that affect both teaching and learning and efforts to change schooling).

Reflecting the literature on structural features and constraints in the OST setting, cited in Chapter Two, I focus on (a) the **setting** of the programs, which tend, in the OST context, to be on loan from other organizations; (b) the **staffing** of the programs, which tend, in the OST setting, to include individuals who also have "day jobs" (and in the cases I highlight involve classroom teachers, an increasingly common pattern in afterschool hiring); and (c) **attendance** patterns which reflect both the voluntary nature of participation, and the fact that programs

held in after-school hours have to compete with sports, music, medical, and other commitments or appointments that are scheduled for children in the after-school hours.

These structural features, as noted in Chapter Two, have been extensively documented in the literature on afterschool programs as the source of logistical and pedagogical constraints. In addition to the logistical challenges that they create, I explore how the structures operate to constitute institutional settings and cultures that have and create systems of meaning for participants. These semiotic spaces create a context in which children can find and generate a sense of meaningful purpose for their science investigations, an essential and driving element, from a transformative activist perspective, for learning.[11]

Program One: Urban Engineers

Urban Engineers (*Engineers*) took place on Saturday mornings, from 9 am to noon, in classrooms located at local college campuses. (From year to year the program might shift college campuses depending on particular funding and partnership arrangements.) The cohort that I observed,

[11] I use the term "science investigations" to denote what otherwise might be called "science activities" (meaning the lessons or tasks that children do in a class or program). I do this to avoid confusion with my use of the term "activity" from a cultural-historical perspective, which describes a larger set of cultural and historical practices.

co-led by Mr M and Mrs S, met at two different campuses during the two years I observed the program. Classrooms were structured in typical fashion, with desks/tables and chairs placed in rows facing the front of the classroom. The adults were positioned at the front of the classroom, where they had and used overhead projectors, screens, and chalkboards to structure the classroom discourse. Mr M was an 8th grade math teacher. His teaching partner, Mrs S, was an 8th grade science teacher. Children used materials like worksheets, calculators, construction materials, rulers, etc., when and as the materials were distributed to them by the teachers for specific investigations. In the investigation described below, children were building "steel can rovers." Over eight weeks, using coffee cans, rubber bands, plastic wheels, and washers in film canisters, pairs of children experimented with the different variables to design rovers that could travel the fastest or the farthest distance. The winning rovers from each of the six cohorts would race each other at the end of the semester.

The following excerpt, from field notes taken on March 29, 2008, highlights some of the structural features of the program: [12]

> When I arrive, at the building (classes are taking place in the basement classrooms of a campus building), the children are already in

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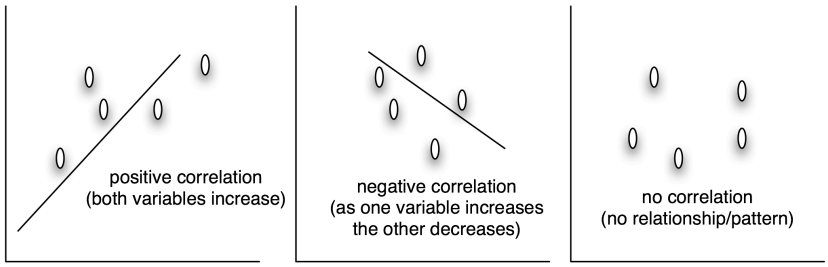
[12] As noted, there are few images of teaching and learning in the OST setting, and many readers may be unfamiliar with the patterns of interaction and activities that one finds in these settings. Therefore I include in this dissertation several excerpts of transcripts that I then analyze for how the structural, developmental, and conceptual features shape opportunities for learning science. My work does not involve discourse analysis and therefore I do not use conversation analysis conventions in the excerpted transcripts, instead relying on methods of representing classroom interactions used by scholars such as Palincsar or Herrenkohl (see Herrenkohl & Guerra, 1998; Palincsar & Magnusson, 2002).

their classrooms. Although the doors to the classrooms are mostly open to the hallways, there is little sound drifting out into the hall. I am directed to Mr M's room, where I find twelve middle school children, half of whom are girls, sitting quietly and sleepy-eyed in rows of desks facing the front of the room, where Mr M is instructing the children. Mrs S is standing to the side working on some papers. On the board is written:

March 29, 2008
Objectives:
To use graphing calculator to observe and discuss performance of the rover.
To explore the relationship between the ballast and the maximum number of wind up turns they can give the rover.

There are three graphs on chart paper taped to the wall, representing work from the previous session two weeks earlier (there had been a break for Easter last week):



Mr M instructs the children to record in their notebooks the definition of a scatter plot, which he then reads aloud from a worksheet. The worksheet says: "Scatter Plot. Type of graph consisting of points, one for each item measured. Points are corresponding numbers from two sets of data called ordered pairs. Relation between two variables is determined by how close they come to form a straight line."

The children are asked to share their results from their homework with each other while the teachers organize their materials and papers.

5:23[13]

[13] In the transcripts that follow the beginning and ending times denote the number of minutes into the recording. For example, this transcript started 5 minutes and 23 seconds into the recording and ends about 3 minutes later at 8 minutes and 31 seconds into the recording. When discussion was paused for a second or more due, not to physical interruptions or distractions (such as writing on a blackboard) but to

Mr M: Let's go over some of these questions, the homework questions that were assigned to you last time.

Mrs S: [from the side of the room] OK, the first question was. Um. What does. What effect does different rubber bands um have on how the rover moves? What effect do the different rubber bands have on how the rover moves?

Mr M: Let's go over some answers. Keep in mind that this is probably the most critical part of the lesson because now we start making observations of what we see in our rover. And from our observations we can start making predictions on how the rover is going to do on the form [the data worksheet]. OK? Depending on how many. Uh. What were the things that we changed? Uh. What were the two things that we changed? Or really three things, not including the rubber band. First question is dealing with rubber bands. What was one of our variables?

Child[14]1: Um, the weight. The number of washers.

Mr M: The number of washers, very good, and what was another variable?

Child 2: The number of wind up turns.

Mr M: The number of wind up turns. So those are the things we need to start looking at in order to determine how our rover. How we are designing it to perform. OK. So how about question number one: What effect do the rubber bands have on the performance. Paul? [inaudible]

Paul: The rubber bands propel the ballast

Mr M: You said what?

Paul: Propel the ballast.

Mr M: What do you mean by that? Put it in layman's terms. [inaudible]

Paul: The rubber bands add energy.

Mr M: You said energy? [he acknowledges Paul's contribution] What I'm doing right now [he says to the children] is just brainstorming. [5 second pause] OK, what else? I pretty much want to hear from each group. What do we have?

8:31

As the children respond to his questions, Mr M records their observations on the projected overhead slide:

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pauses in trains of thinking or speaking, I note these pauses in parentheses. Otherwise, the conversation is following its natural rhythm and pace. Ellipses denote deleted text.

[14] When I cannot identify a child's voice I will refer to him or her as "child." When I do hear or know a particular child's voice, I use a pseudonym for that child.

Changing weights change the spread and distance Few washers → more distance More washers → slower

Setting. The *Engineers* program does not have its own dedicated classrooms or learning settings. Instead they make arrangements with local colleges to borrow their spaces on Saturday mornings. (The ultimate goal of the *Engineers* program is to get students into college, therefore locating the programs on college campuses is an intentional strategy for supporting children's sense of being, becoming, and belonging in the college setting.) These settings are physically structured to have learners sitting in rows facing the front of the classroom where the teacher stands in front of the chalkboard and/or overhead projection screen. Thus a structural feature of the program, one quite common to OST programs, is the use of borrowed spaces; in this case the borrowed spaces were classrooms, which have been historically organized to maintain the locus of authority in the adult figure who stands at the front of the room. This physical arrangement is suited particularly well to the use of Initiation-Response-Evaluation (IRE) methods of interaction (Mehan, 1979), a mode that is enacted throughout the *Engineers* program. As the transcript shows, in this case the teacher directs the conversation, including the substance of what was said, the turn-taking and the pacing. The children wait until they are asked questions to provide answers. The adult validates the answers.

Staffing. Another structural feature that this transcript illuminates is the OST field's dependence on working with adults who have other "day jobs" – in

this case the adults are classroom teachers, hired specifically for their pedagogical and content expertise in science and mathematics. My data reveal that, in their interactions with the children, classroom teachers in the OST setting often stress school science concepts and terms. For example, Mr M, in his exchanges with the children, starts with a codified definition of a scatter plot, which the children are asked to record in their notebooks. In this brief exchange (and in excerpts that follow in this chapter) he stresses terms like *variables*, *energy*, *predictions*, etc. He also uses the common classroom tool of an overhead projector to synthesize and emphasize the scientific concepts embedded in children's comments and answers to his questions. He works comfortably within an IRE framework. In interviews, Mr M reported that his view of the main benefit of the program for participating children was to give them a leg up in school by familiarizing them with tools and concepts that they would be encountering in school in the following years.

Attendance. Finally, although the field notes per se do not reveal the stability of the attendance patterns, as noted earlier, there is a waiting list for participation in the program, and regular attendance is a requirement. The cohort of twelve children that Mr M and Mrs S are working with is in full attendance on the day represented by these notes. It will develop that over two years the program has a 95% retention rate.

How did the structural properties affect program scope and stability?

The school-like structures (with respect to setting, staffing, and attendance) appeared to define the scope of activities to include school-like activities and behaviors. The structures created stable conditions in which teachers controlled the flow of information and activity. The material resources (chalkboards, overhead projectors, graphing calculators, worksheets, and designated investigation materials for the steel-can-rovers) were purposefully assembled to proscribe and focus children's choices and activities. Concepts and ideas were developed over multiple weeks and linked to experiences from prior semesters. The stability of the learning environment was thus quite strong.

The teacher-directed nature of the program, reinforced by the setting and physical organization of the space, appeared to limit student talk and activity to responding to questions or following directions initiated by the adults. Thus, the structural features operated to locate power and authority in the adults. Unlike in the theorized OST science programs cited in the previous chapter (e.g., Douglas & Katz, 2009; Furman & Barton, 2005), children's "voices" or choices did not guide the investigation, the investigations were not grounded in authentic personal or community needs or in questions or concerns of the children. Children did not have opportunities to expand the scope of the investigations in new directions. They worked with preconceived purposes and palettes of materials.

Yet, there were structural differences between the OST setting and typical classroom settings that shaped the organizational culture and contributed to forms of social cohesion that created opportunities that children might not have in

a classroom or other type of learning setting. For example, each *Engineers* cohort was small: no more than 15 students. There were two teachers assigned to each cohort; this, the teachers said in interviews, allowed them to both attend to specific children's questions or challenges and also keep the class moving ahead. (Both of the teachers highly valued the co-teaching aspect of the program.) The teachers were specialists in science or mathematics. The children were not graded in the program. Additionally, each Saturday for 8 weeks each semester children's mornings was devoted to STEM activities.

Thus, while the school-like patterns of interaction were clearly present, at the same time the program signified an unusual social investment – of resources, time, and space – in both the present and future, the being and becoming, of the participating children and in the subject matters of science, mathematics and engineering. Science was presented as a human endeavor and pathway in which these children were invited to see themselves and their futures. Consistently high rates of attendance and the program's waiting list suggest that parents saw this signification. It might be possible to assume, based on the evaluation data that the program has collected that shows that most *Engineers* children go onto college and frequently to major in science-related fields, that children did as well.[15] How this semiotic formation shaped social and developmental conditions in the program will be explored in the next section of this chapter.

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[15] A parent I spoke with said that she had once been a *Engineers* student herself, and although as a child she had hated waking up on Saturday mornings to go to the program (as opposed to staying home and watching cartoons like her friends), she now

To recapitulate, the structural conditions of the *Engineers* program created school-like conditions that at once provided stability and coherence, and also located power and authority in the adult leaders. This power dynamic appeared to put children in relatively passive positions as learners with respect to the subject matter and to the program itself. At the same time, the structures operated to create and signify a special learning setting, which built meaning and social cohesion in the context of science and a community of science learners. This seeming contradiction – between developing program stability and social cohesion (a common goal of OST educators), that operates, in part, to place children in passive positions[16] for learning (a goal not commonly described in the OST literature) – is one of the findings of this study and will be explored further in later chapters.

Program Two: Energy Explorers

The Energy Explorers afterschool program I observed met in the middle school classroom of one of the two co-teachers leading the program two afternoons a week each semester. The classroom was located in a row of "portable classrooms" [trailers] behind the school building. Materials and boxes

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saw it as the most valuable educational experience she had had growing up, and she had put her own daughter into the program as soon as she was old enough. This parent had become a banker.

[16] I use the term "passive positions" to describe structures and patterns of participation that do not permit or encourage children to initiate activities or discussions, but instead require children to wait until instructed or invited by adults to speak or act.

flowed off the shelves and file cabinets and onto the floor where they hemmed in three rows of desks tightly jammed together facing the teacher's desk and chalkboard. There were four girls and six boys in the classroom; about half appeared to be European-American. The children in this program were 6th and 7th graders who attended this same school during the day, but were not necessarily students of the teachers leading the OST program.

On this day, five children were not in attendance because of preparation for state testing. The cohort was led by two white female middle school teachers, one of whom, Mrs R, took the lead in interacting with the students. It was a hot spring day and the Program Manager [referred to as PM in the transcripts that follow] brought in store-bought ice cream cones, which both adults and children lit into when they were distributed. There was a scheduled 30-minute "transition-time" or snack time between the end of school at 2:30 and the beginning of the program at 3:00. As they ate their ice creams, children and teachers sat quietly at their desks talking and giggling in low tones. The mood was convivial. The three adults engaged in cross-talk, alternately involving the children and talking to one another about matters that did not involve the children. The second teacher, Mrs T, worked on the computer to assemble the instructions for that afternoon's investigation. At about 10 minutes past 3pm, she left the room to gather the materials. While waiting for Mrs T to return, the program manager described a solubility experiment she and students in another setting had conducted. The children had to put an Altoid peppermint on their tongues and either leave it there, move it around, or bite it, to see which one dissolved most quickly. Today

the children in the classroom discuss what candy they'd like to use in this experiment.

6:44

Child 1: I want to do a Reese's, OK?

Mrs R: You want to do a Reese's? What about more like cinnamon, hard peppermint, butterscotch?

Child 2: I want to do one of the um Jolly Ranchers.

Children: [general murmurs of agreement or disagreement]

PM: Oh, Jolly Ranchers take a long time.

Child 3: No, I want to do one of these Smarties.

PM: That would be a good choice because it doesn't take so very long that that people lose lose interest, and it's not quite as strong as the Altoid so people aren't quite in so much pain.

Mrs R: I don't think I could do that [hold an Altoid in her mouth]. I don't think I could do that. … [17]

Mrs R: I'm going to rearrange my room, after T-Camp this summer. And I'm going to have lots of shelves and cubbies. Wonderful places to put things. And [the principal] sent out an email that he is trying to get rid of these portables. I said please, I do not want to leave. I want to stay exactly where I am.

Lucas: Why don't you want to move in a room?

Child 4: Yeah?

Mrs R: Uh. I have exactly what I want right here. I don't have to listen to kids going up and down the hall all day long making noise. I don't have to worry about teachers popping in just to pop in. I don't have to worry about kids knocking on the door and running off down the hall. I don't have to listen to other teachers that are talking. Other teachers don't have to listen to me. When I get up here and start going [Yells] "OK GUYS WHAT IS THE WORD?" See? And then when you have to take a run, I don't have to open the door and run out to the parking lot or anything. You can just go out there. And Charlie do we get bothered by a lot of people?

Charlie: No.

Mrs R: It's just great. Plus, we can control our own heat and our own air conditioning. Because if you've been in the computer lab, remember how hot it is there sometimes? You can't even breathe. So I'm perfectly happy. And then I don't want to move

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[17] Deleted two minutes of discussion between Mrs R and PM about another matter.

because [three second pause] look what I have to move. [Gestures around the room overflowing with papers, books, boxes, etc.] Yep and I don't want to have to do it again. I've moved too much. Alright Joe, what's the scientific method?

Joe: [four second pause] A scientific method is a theory for scientists to figure out a experiment or research.

Mrs R: OK. Good. Pat, what do you think would happen if you dunked your nose down that ice cream cone? [kids laugh]

Pat: It would get cold.

Mrs R: It would get cold. If it got stuck all the way in there though, what else would happen? That's what you were doing a second ago. [inaudible] So, what do scientists do, Michael? What do scientists do?

11:37

Setting/Staffing. In this case because the setting is the classroom that belongs to the teacher leading the discussion, I am combining the two constructs. I include this first part of the transcript to show how fluidly the conversation moved from discussing an experiment, to candy preferences, to a teacher's feelings about her classroom, to definitions of the scientific method. It serves to illustrate how the absence of demands on time, curriculum coverage, and other typical classroom constraints may create conditions for different, more relaxed, and possibly more personal, interactions to occur. Yet, despite the casual and convivial nature of the relationships and discussions, the locus of authority remains situated in the adult figure, who is a teacher in her own classroom which the program is borrowing. Thus despite the teacher's willingness to reveal personal preferences as to candies or to her classroom and her relationship with her colleagues, the relationships and interaction patterns with respect to the students cross over from the school day into the afterschool hours: she is in charge of the room. After discussing the merits of her classroom, when the

teacher chooses to move into instructional mode she does so abruptly, asking Joe “what is the scientific method?” Joe himself moves immediately into student mode with an attempted answer. The transcript continues uninterrupted (I repeat the last utterance to preserve the flow):

11:20

Mrs R: It would get cold. If it got stuck all the way in there, what else would happen? That’s what you were doing a second ago. [inaudible] So, what do scientists do, Michael? What do scientists do?

Michael: They try it out.

Mrs R: Well, so do they have a particular way that they go about it?

Lucas: No. Everyone does their own way, pretty much.

Mrs R: You think so?

Lucas: Yeah, a lot of people.

Mrs R: What do the scientific experiments have to be, Alison, in order for you uh to think about whether or not the results are valid? [2 second pause] [inaudible] Joe?

Joe: The experiment has to be tested before you can um show it to a live crowd.

Mrs R: OK.

Joe: If it’s a chemical. If it’s a chemical that could be loud. And so you know if it is poisonous or not.

Mrs R: Ok [inaudible]. Lucas?

Lucas: When I did my project, I just heard somebody say it, so I just used a bottle of diet coke and two menthos, and I tried it.

Mrs R: Did you do it exactly the way that you found it on the [inaudible] video thing?

Lucas: Pretty much.

Mrs R: No, did you do it exactly the way?

Lucas: No.

Mrs R: Did yours turn out exactly the way it did on the video?

Lucas: No.

Mrs R: So if you wanted to get exactly the same results, what are you going to have to do?

Lucas [one second pause] You’re gonna. [two second pause] I don’t know.

Mrs R: Yes you do! What’s going on? Isabel, what are you going to have to do?

Isabel: [inaudible]

Mrs R: If it's gonna to turn out exactly the same way, what do you have to do? If you see an experiment done, what do you have to do? Joe?

Joe: You have to test it out.

Mrs R: How?

Children: [inaudible murmuring]

Mrs R: Kevin what do you have to do?

Kevin: You have to do, see what they do, and then so you can do it so it might turn out the same way. And hopefully if you use the right things in order.

Mrs R: So if you use exactly what the first person or people did on the experiment, if you use exactly the same materials, and you do it exactly the same way, what do you expect the results to be?

Child: Exactly the same.

Mrs R: Exactly the same! Why I had to pull that out of you like pulling teeth out of a tiger. You guys know this stuff.

14:10

This excerpt shows that while the discussion is friendly and relaxed in tone, conducted while children are eating ice creams on a hot day, the teacher is clearly driving for a particular response. Indeed she appears to be slightly surprised when she doesn't get the answer she wants. ("Why I had to pull that out of you like pulling teeth out of a tiger. You guys know this stuff.") The power dynamic appears to shift slightly when Lucas challenges her assertion about following directions carefully:

Lucas: When I did my project, I just heard somebody say it, so I just used a bottle of diet coke and two menthos, and I tried it.

Mrs R: Did you do it exactly the way that you found it on the [inaudible] video thing?

Lucas: Pretty much.

But the teacher persists with her perspective on the correct way to think about scientific experimentation, which effectively puts Lucas into a position of

"not knowing," despite his report that he did successfully conduct an experiment with coke and a menthos:

Mrs R:	No, did you do it exactly the way?
Lucas:	No.
Mrs R:	Did yours turn out exactly the way it did on the video?
Lucas:	No.
Mrs R:	So if you wanted to get exactly the same results, what are you going to have to do?
Lucas	[one second pause] You're gonna. [two second pause] I don't know.

As in the *Engineers* case described above, the structural features of the program, using classroom settings as well as classroom teachers, operate to create school-like participation patterns, including placing the locus of authority in the teacher.

Attendance. As the field notes state, one third of the students were out that day for test preparation. The program took an approach that modularized the investigations so that missing a session would not adversely affect children's overall participation. Frequently the program was structured so that investigations were begun and completed in a single session.

How do structural properties of the OST setting affect the program scope and stability?

In this program, locating the program in a classroom, and indeed the classroom of the OST teacher, seemed to maintain the authority structures of the

school day into the afterschool hours. Although much of the afterschool literature stresses youth development features such as student ownership, voice, and choice, one can see in this excerpt, as in the *Engineers* excerpt, that such features were not always present in these afterschool programs. As such, the power dynamic resided primarily with the teacher, who defined the scope of what science was and how it would be experienced. There was clearly a specific answer to describe the scientific method that the teacher wanted and that the children were unable to provide her. This pattern seemed to shut down Lucas who at first described his successful experiment using menthos and a diet coke, but, when he found himself unable to provide exactly the wording that the teacher was seeking to describe the scientific method, retreated into saying “I don’t know.” The teacher said to him supportively “Yes you do” but then turned to another student to ask for his response. She finally provided the words she was seeking “exactly” to get the child to repeat back to her “exactly the same.”

In terms of how the structures affected the stability of the setting: the teachers went straight from the classroom day to the after-school part of the day. While ice cream cones kept the children engaged at their desks during the transition period, Mrs T turned to the computer to locate and print out the investigation worksheet for the day. She then got up to leave and find the materials needed for the investigation, which were left in another classroom. This lack of readiness provided time for banter among the adults and children, but it also surfaced later in the investigation (discussed in part three of this chapter) when it turned out that the teachers had not tested the materials to see if they

worked. Thus it might be argued that the lack of dedicated time and staff to this program, the tacking on of the program to a school day, led to a lack of full attention to the design and implementation of the program investigations that afternoon, and affected children's opportunities to learn, at least on that day.

My observations about the power structures and planning are not meant to be overly judgmental or negative. There was a great deal of laughter and giggling in this group, throughout the afternoon, even as things did not work out as planned later in the investigation. The reader might recall that it was this program on this day that I cited in Chapter One to describe the kind of crisis or confusion I faced as I both saw "things not working" (wrong materials assembled for an investigation) and yet also saw "things working" (children actively, happily engaged in the investigations and the social learning community). As with *Engineers*, the *Explorers* program appeared to provide an institutional setting that signified to children that science was something that was fun to do; that the program was "special" (in this case the experience offered access to the usually adults-only "behind-the-scenes" at school in that the children got to eat ice cream with the teachers and got to partake in conversations about administrative decisions such as moving classrooms); that the teachers found it an activity worth their own time; and that their peers also valued. It provided a social context in which children could expand their ways of being, doing, knowing, and becoming in the context of science.

To recapitulate, the structural features in this program appeared to affect both the scope and the stability of student activities. The scope was defined by

the teachers, in whom authority was vested for what science was and how it would be experienced. The stability was affected by the apparent lack of time for planning and assembling materials that was perhaps a result of requiring teachers to move straight from classroom to OST time. Yet at the same time there was a clear signification of science as a supportive context for social interaction. The ongoing laughter and joking, the easy dialogic nature of the setting, exemplified by the excerpt from the transcript provided here, continued throughout the two hours. This contradiction between the maintenance of school-like authority structures (resulting from the location and staffing of the program) and the rather un-school-like playful banter in the classroom interactions will be explored further in the next section of this chapter.

Program Three: Environmental Researchers

Environmental Researchers (*Researchers*) took place in a science building at a small private college. The program was led by Lisa, the Head Coach, who was also a high school science teacher at a nearby private school. Before that she was a chemist in industrial research. In addition, there were six "coaches," undergraduate students at the college who were working towards their teaching credential. Children met one afternoon a week during the school year, and attended a two-week camp during the summer. The program was a one-year experience and ran on a calendar, as opposed to an academic, year. The spring semester was organized around a series of investigations designed to develop inquiry process skills – observation, hypothesizing, data collection, data

recording, analysis, argumentation, etc. The two-week summer camp, held in June, was a mix of investigations, group research projects, and field trips to local science-rich sites. In the fall semester students formed small research groups and conducted a multi-week experimental design study of local environmental conditions. They then shared the results of their studies in a poster session attended by their families on the last day of the program. The undergraduate coaches worked with the children at a ratio of about 1:4. During the spring and summer they were assigned to different small groups, or they moved among the children; during the fall semester, they were assigned to one research group per cohort.

With the exception of field trips, almost all program activities took place in the college science building, in a science laboratory. The lab was well equipped with high quality lab tables and lab chairs on roller wheels, plenty of storage space, computers, microscopes, projection screens, and shelves of beakers etc. Each class began with one or more whole-group investigation that were usually brain teasers designed to get children in the mode of asking questions, noting variables and the relationships among them, and hypothesizing or deducing solutions. (I will present some examples of these in the next section.) Typically, this whole group time took about 30 minutes before they broke into smaller investigation groups.

In the fall semester session described in this transcript (which was from my first visit to the program, and which was not tape recorded) there were several different research teams. One was looking at the effects of insects on

decomposition. One was looking at the effects of pollution on local pond water. A third was looking at the effects of chemicals on soil quality. The fourth was looking at pH level effects on plant growth.

My field notes[18] remark that, after the children move into their research teams:

> The groups work quietly, and intently, picking up where they left off [from the prior week], and needing only minimal supervision. The adult leader [Lisa] and two pre-service teachers [coaches] roam through the room helping students with data recording.

At one table there are four girls, all from the same middle school, who are doing a pond study. They are sitting around the lab table each with a sheet of graph paper on which they are planning to develop a data recording method. Their research question is "What chemicals affect microorganisms in the pond?" In addition to a control sample, they plan to add one of either miracle-gro, sand, or salt (three chemicals common to community life in this Midwestern city) to pond samples to observe their effects on microorganisms living in a campus pond. Today they are trying to determine (1) their experimental design, (2) the microorganism they will use in the different pond samples, and (3) the method of data recording. Their coach is a young man, who walks over to see what they are drawing on their graph paper, which is a chart with three rows for data entries.

Coach: Do we want to take data three times?
Child 1: Yes so we can see.

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[18] Because these notes are not from a taped transcript I do not note times here.

Child 2: Yes, I think it will be important.
Coach: Because our biggest thing is to crunch the data and figure out what's going on.

In this example, the coach helps the girls to articulate why they need to record data multiple times: to "see" what is going on more clearly and accurately. The exchanges I observe during this visit are consistently organized around coaches asking children for their opinions and ideas. "What do you think?" The coaches tend to state the various options or decision points, but the children need to decide. There is no one right answer per se. For example, this pond study team needs to decide which microorganisms – daphnia or another – to use in their experimental design. In this case the coach suggests that the girls do some research on the computer to determine which microorganisms to use. While two of the girls go to the computer, two of the girls stay behind to talk about the data table.

Child 3: We could do two [columns], one for macroinvertebrates and the other for the chemicals.
Coach 1: Whatever you want, but what is the point?
Child 4: To show what's going on.
Coach 1: Yes, and make it easy to read.

At another lab table a group of three boys is studying decomposition by measuring the weight of decaying apples under three conditions: with snails, with red worms, and with no animal forms. On this day, they have retrieved the three experimental treatments (in three plastic boxes) from the storage room and have

placed them on the lab table. They gather around the lab table to begin to count the number of snails or red worms, and to weigh and record the weight of the decomposing apple in each box. To their surprise, they discover that all of the snails have died in the intervening week since their last session. The boys speculate on why this might have happened. They then begin to figure out how to salvage the experiment. Their coach sits with them as they talk through options about changing the decomposer or getting new snails.

Coach 2: How could we keep new snails alive?
Child 4: More water and a sealed box.
Coach 2: Why?
Child 4: That's how they came [in the mail]: with a wet sponge and a sealed box.

Thus again, the coach elicits reasoning and explanation from one of the students, rather than instructing the children how to solve their problem. Once the children have agreed on this strategy: getting new snails, and providing more water in a sealed box, the coach reminds them to record what has happened in their lab books. One of the children writes in his lab book:

Redworms =
Snails = All losses. No survivors. Same environment

The session runs from 4 to 6pm. My field notes show that at 5:40, when I do a time check to document what all of the children are doing, they are all

working independently, in small groups, engaged in a variety of activities in the lab. The list from my notes is as follows:

> 5:40
> 2 girls are cleaning out a tank of pond water
> 2 boys are roaming in the hallway
> 4 boys doing the plant study are working on data tables, with everybody laughing and chatting with each other as they work
> 2 girls are talking to a faculty scientist who has come in the room
> 2 kids are working at microscopes
> 3 boys are still working on the compost bins
> 2 girls come in with bacteria samples

Setting. This snapshot of the afterschool session shows that a structural condition of the *Researchers* program is the use of a laboratory (and later the outdoors) for a learning environment. This feature allows the program to put children in small groups at lab tables with their material and various scientific apparatuses. This arrangement seems to support a shift in the locus of control to the children. Children gather together to devise or to examine material, experiments, and data strategies. Sitting around the table together, looking up at one another, they discuss and devise strategies to advance their work. The coaches move through the room helping children to think through problems and solutions.

Staffing. The staffing of this program by young undergraduates is another significant structural condition. At the same time that the children are engaged in the learning activities, the “coaches,” who are not yet experienced teachers, are learning about teaching, about children, and in some cases about the same

natural phenomena that the children are studying. As the transcripts show, their mode of interaction is largely centered on asking questions that can help children structure their approaches to the tasks at hand. This also helps to shift the locus of power to the children or the research teams.[19] In interviews, program leaders stated that the coaches were a major factor in engaging children's interest and emotional investment in the program.

Attendance. Attendance in this program is reported to be stable, although about one-third of students dropped out of the program at the end of the summer, as they transitioned to a new school year and a new set of afterschool commitments. Nevertheless, those that remain tend to participate each week. The team structure, with research teams of four to five children and a coach, allows for the work to continue despite the occasional absence of a child.

How do structural properties of the OST setting affect the program scope and stability?

The structural properties of this program, particularly the use of a laboratory classroom, where children were grouped around lab tables, as opposed to seated in rows facing the front of the room, encouraged the development of a research team ethos that put children in charge of the design

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[19] Cole and colleagues, whose Fifth Dimension project relies on undergraduate psychology students acting as mentors in their afterschool programs, have noted how the structure of having young mentors, who are also in learning mode, supports the constitution of a learning culture (Cole, 2006).

and conduct of the experiments. While the scope of research questions (for example, soil quality, decomposition, or pollution in pond water) was proscribed by the program, children first gained familiarity with these types of phenomena and settings during the spring and summer semesters and were able to elect, in the fall, which questions they wanted to pursue. As noted, the laboratory setting was equipped with computers, microscopes, beakers, and various science lab accoutrements. Adjacent to the lab was a storage room filled with materials, which the program could use in between sessions. This space allowed the program to design multi-week experiments, with materials and live specimens like daphnia or snails, and leave them uninterrupted in between sessions. The availability of storage space, a range of material resources and instrumentation allowed the teacher to respond to children's interests and self-pacing. This is evidenced in the range of different activities children were engaged in throughout the session, as noted at the 5:40 pm time check in the transcript.

In terms of stability, the program designed the structured activities of the spring and summer to build students' capacity in different aspects of scientific inquiry, and also to develop their understanding of what constituted a valid experimental design. This effectively prepared students for the challenge of designing and leading their small team investigations. The lab setting further supported the research team ethos, allowing children to put their materials on the lab tables, gather around them, and make their observations jointly, while recording their data in their notebooks. The research team design also allowed work to continue when individuals had to miss a session for personal reasons,

thus making possible coherent and semester-long investigations in which the experiences of one day built on prior experiences and investigations. Thus a major structural constraint of OST settings was taken into account and accommodated for by the program design.

In terms of the semiotic formation of the program, the institutional and programmatic setting communicated the ways in which science could be experienced through place (college laboratory), as well as (like in *Engineers* and *Explorers*) materials, questions, and processes. The use of undergraduates as coaches was, according to the program leaders, a major feature that engaged and excited the middle school children. Program leaders reported that children developed close younger/older sibling-like relationships with their coaches that shifted the power structures away from adults to the research team. So while on the one hand science was experienced within a professional research and lab-based ethos, it also was experienced as a set of relationships with fellow students and with the young undergraduates whom the children seemed to (according to program leaders, and from what I could tell in my visits) look up to and like. As with the other two programs in this study, science thus became more than a set of concepts or procedures, and instead became a context for relationships.

In summary, the structural conditions of the *Researchers* program appeared to affect both the scope and stability of student activities. Specifically, the program structures of undergraduate coaches, laboratory space, and research teams, operated to shift the locus of control to students and prepare

students over a period of months to take on responsibility for designing and leading their own investigations.

Summary of Structural Features in the Three Programs

In this section I sought to address the question: How do structural properties of the OST setting affect the program scope and stability? The three examples I have provided are different as to form of the data (transcripts versus field notes) and represent three different types of programs. I do not intend to present the programs with assumptions about the value of one approach over another. However, because the literature on teaching and learning generally supports the need for stable conditions for learning, and because the OST literature stresses the value of child-centered activities, it would be easy to draw conclusions about which of these program excerpts is "more" successfully OST-like (child-centered) and organizationally stable. But I caution the reader against jumping to such conclusions because my data provide incomplete accounts of the programs with regard to actual effects on (or contributions to) children. Instead my data highlight learning opportunities that are created through design decisions.

In the three programs I highlighted, all involved borrowed spaces from academic settings. Two were in universities and one was in a classroom. In all three cases, the settings were clearly recognizable as educational, they thus brought with them particular resources and schema (see Hedegaard, 1999; Lemke, 1990; Nicolopoulou & Cole, 1993) signifying that the programs were of

educational purpose and value. While the use of traditionally organized classrooms (desks facing the front of the room) in the middle school and one of the universities operated to maintain the locus of authority in the teacher, who initiated and led conversations and investigations, in the case where a laboratory space was used, the alternative arrangements of groups sitting around tables helped to shift the locus of authority to the research teams. In all cases, programs were required to put materials out of the way of the day-time use of the spaces. In the laboratory case, there was sufficient shelving space to accommodate the children's work, which allowed for multi-week investigations.[20] In the case of the school and the other university, the programs were required to pack up and store materials off-site. Because of their stable attendance, *Engineers* was also able to conduct multi-week investigations in the design and testing of the steel can rovers, but teachers had to pack up and cart home the materials and bring them back each week.

Staffing at the three programs relied on classroom teachers in two cases and future classroom teachers in the third case. Classroom teachers were positioned as the experts in the learning setting, and maintained the locus of authority. The undergraduates, who were learning how to teach in the OST setting, were positioned as facilitators of processes of investigations.

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[20] Faculty from the science education department were co-Principal Investigators on the project, and thus willing to make storage space for the children's work.

Attendance at all three programs was fairly stable. Two of the programs required firm weekly commitments. One of them was subject to more fluctuation as was seen when one-third of the students were pulled out of the *Explorers* program to participate in test preparation.

My first finding from this analysis is that these data seem to suggest that use of school classrooms and school staff maintains school-like approaches to science, which are often teacher-directed with teachers controlling the scope of questions and processes with which children engage. The *Researchers* program's use of laboratories, which have been historically designed to support scientific experiments usually conducted by individuals or small teams, provides a counter example for how structural features created conditions more closely aligned with the child-centered and inquiry-based goals of many OST science programs. Situating the learning environment in a laboratory setting seemed to create opportunities for children to engage in ways of being, doing, knowing, and becoming that were driven by children's own questions and goals. Their use of undergraduate coaches also operated to shift the locus of control to students. A transformative activist stance suggests that programs that are more school-like would provide children who are already invested in the purposes and processes of schooling increased opportunities to do science in a context that is meaningful to them (participating in school science). On the contrary, for children who are not already invested in the purposes and processes of schooling, such school-like approaches to OST science would be less likely to provide opportunities to create and pursue meaningful and consequential goals.

A second, related, finding is that the school-like conditions that were created through the use of school settings and staffing operated to provide program stability and helped to build social cohesion. The *Explorers* program, while strongly teacher directed, was infused with a sense of belonging that encouraged conversations to stray back and forth between the personal and the scientific. All three of the programs established their programs as "special" in nature in terms of (a) the setting (for example, using college settings in two cases, a laboratory in one of those, and even the "behind-the-scenes" experience of Mrs R's classroom), (b) the investment of adult's time (each of the programs had at least two adults working with the children; thus, teacher-student ratios were 1:8 or better), and (c) the material resources that children had access to – in two cases, *Engineers* and *Researchers*, involving materials such as graphing calculators, microscopes, and other types of instrumentation that 6th graders did not normally access. All of these structural elements operated to create institutional settings that expressed value for the children as legitimate science participants (Gallagher, Michalchik & Cheng, 2010) and for science as an important social endeavor. A transformative activist perspective would argue that such conditions provided children with important opportunities to create and pursue meaningful goals.

This apparent contradiction: structural conditions creating stability that both limits opportunities for agency (by maintaining school-like power structures) and also creates the conditions for agency, through building social cohesion and a sense of belonging, is something I will explore further in this dissertation.

A third finding is that the low-stakes (unassessed) nature of the setting also operated to support social cohesion – by creating conditions where students attended voluntarily, where laughter and banter characterized much of the dialogue, where being “correct” or “incorrect” did not have negative consequences for children. At the same time, it also seemed to contribute, in the case of the *Explorers* program, to a lack of preparation that impacted the experience of the investigation (which will be explicated further in the third section of this chapter).

Thus in these three cases, I have found that structural features *shaped* the program experience. However, contrary to some of the literature about the OST setting, the structural features did not operate to significantly *impede* the coherence of the programs. Staff were generally well prepared and stable. Attendance patterns were generally stable. Funding was secure. Space, while borrowed, was relatively well equipped and furnished. The programs I studied were, as noted earlier, well-funded and science-specific programs, and were not “typical” multi-subject OST programs. But they were subject to several of the same constraints in terms of borrowed space, part-time staffing, and variable attendance, and these structures did not drastically or adversely affect the scope or coherence of the programs. While they did operate to import school-like patterns into the OST setting, these same structural features also appeared to signify a shared educational endeavor that provided children with opportunities to engage with science in ways beyond “knowing” to include ways of being, doing, and becoming. At the same time, in two of the programs, school-like norms,

which served to stabilize the programs, also operated to keep the locus of control with adults, and keep children in somewhat passive positions as learners. In one of the programs the low-stakes and inclusive nature of the program, at least in this one observed instance, seemed to correlate with a lack of planning and preparation that would stymie children's opportunities to complete their assigned tasks. These contradictions will be further examined in sections to follow.

5.4 Developmental Features and Affordances

In this section I highlight features of the OST science programs that constitute the developmental conditions of the programs. The developmental conditions that I describe support particular *modes* of activity – the ways in which people engage with each other and the subject matter within the context of the program activities. They create conditions in which children are, or are not, welcomed in and supported to engage in science. The excerpted transcripts in this section have been selected because they exemplify the nature and patterns of activity and interactions among participants.

Specifically, I examine (a) the role that **goals** for the investigations play in creating a sense of purpose and shared endeavor and commitment among participants (Stetsenko, 2008; Stetsenko & Arievitch, 2004); (b) the ways in which **participation** is structured to provide opportunities for children to bring, engage, and develop their interest, capacities, and commitment to the investigations (Cornelius & Herrenkohl, 2004; Herrenkohl & Guerra, 1998); and (c) the role that **relationships** (operationalized in terms of the enacted proximal

processes) among activity participants play in advancing the learning experiences (Bronfenbrenner, 1979, 2005). Referencing studies cited in Chapter Three, I attend to proximal processes such as reciprocity among adults and children[21]; intentional complexification of thinking and acting; and supportive, low-stakes, non-judgmental exchanges and contexts. These constructs – purpose, participation structures, and the proximal processes that constitute relationships between participants – create the developmental conditions within which children's being, doing, knowing, and becoming in the context of science are sparked, supported, and sustained.

Program One: Urban Engineers

The following excerpt from an *Engineers* transcript comes from a session led in the fall of 2008, after the children have begun 7th grade. Mr M and Mrs S were working with a group of 15 children, seven female, to build mechanical toy cars using a Society of Automotive Engineers (SAE) *World in Motion* curriculum kit.[22] These cars, like the steel can rovers from the prior academic year, were to be raced within and across the different *Engineers* cohorts. The program used

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[21] By *reciprocity* I mean the ability of both adults and children to shape, respond to, and influence the direction of the activities, which necessarily means that the locus of authority shifts between adults and children.

[22] Each year, the *Engineers* program reshuffled the groups of children so that all children would have opportunities to learn with different teachers and to learn with different mixes of students. Therefore, some of these children would have been in Mr M and Mrs S's cohort from the previous year, and others would be new, coming in from other teachers' cohorts.

the context of building the cars to explore different mathematical concepts. In this session, children were asked to use a data worksheet to identify the circumferences of different wheel sizes, as one set of variables in their designs. Before they were asked to complete the worksheet, Mr M and Mrs S reviewed the terms and variables involved in determining the circumference. They first discussed the definition of a diameter. After a brief interruption by the program leaders who came to present an award to a team of three boys for their car design (which will be referenced in the transcript), Mr M picked up a discussion about radii:

12:28

Mr M: Alright. Let's go on. The definition. How about radius? Radius. What's a radius? How do I find the radius? [2 second pause] How do I find the radius? If I know the diameter I can find the radius.

Child 1: [inaudible]

Mr M: Right. Half the diameter, or half the measurement of the circle. Very cool. [Writes it up on the chalkboard]

Mrs S: OK, did everybody hear that? [2 second pause] So, once you find, once you find the diameter [2 second pause] it's easy to find the radius. OK?

Mr M: Or, you can say if you measured half of the circle, then that's also uh the definition of radius. You can find it even without the diameter. You can find it with the diameter or without. One half of the diameter, I'm also gonna put it "half of the measurement of the circle" [writes on the board].

Mrs S: That would be kind of easy. That would be pretty easy with this [holds up a car wheel] wouldn't it? Because you've got this this circle right in the middle so it would make it really easy to have a guide or a point of reference to follow. [3 second pause] Because they have half the diameter anyway.

13:56

Mrs S provides context for the children in the practical example of the small plastic wheels that they are seeking to measure. She points out a circle in the middle of the wheel and shows them physically how they could measure from that circle to the edge to get the radius of the wheel. The interaction continues:

13:56

Mr M: Alright. OK, and how about circumference? That's according to a formula. First, what do I mean by formula? Formula. What's a formula? Dolores?

Dolores: Um, something that you [inaudible].

Mr M: Like an expression or something like that? And you? Do you want to add to that?

Child 2: [inaudible] It's like [inaudible].

Mr M: Excellent. Well, in science. You're right a formula can be a scientific term. But if I want to find a formula for a certain uh chemical then it is done the same way. And if I have a formula for a circumference or a formula for a perimeter then it's always the same equation or the same expression. So you are correct. But in science terms you're right you would have to use the same. If I wanted to make a formula for soup.

Child 2: [inaudible]

Mr M: Yes, everything is the same. Excellent. But how do I find the formula for the circumference? What is the formula for the circumference? Go ahead Dolores.

15:22

In this example, Mr M picks up on a child's explanation of a formula as being recipe-like, with particular ingredients and quantities that, when followed, will constitute the same solution. He notes that her response was "excellent" and then goes on to point out that there are different ways of thinking about formulas. One being an exact recipe to reproduce the same product. The other being an abstraction, in the form of an equation, which can be followed using different quantities, in constant relation to one another. It is the latter use of the word

"formula" that Mr M is looking for. The exchange continues (I repeat here Mr M's last statement so as to maintain the flow of the conversation):

15:12

Mr M: Yes, everything is the same. Excellent. But how do I find the formula for the circumference? What is the formula for the circumference? Go ahead Dolores.

Dolores: Um. It's the diameter times pi?

Mr M: Diameter times pi. [He writes the equation on the chalkboard.] Pi times diameter. Now, as we're in seventh grade now. [He looks over at the boys who were just awarded a prize for their cars and who are talking with each other in low tones.] You guys are all excited. Put [your prizes] away. I know you're excited and you did a good job. [He looks back at the whole class.] Now as you guys are in algebra. Now you guys are in pre-algebra in 7^{th} grade. You've been doing algebraic expressions, as you have taken the [state achievement test] I know there is algebra on it. Now when we move to algebra we don't use this times multiplication operation [writes an "x" on the board] as much. Why? Why don't we use it?

Child 2: [inaudible]

Mr. M: Yes?

Child 2: [inaudible]

Mr M: It looks like a. What's a variable?

Child 2: [inaudible]

Mr M: Alright. A variable. Yes, that is the reason. It looks like a variable. A variable. What is a variable? What's a variable, René?

René: It's a letter that likes stands for a number.

Mrs S: Right.

Mr M: Yes. A sign. A sign to evaluate. A sign to evaluate an expression. And to solve equations you use variables. [inaudible] OK. So that's why we write the symbols. Take a look up, Mark's not looking. Pi. [he writes on the board]:

∏ x d
∏ d

Mr M: This is still Pi, times, and d. Whenever you have a symbol. This is a symbol [points to the ∏] next to a variable. D stands for diameter. [writing on the board] OK I put my d in cursive. D is for diameter. This is Pi times d. I can also write it as [writes on the board]:

∏ •d
∏ (d)

Mr M: What's that dot?
Child 3: Times.
Mr M: Times. It's a multiplication sign. Right. So those are the different ways that you can write it.
17:41

Mr M takes the time to show how there are multiple ways to represent the ideas that the children are working with, thus moving beyond the equation that they need to complete the investigation (c=∏d) and introducing several ways of representing the same equation using different symbols. Similarly, he had earlier discussed the different uses of the term "formula" and had shown two different ways to find the radius. Thus, he complexifies children's understanding of the equation and its various symbolic representations.

17:46
Mr M: Uh huh. Very good. If I know the diameter, can I use my radius to find the circumference? Or do I just need the diameter? Can I use the radius to find the circumference? Now what would the formula be for that? OK René.
René: Pi times … [he hesitates for 3 seconds]
Mr M: Think about it. A matter of fact, take a second to talk about it in your group. Take 30 seconds to talk about it in your group. How would you find the circumference using the radius? How would you find the circumference using the radius?
18:32

Mr M frequently asks the children to confer with their partners to come up with responses or ideas, thus reinforcing relationships among the children, who are working in teams to build their cars, and also acknowledging that children

have insights and understanding and that they can learn from one another and together. The interaction continues after about 20 seconds of small group discussions:

18:55

Mr M: Alright. What. Uh. How do I find the circumference using the radius?

Child2: Pi times r.

Mr M: Pi times. [He does a double take and looks back at the child.] Are you saying it's the same thing? Pi times d, the same one?

Child3: [inaudible]

Mr M: It's got to be a little different. Because our first r. If you're saying pi times r you're telling me that diameter and radius are the same thing. Are they the same thing?

Children: No.

Mr M: No, you couldn't use the same formula. What is the formula for the radius?

Child3: [inaudible]

Mr M: Pi times one half r? Dolores?

Dolores: Um … Pi times 2

Mr M: Why is it pi times … 2 what?

Dolores: Times the radius.

Mr M: The radius. First let's see how we did that. I want you to understand why. Just like we want to start with the value of pi. We know it but we want to discover how they found that out. How the mathematicians found that out. [Mr M goes to the board and draws a circle with a radius.] What did I draw in this circle? Look up. What is that? A radius or diameter? A diameter?

Children: A radius.

Mr M: A radius. And what if I did this? [He extends the line of the radius across the circle.] Now what did I have?

Children: Diameter.

Mr M: The diameter.

20:31

Purpose. Transformative activist perspectives posit the pivotal role that goals play in driving activity and learning. The developmental literature in OST

science also holds that authentic and meaningful goals are essential for engaging children's participation and commitment to the investigations. The ultimate goal of the investigation described in this excerpt is to review the terms and formulae related to determining the circumference of the wheels to help children identify and select the wheel size that would optimize the performance of their cars. To do this, children are asked to measure and record different wheel sizes, which they will later test, along with other variables. To measure and record the wheel sizes, they need to know how to determine the circumference of the wheels. To help the children determine the circumference using the equation c=∏2r or c=∏d, the teachers review the terms and what they represent in the actual case of the wheels. Thus, although the IRE mode of interaction in this transcript appears to be quite typical of classroom interactions, and the use of a worksheet is another common classroom artifact, the substance of the discussion is not abstracted from the vested goals that children had to make their cars competitive.

Participation Structures. The participation structures in this program, as noted above, are traditionally teacher-centered, using IRE modes of interaction. These structures create familiar and passive patterns of interaction for the children. In this sense they do not challenge children to think or act differently than they might in the classroom. As is also seen in the transcript excerpt from earlier in the year, children are subdued during these sessions, usually only speaking when called upon, speaking in low voices, and not getting visibly excited about the conversations (thus much of what the children say is inaudible

on my recordings; Mr M's teaching pattern of repeating what children say to the whole class allows the reader to infer the substance of what children say). From a transformative activist stance, the program has created limited opportunities for children to create and pursue their own meanings and goals within the program's science investigations. Rather, as in school settings, the science learning goals are fairly proscribed and the patterns of participation are fairly uniform. Instead, participation structures are organized to affirm the children's studentships: their role as learners who wake up early on Saturdays to advance their academic (and career) prospects, their role as respectful participants in a community of other learners, and their role as capable students in the field of science.

Relationships Expressed Through Proximal Processes. Bioecological perspectives view proximal processes as "the engine of development." They are the means by which adults welcome in and support children's engagement in social activities. Mr M and Mrs S are consistently patient and respectful. In the excerpt, we see the adults consistently affirming the ideas of children, working with them even when the ideas are not quite right, as when one of the children asserts that you can find the circumference through the formula "pi times r" and Mr M, pressed for time, doesn't simply say "no" but instead probes further:

> Mr M: Are you saying it's the same thing? Pi times d, the same one? It's got to be a little different. Because our first r. If you're saying pi times r you're telling me that diameter and radius are the same thing. Are they the same thing?

Additionally, Mr M asks children to confer with one another, creating conditions for reciprocity, in that children's ideas and understanding are given privilege in the classroom. His modes of interactions seek to complexify children's understanding, at least discretely, for given concepts or ideas as they are encountered. Mrs S helps to contextualize many of the concepts children are encountering by reinforcing key ideas and by providing practical or concrete tips that they can use as they carry out their assigned work.

How do the developmental conditions affect children's patterns of interaction and social cohesion?

As described in Chapter Three, development is understood as a lifelong process of continuity and change with respect to one's capacities (physical, emotional, intellectual and social) to act in and upon the world. Action always takes place in social contexts, mediated by culturally and historically developed tools. Being supported to take up, appropriate, and transform these cultural-historical tools through processes of doing, knowing, being, and becoming is what constitutes teaching-learning. In this section, I examine how the developmental conditions of the OST programs, specifically, the goals, participation structures, and relationships, provide opportunities for children to move along a trajectory of learning and development that encompasses introducing children to cultural-historical tools and schemata, and supporting their active appropriation and goal-oriented use of these tools to contribute and make change in themselves and their worlds (see Figure 6).

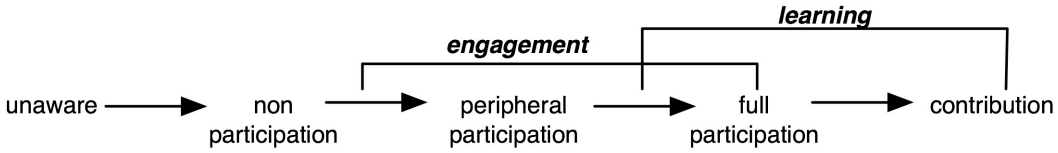


Figure 6. Trajectory of Learning and Development: Participation to Contribution

In *Engineers,* the investigation was structured to engage children in designing, testing, and racing their own cars, and the science, mathematics, and engineering that children reviewed and used was oriented towards these goals. Children used the equation for finding the circumference to measure and record the effects of different wheel sizes on their cars' performance. The goal was established by the adults, but it had been selected to appeal to children in the context of racing their cars. While the investigation was tied to goals children had to maximize the performance of their cars, the participation structures operated to keep children in primarily passive positions, if psychologically safe (they were not chastised or punished for having wrong answers, as the transcript shows), with respect to the activities of the classroom.

Despite the locus of control residing with the adult, we saw different levels of reciprocity in the interactions: children's ideas were welcomed and valued and were treated as the substance through which the conversation developed. Children were asked to confer with one another. Teachers did not simply provide information or answers but instead engaged the children to verbalize them. Although the transcript made clear that there were answers that the teachers were driving towards, there was not a simple dichotomy between teacher or

student centered interactions, or even between right and wrong. The inviting, patient reciprocity in these exchanges, along with the structural features such as stable attendance described in the prior section, operated to build forms of social cohesion and belonging in this program. That social cohesion was reflected in consistent attendance, cooperation, and contribution to the classroom discourse. The teacher-centered instruction made room for children's ideas and insights, whether they were the answers they were looking for or not (as in the case of the definition of a formula). The investigation's purpose and the proximal processes thus created conditions in which the balance of power could shift, but the participation structures operated to stymie such a shift.

This excerpt also shows how the instruction sought to complexify children's understanding within particular boundaries or concepts, with the teachers introducing terms, symbols, and different ways of using them, to help to broaden children's awareness and understanding of the concepts they were encountering. This is consistent with Mr M's comment, in an interview, that a major benefit of the program for children was that it gave them advance experience with concepts and tools they would encounter in school in the coming years.

In summary, the goals of the investigation were ultimately about optimizing performance of their cars. Reviewing and understanding school science and math was positioned as a means towards this end. While the purpose and proximal processes evident in the relationships invited children in to participate in and commit to the social formation and cohesion of the program, the participation

structures possibly counteracted this invitation by maintaining children in passive positions (i.e., they did not choose, initiate, or direct) with respect to the activities. Thus, in the case of *Engineers*, it appeared that the developmental conditions were somewhat mixed: they maintained passive student roles, but they were welcoming and supportive of children's participation within this passive framework. It was a psychologically safe (non-judgmental) environment for children. The result seemed to be that the children were not threatened, or terribly bored or disruptive, and at the same time they were not actively or eagerly participating or leading the investigations.

Program Two: Energy Explorers

The following excerpt picks up where the previous *Explorers* excerpt ended. The conversation has moved from general discussions about scientific experimentation to the investigation for the day. The investigation will involve following worksheet instructions on how to construct a battery-operated motor, using copper wire, a cardboard tube, two paper clips, and a D-cell battery. To introduce the investigation, while the second teacher is downloading the worksheet from a computer in the classroom, Mrs R, the lead teacher begins a group conversation about motors. "How many of you came to school today in something that was motorized?" she asks. Many of the children raise their hands. The teacher asks: "What does motorized mean?" The children murmur and raise their hands.

19:52

Mrs R: Madison, How did you get to school?
Madison: I rode in a car.
Mrs R: I guessed. So, does a car have a motor in it?
Children: Yes.
Mrs R: Are all motors the same?
Children: No.
Children: Yes.
Lucas: No they're not. There's a V12 engine.[23]
Mrs R: Alright. Tell me what you know about a motor, Lucas. [inaudible] What do you know about a motor?
Lucas: Well. My dad works [inaudible]. I know that um. I know how it works, a car motor.
Mrs R: [Addressing another student] I want you to move your chair and I want you to turn around, ok?
Lucas: I know how a boat motor works.
Mrs R: [To the other student] Turn your chair around. [To Lucas] You know how a boat motor works? [Two second pause] Tell Carter, whisper it to him. Joe, do you know how a motor works? [One second pause] Pat, do you know how a motor works?
Pat: I think I do.
Mrs R: Well, ok, go over there and tell Isabel. Madison, quit drawing for a minute. Put it up. Jimmy, you know how a motor works?
Jimmy: Nope.
Mrs R: [surprised] Of any kind?
Jimmy: Nope.
Mrs R: Richard, I bet you know how motors works, don't you?
Richard: No.
Mrs R: [surprised] You don't? Alison?
Alison: Yeah?
Mrs R: Violet?
21:48

Over the next 80 seconds, in IRE mode, the teacher asks the children to begin to name the parts of a car. The children identify several different parts of

[23] Deleting about 30 seconds of side talk where a student comes in and others ask him where he has been.

the car including spark plugs, timing belts, air filters, and wiper fluid bottles. Children proffer what they know without waiting to be called upon, talking over each other, directing their statements to the teacher, but also responding to one another in agreement or disagreement. The teacher drives the conversation forward, seemingly looking for a particular answer:

23:20

Mrs R: What is uh happening to our economy these days that's that's caused us to go into recession and things are costing more but we're not being able to buy more because our our salaries aren't going up? Y'all are you going to let Joe be the only one in here [inaudible]. Joe and Lucas. Isabel?

Isabel: Gas

Mrs R: Gasoline. What else comes out of uh gasoline, what else goes into a car that is made from fossil fuels? [3 second pause]

Child: Oil.

Mrs R: The Oil. Are fossil fuels renewable, or not?

Child: Non-renewable.

Mrs R: Non-renewable. So what are they coming up with instead to try to have automobiles run on? [3 second pause] This is affecting our economy too. Joe?

Joe: Vegetable oil.

Mrs R: What kind Carter? The main one?

Child: [inaudible]

[giggles]

Mrs R: Carter? What kind?

Carter: I don't know

Mrs R: Lucas?

Lucas: Um. Cooking oil. I've seen it on Myth Busters.

Mrs R: Well, yeah, that used cooking oil and stuff is one. But there's a a grain that [inaudible]. Remember I talked to you about it. I talked to you when wheat was going up. So anything that has flour in it would be going up.

Child: Corn.

Mrs R: So they're making. What kind?

Child: Corn.

Mrs R: Corn! They are trying to make alternative fuel out of corn. [inaudible]

Lucas: I want to know [inaudible] oil in your car.

Mrs R: I think if you just put some straight cooking oil in your car it would probably jam up the moving parts of it.

Lucas: But my.

Mrs R And it would probably get mixed in with the uh regular motor oil. Because you have to get a certain consistency to keep the moving parts lubricated the way that they do.

Lucas: They showed it on Myth Busters. [inaudible]

Mrs R: Wait a minute, they what?

Lucas: They were using used cooking oil and they had like this tube and they filled it up to the top with cooking oil. They hooked it up to the carburetor and they showed the, it showed how much, how far they got with the cooking oil. And they said how they could run a car with what. [inaudible]

Mrs R: What kind of car was it do you remember? I'm just curious.

Lucas: Um [one second pause] I think it was a [four second pause] 73 Honda, I can't remember.

Mrs R: 73 Honda?

Child: What's a carburetor?

Mrs R: A carburetor is another part of an engine. In an automobile. A muffler that's from the bottom underside. And what does the muffler do?

Child: [inaudible] the exhaust.

Mrs R: And so the exhaust is what? What is exhaust?

Child: Dirty [inaudible]

Mrs R The air that is belching, letting out carbon monoxide. What does it do our environment?

Child: It makes pollution.

Mrs R: It makes pollution. What particularly does it do? Violet?

Violet: [inaudible]

Mrs R: Lets go higher?

Violet: The ozone layer

Mrs R: The ozone layer. [inaudible] And what happens if the ozone layer goes away?

Child(ren): We die.

Mrs R: We *die*.

Lucas: We burn up and die.

Mrs R: Yes underground homes going on, build all the Atlantis on Stargate Galaxy. [inaudible]

Lucas: We'll blow up the sun

Mrs R: We don't want to blow up the sun. Now, let's see. What else?

27:32

Purposes. The goals of this exchange are to draw on children's experiences and prior knowledge about motors before they engage in a battery-operated motor investigation. The adults have not been explicit to the students that the discussion of the car will lead to the building of a battery-operated motor. At the same time, the discussion flows fairly easily out of their earlier discussions about candies, classrooms, and the scientific method. Throughout the recording children giggle and offer their ideas willingly: their easy participation seems to suggest that they are invested in the purpose and value of having the conversations which are related to the immediate classroom context, but also to economic trends in the news, and television shows that they might watch or have heard about.

Participation Structures. The participation structures are, like in *Engineers*, somewhat passive, in that the teacher leads the discussion using IRE modes of interaction. Children for the most part interact directly with the teacher and not with one another, and later they will work individually to build their battery-operated motors. This excerpt is exemplary of the way in which the teacher structures participation in discussions about the science concepts in the context of the whole group social dynamic. Although the dialogue is teacher-directed, it is clear that the teacher is working with the children as a social group with distributed understanding of how motors work. The teacher asks the children to explain what they know to each other, thus validating the knowledge they have brought with them to school as important to be shared with others. Students speak up as ideas come to them.

Relationships Expressed Through Proximal Processes. The group mode of interaction is easy and relaxed. Mrs R invites Lucas to report on what he learned on the television show “Myth Busters” and she references a science fiction show, “Stargate Atlantis,” that the children may know from watching television. She thus allows them to relate the conversation to their home and social lifeworlds. She also expands from car parts and discussions of batteries and motors, to topics such as alternative fuels, effects of pollution, and the consequences of ozone depletion. There seems to be a luxury of time, and a lack of evaluative pressure on the children to provide the right answer on the spot (although she sometimes seems to be looking for particular answers to emerge in the group). These relationships appear to support a sense of belonging among the children.

How do the developmental conditions affect children’s patterns of interaction and social cohesion?

The goal of this investigation was to provide students with a hands-on experience with a battery-operated motor. The introduction to the investigation, shown here, was structured to draw on children’s everyday working understanding of motors. Students referenced boat motors and television shows. The teacher referenced the current economic crisis, and the rising costs of gasoline, which was a major issue in the news at this time. The easy banter in the classroom appeared to secure or reflect children’s active engagement, and

possibly their commitment to acting as full participants in the investigation that will follow.

Of note were the social and the individualized aspects of this exchange. The teacher engaged the group of children as already possessing legitimate knowledge about motors and engines. The children brainstormed as a whole group what they knew about the parts of a car, talking over one another, giggling, sharing their own experiences, referencing experiences from home (one child talked about his father's job, another about television, or their understanding about the ozone). In this sense the teacher created a safe psychological space where science was signified to have salience in their everyday lives as well as value in the program (Hedegaard 1999; Lemke, 1990). The balance between the individual knowledge and contributions to the discussion, and advancing the whole group's trajectory in identifying the relevant components of engines, was achieved through teacher-directed exchanges, where she called on people individually to declare and share what they knew. In this sense, the social and developmental conditions were welcoming and reciprocal, despite the school-like participation structures. Children were thus developing their capacities to participate in social communities organized around science and science learning. Knowing and sharing knowledge, especially knowledge that has practical applications in the everyday world, was an important practice within this community. In this way, the developmental conditions provided opportunities for children to move along a trajectory of deepening participation and affiliation with a community of science learners.

In summary, the purpose of this investigation was adult-driven but seemed to be comfortably connected to the patterns of interaction of this program. While the investigation's goals and participation structures were teacher-directed, arising from the power the teacher maintained in this setting, the proximal processes that animated the exchanges signaled an openness and reciprocity and sense of belonging. There was a more relaxed atmosphere than one might expect to find in a school. Through the lens of a transformative activist stance, children were seen to be provided the opportunity to develop themselves and their learning community as legitimate participants in science discourses and investigations. This provided a grounding through which they might later develop and articulate goals for themselves or their world vis a vis using cultural tools of science to achieve change. The extent to which the program further equipped children with tools and knowledge to engage in such practices will be reviewed in part three of this chapter.

Program Three: Environmental Researchers

The following *Researchers* observation was made during the third week of the second year of this program, which involved a new cohort of students. As noted previously, the beginning of each *Researchers* session began with whole group brain teasers. The goal of the brain teasers was to get children into a mode of noticing, hypothesizing, and communicating their ideas. Because this excerpt comes from early in the year, this particular session engaged children in

three different brain teaser exercises before they moved into research teams; later in the year, the sessions usually began with just one.

On this day there were 18 seventh-grade children, five female, along with 6 undergraduate coaches (three female and three male) and Lisa, the Head Coach. After the first brain teaser investigation, Lisa refers to the chalkboard where she has written a definition of a scientific hypothesis:

Must explain how or why Must be possible Must be testable

3:45

Lisa: We want to remember that a good scientific hypothesis explains how or why. It has to be possible. So we have some very creative people in the room so let's make sure that it is within the realm of possibilities, when you're coming up with it. And then it has to be testable. So that means that it has to have the possibility of being wrong or being [inaudible] to negative evidence. So the first one that I'm going to read. I'm going to read the scientific findings and then give you one of my ideas of what I think. And that's to encourage you to realize that even though there's one hypothesis, you've got to open up our brains and think about other possibilities that there could be. Different possibilities. So here we go with our first one.

Lisa then reads a short clip from a newspaper article that reports that a study has found that in Los Angeles the fires that cause the most damage are the fires that have the most fire engines attending. She looks up at the children:

5:44

Lisa: So my idea is that if there is a fire in a city you are better off sending one truck. That is my recommendation. Do you agree with this? How about other ideas?

Child 1: Um. Maybe they bring more damage because more trucks come because it's a bigger fire.

Lisa: Oh. Your idea is that the reason more trucks are going.

Child 1: It's a bigger fire.

Lisa: Is that it's a bigger fire and.

Child 1: [inaudible].

Lisa: OK, so you're tying the number of trucks to the size of the fire. Any other ideas? So I had the idea that it would be better off [be]cause more trucks cause more damage. [inaudible] Now we have another hypothesis that maybe all of the trucks are going because the fire's bigger and that means there will be more damage. Does someone have another hypothesis that might be different than those? Think about the two things that have already been said, and something different.

Child 2: Well, maybe they're sending all their trucks because the fire is like so big and everything. It's actually the trucks that are getting damaged so and like the trucks might be pretty expensive so.

Lisa: OK.

Child 2: It might be the actual trucks that are being damaged because of all the fire.

Lisa: OK. Explain that a little bit more. It's not because of the fire. But what's happening since there are all these trucks?

Child 2: Well. If they say 'oh it's a big fire.' So they send all their trucks, and um there are. Fire trucks are pretty expensive, I think. So what they would do if they sent all their trucks and maybe their trucks get damaged from the fire then that actually might be most of the damage that they are talking about.

Lisa: Oh. So it's not the damage caused by the fire trucks. It's the fire that damages.

Child 2: The trucks.

Lisa: So that's a little bit different.

Child 3: Um. I think there's no difference because um I think that the water from the fire trucks is what is doing the damage.

Lisa: Ah?

Child 3: So if they send more or less, it would be the same.

Lisa: So who's who's putting the water on the fire?

Child 3: The fire trucks.

Lisa: OK. So what you want to say is that more… If I send my idea [inaudible] and they're saying

Child 3: Well, if there's more, they take out the fire quicker, but there's still the same fire damage.

Lisa: OK, so help me put that together with [inaudible]. Does it explain more trucks making more damage? [inaudible]

Child 3: Like. The trucks when they shoot the water, the water can damage. [inaudible]

Lisa: So you're saying that the more trucks are being damaged because they use more water. [inaudible] We have a couple of those. You did a great job of picking different ideas and using them [inaudible].

9:18

Lisa acknowledges each contribution, restating or asking for clarification, stressing "*another hypothesis."* She does not try to make the last hypothesis perfectly clear. And she does not draw the conversation to a close with a consensus hypothesis. Rather, after three children have shared possible alternative hypotheses, she turns to another newspaper clip that claims that older people with heart disease don't laugh as much as older people without heart disease. Lisa tells the children that, based on the evidence the report has provided, her hypothesis is as follows:

9:52

Lisa: So here's my hypothesis: If you have a good sense of humor, you'll be healthier than if you don't. That's one idea that I have: is that humor is tied to your health.

Child 4: Um. Maybe people with heart problems are a little bit older than people without heart problems. So, they might um like [inaudible].

Lisa: OK, so the age. If they're a little bit older, they might have a different sense of humor than people a little bit younger without heart problems. That's one idea. So [inaudible] maybe I could go and pick a variety of different [inaudible] and test if there's a difference. Yes?

Child 5: Um. I know that like often people who laugh. Isn't that like good for people? They laugh. [inaudible] So maybe that's like their maybe people who just don't have heart disease they um like laugh at less funny things. Or they laugh more.

Lisa: Say that one more time.

Child 5: Um people who have. Beause um laughing is good for your health. So um people who don't have heart disease maybe laugh a bit more. And that helps them.

Lisa: OK, is that a little different than mine?

Child 5: Yeah.

Lisa: But we're kind of tieing laugter to health. And healtheir people are laughing more. Somehow that's tied together. [inaudible]

Child 6: [inaudible]

Lisa: Ah Excellent. It's not a sense of humor and it might not be about health, but it might just be that when people with heart disease are trying to laugh maybe it hurts. So it's a physical pain that they don't want to laught so much. Yes?

Child 7: Maybe it's because people with heart problems are worried about their heart problems. [inaudible]

Lisa: So that's different than physical pain, they're just kind of emotionally worried and sad. [inaudible] OK. One more.

Child 8: Maybe too much laughter will kill them. Maybe if they laugh too much they could [inaudible] or they can't hear so they [inaudible].

Lisa OK, so we would just have to be careful about deafness being associated with people with heart disease. So the heart disease people might be older and that might correlate with [doesn't finish sentence].

13:15

Throughout these exchanges, Lisa asks the children to clarify and restate their ideas, thus complexifying their thinking and articulation. Some children appear to speak up more than others, but as a group the children appear to be listening and attentive. Then she turns to a third newspaper clip. She asks the children to work at their table groups and develop three possible hypotheses to explain the study results. This device ensures that more children have an opportunity to vocally participate. She reads from a report that says that the number of shark attacks on humans swimming in Florida has increased over the last few years even though there are fewer sharks than there used to be. The children erupt into conversation (there is a lot of background noise on my

recording so some of what the children say at my table is inaudible). At the small table where I am observing, the coach leads the conversation:

14:47

Andrew: [laughs] So here's this. Here's mine. OK. So uh. Cause there are less sharks there might be like less competition for food so the sharks might be getting a little [inaudible] and going after anything that they can find. I mean that's kind of. I guess that's kind of contradictory.

Coach: Why? Why? Why is that contradictory?

Andrew: Because if fewer sharks I'm guessing there are fewer chances for food. I mean more sharks means fewer chances for food.

Coach: Oh, ok, yeah.

Andrew: So. I was just thinking maybe like the sharks are getting like kinda getting greedy?

Coach: Oh, OK.

Raine: I think that people in. [two second pause] America is getting less healthy and getting fatter. [Children laugh] And so the sharks think they they're attacking a turtle.

Coach: OK.

Andrew: But how does that explain though the shark decrease?

Coach: OK. Well. So, well, does that mean that we look more like a turtle, because we're fatter?

Raine: Yeah.

Coach: OK. So that that explains pretty well how there are more shark attacks but how does that explain that the numbers of sharks are going down?

Raine: Because we kill the sharks.

Coach: OK so there's kinda two things. So we're killing sharks and we're getting fatter.

Matthew: Well I was thinking maybe…

Coach: [to Andrew who is writing down the hypotheses] Are you getting this down?

Andrew: Oh, these are hypotheses?

Coach: Yeah. I have to comment about the order [one or two words are inaudible].

Matthew: Maybe um for the shark attacks um people have noticed, like in the news thing that says that on the ocean in Florida um there's a lot less shark attacks. So maybe they're being more careless. And.

Coach: OK.

Matthew: And like maybe they're not being very careful. There's a lot of [inaudible].
Coach: Ok, so that explains the more shark attacks. What about the decreasing amount of sharks?
Matthew: [5 second pause] Well it's sort of like people don't really like sharks.
Coach: OK?
Matthew: So [inaudible] they're trapping them and they die.
Coach: OK, so its kind of another double thing. We're trapping sharks *and* we're being more careless? Is that? OK?
Child: Can we get more snack?
Coach: We have to hold it to one cup at a time, snacks are going pretty fast.
Child: I didn't know that. [laughter]
Coach: We'll share. Um. I have to make one comment about your um and it's that we have to look at all three of those things up there [gestures to the definitions of a hypothesis on the chalkboard]. And yours had to do. What was yours again?
Andrew: Getting greedy.
Coach: OK.
Andrew: Getting greedy.
Coach: Greedy that was the word that interested me because I think that that hypothesis explained how or why pretty well.
Andrew: But we do not have the ability to know shark psychology.
Coach: OK, yeah! And which one, so which one is that?
Andrew: I think it's [the definition] "testable." We really can't.
Coach: Alright.
Andrew: We can't see into a shark's brain.
18:17

Purpose. The purpose of these exercises is explained to the children, and also is an expected part of each session. The purpose is to think through what a viable hypothesis could be, and also to help children understand that there could be multiple hypotheses to explain a given phenomenon, and that one task of scientific practice is to develop ways to test the hypotheses to arrive at the best possible explanation. In these particular brain teasers, the subject matter come from newspaper items that might be of interest to the children: the role of

laughter and longevity, fire and fire trucks, and shark attacks. In this sense, the purpose of thinking through what constitutes a valid hypothesis is not only a clear part of the process within the program but is also made relevant to the lifeworlds of the children and their communities.

Participation Structures. This transcript shows two different forms of participation structure. The first one, when Lisa is leading the conversation about fire trucks and about heart disease, is, like in *Explorers*, a conversation between the adult leader and the whole class. Children are invited to contribute ideas, listen to each other's ideas, and build on each other's ideas. The conversation occurs within a social dynamic of the kids together trying to figure out the answer to a puzzle. While it is somewhat clear that the adult probably knows the answer, the context is not a trick question or a fake question but a puzzler. This creates a sense of playfulness, which provides an opportunity for children to share their ideas before they are fully formulated. In the second half of the transcript, children work in small groups with a coach who serves as an interlocutor to elicit ideas from the children (which will later be shared with the whole group). The adult status of the coach places him at the center of the discourse (children propose ideas to him, he responds). But the participation structures are fairly non hierarchical, with students proposing their ideas as they come up (not waiting to be called on), and the coach and sometimes other children (such as Andrew in this excerpt), helping to clarify what is being proposed and whether or not the proposals are valid hypotheses. Thus the program is structured in ways that value the experiences and thinking of the children: their thoughts and comments

constitute the majority of speaking turns. There is no right or wrong, there are ideas being expressed and worked through, and sometimes, as in the case of Andrew's explanation of greedy sharks being the source of increased attacks, withdrawn based on his own realization of the faulty reasoning.

Relationships Expressed Through Proximal Processes. There is a high degree of reciprocity in these exchanges: The coach welcomes all ideas into the mix, he asks children to restate them to clarify their thinking, and he clearly is working through what they are saying as they attempt to express their ideas. After helping them to restate, he gently pushes back on first whether the hypotheses address both phenomena, and second whether they pass the definitional test that is on the board. In this sense, he complexifies the thinking of the students, to the point where Andrew himself says that his hypothesis can't be tested because of not being able to "see into a shark's brain" meaning to understand, and therefore test, the shark's intentions or thinking.

How do the developmental conditions affect children's patterns of interaction and social cohesion?

In this excerpt children were asked to talk in a small group to hypothesize explanations for an apparent contradiction noted off of the coast of Florida: despite falling shark populations, shark attacks had increased. The subject of sharks was one that many children might have been interested in, and indeed the children had no shortage of ideas for possible explanations, even drawing on information they had picked up in their own reading.

> Matthew: Maybe um for the shark attacks um people have noticed, like in the news thing that says that on the ocean in Florida um there's a lot less shark attacks. So maybe they're being more careless. And.

The relationships evidenced in this transcript show an ease of exchange of ideas, despite how early it is in the year. While the coach was leading the conversation, at several instances the children engaged with one another's ideas. The patterns of participation in this program, built upon the structural features described in the earlier section that included small group work, and undergraduate coaches, appeared to have made children more responsible for their participation, even if the goals of the participation were defined by the adults.

This transcript, more than the other two, shows how the program engaged children in disciplinary practices of science by proposing and talking through possible hypotheses. In this case, participation was constituted by scientific argumentation, which was undertaken through *being* a part of the social group. In this context, science was not being experienced as a set of correct answers or facts, as it was in the *Engineers* and *Explorers* programs. Rather, children in the *Researchers* program were invited in and supported to take up and engage in scientific practices of argumentation as a mechanism for participation.

In summary, the developmental conditions of the *Researchers* project appeared to work reciprocally with the structural features to provide children with opportunities to participate in a social group through the tools of scientific

argumentation. Thus the program was designed to provide integrated opportunities for being, doing, knowing, and becoming in the context of the social group: Opportunities included *being* through serving as a productive member of the social group, *doing* through participation in the group through use of scientific argumentation, *knowing* through reasoning about what constituted a valid hypothesis, and *becoming* through the growing sense of interest, validation, and belonging. (These features are integrated and overlapping, and not isolatable.) As in the other two programs, the proximal processes were welcoming and supportive. They were also reciprocal and operated, through scientific argumentation, to complexify children's engagement and understanding. Thus through a transformative activist lens, in *Researchers*, the developmental conditions appeared to be particularly strong for children's learning and development: the tools and practices of science were the means by which children engaged and participated in a social group that was welcoming and inclusive.

Summary of Developmental Features in the Three Programs

In this section I sought to address the question: How do the developmental conditions affect children's patterns of interaction and social cohesion? My data show that the developmental conditions promoted engaged patterns of interaction and the creation of social cohesion. Reflecting the interrelationships between the social and the structural properties described in the previous section, the ways in which power was located in the adult figure

appeared to directly impact the nature of the goals and participation structures of the different investigations. In the two programs where power resided more firmly with adults, participation structures were more passive and goals were more adult-centered. In the one program where power was more distributed, participation structures were more active and varied; goals were similarly adult-directed in this example. Thus developmental conditions appeared to directly affect children's opportunities to take initiative and pursue their ideas, which, according to a transformative activist stance, would directly affect their opportunities for learning.

The literature on learning and science learning discussed in Chapter Three posits the importance of the creation of authentic goals for supporting the ability and willingness of children to join in the investigations and take up the tools of science to participate and contribute (see Stetsenko, 2008). Meaningful goals, which may have different meaning in different contexts and for different students, help to engage children in the material purposes for which the cultural tools of science can be deployed. For example, science-as-cultural-practice programs described in Table 1 posit that rooting the activity goals and experiences in meaningful contexts is a critical feature of successful learning designs. The purposes and learning goals for the program investigations described here were varied. The *Engineers* program goals were to provide children with advanced experience and insight with concepts and tools (such as the circumference formula) that they would need in school during the next year, thus giving them an academic advantage. This academic work was done in the

context of hands-on constructionist investigations, capped by competitions for the fastest or farthest-traveling cars. The investigations described here grounded discussion of the mathematical concepts in the need to optimize performance of the cars that children were building. The *Explorers* program goals were to engage children in different modular investigations, associating key concepts (such as energy) with local industries and careers (such as power plants). Thus the program aimed to develop children's awareness and interest in science-based fields and investigations. In the transcript included here the investigation's goals were to surface children's prior knowledge about cars and motors. The *Researchers* program aimed to develop students' understanding of scientific experimentation. Thus it engaged students in small groups to practice scientific argumentation. As such, the purposes underpinning the investigations described in these three programs spanned (a) mastering school subject matter (as in the case of *Engineers* and *Explorers*), (b) relating science to student's lifeworlds or outside interests (as seen in *Explorers* and *Researchers*, and possibly in *Engineers)*, and (c) relating the investigations to the disciplinary practices of science. The *Researchers* program clearly did the latter in children's work with hypothesis development. Such links to disciplinary practices were less evident in the *Engineers* and *Explorers* transcripts, except for the fact that children were engaged in productive participation in communities dedicated to science, which is clearly a disciplinary practice of science. One finding of this analysis is that the goals of OST science programs are varied, and linked to the structural and

developmental conditions that affect the ways in which children can engage in the program activities.

As many scholars have shown, participation structures in learning activities are critical to student engagement. Wertsch (1993) notes that many students function well within traditional IRE participation structures; however, for those who do not respond well to traditional classroom structures, or perhaps for those who are not comfortable or interested in the subject matter, shifting participation structures to support greater agency on the part of learners may spark new levels of engagement. Participation structures were different in the *Researchers* program than in the *Explorers* or *Engineers* programs. In the former case, participation was structured around small group inquiries, coached by undergraduate students. In the *Explorers* and *Engineers* programs, participation structures were more traditionally school-like, with children mostly learning as individuals following the lead of the teachers. The *Explorers* program was more informal than the *Engineers* in terms of the degree to which adults and children bantered or strayed off topic, whereas *Engineers* was more oriented to keeping children focused on the task at hand.

My analysis finds that all three programs were structured in ways that validated individual children's participation in a social community engaged in science, *Engineers* was a more school-like social environment, *Researchers* was a more laboratory-like environment, and *Explorers* was closer to school or even a home-like environment with joking and teasing and familiarity being expressed several times by the teacher towards the students. These values were embodied

in the ways in which the program leaders structured activities to explicitly draw on children's prior knowledge and engage children in science talk.

Bronfenbrenner and colleagues have found that reciprocal, complexifying, non-judgmental relationships that develop over time are linked to children's development and learning (Bronfenbrenner, 1979; Bronfenbrenner & Morris, 1998). Their work specifically has been directed to providing adults (whether teachers or caregivers) with tools and strategies for creating such supportive proximal processes for children. In the three programs studied here, there were supportive relationships between adults and children manifested in the reciprocal proximal processes that welcomed children's participation and ideas, provided time for digressions and the personalization of the activities, and were respectful of children's ability to learn and do science. The *Engineers* example, showed how Mr M welcomed and accepted a child's definition of a formula despite it not being the answer he was looking for. The *Explorers* example illustrated how children drew on their own experiences and home lives to share what they knew about motors. The *Researchers* example showed how children were supported to develop and then question the validity of their hypotheses to explain rising shark attacks concurrent with dwindling shark populations. The *Researchers* transcript also provided strong evidence of processes at work to help to complexify children's engagement and understanding. Such complexification was also entailed in the *Engineers* transcript when Mr M detailed ways of representing multiplication in algebra, even though that particular mode of inscription was not relevant to the immediate task at hand. Finally, the non-

judgmental nature of the proximal processes was an important dimension of the developmental nature of the OST setting. The *Researchers* coach accepted and probed all of the ideas that children provided to explain the conjunction of falling shark populations and rising shark attacks. Mr M worked with all ideas that children put forward, whether they were precise, right, or wrong. Mrs R, in the *Explorers* program, was perhaps less accommodating of children when they did not have the right answers, but she did not discourage them from participating and sharing their thoughts.

In summary, my study finds that OST programs may be more adult-centered than is commonly acknowledged in the literature – maintaining IRE participation structures and working from adult-directed learning goals. The resulting power dynamic affects the goals and participation structures, which in turn affects opportunities for learning. A second finding is that OST science learning goals are varied, and related to developmental and structural conditions shaping the program. A third finding is that the developmental features – inasmuch as they welcomed in, supported, and maintained a “low stakes” environment that did not negatively judge children’s contributions – appeared to create social cohesion (Nicolopoulou & Cole, 1993) that provided opportunities for children to deepen their commitment to being, doing, knowing, and becoming in the context of science, and laid the groundwork for engaging with the tools and disciplinary practices of science, which will be explored in the next section of this chapter.

5.5 Conceptual Positioning of Science

While science in OST settings is often described in the literature as hands-on, inquiry-based student-centered investigations (e.g., Coalition for Science After School, 2007), as the previous sections of this chapter have shown, it in fact can look quite different from setting to setting, varying as to the goals, participation structures, and modes of interaction, and supporting differing degrees of student agency, inquiry, and active engagement. From a transformative activist stance, science, when exercised in its historical role as a tool of inquiry and agency, is a potentially powerful context for children's learning. In the low-stakes developmental settings of OST programs, where children's agency is supported through reciprocal and complexifying interactions, there is an even greater potential for learning. As noted before, this view theorizes agency as exercised in contexts that offer authentic and meaningful purposes, where science is a tool to solve matters of consequence to oneself and one's world. Thus, in the following analysis of the OST programs I note (a) where and how the **disciplinary tools and practices of science** are introduced and taken up with authentic purpose and within authentic contexts, and also (b) the ways in which the investigations are structured to advance **students' inquiry and agency**, helping them to move from "participation in" to "contribution to" joint and valued activities. As noted earlier, I theorize inquiry to consist of processes of asking and pursuing questions and I theorize agency to consist of processes of taking initiative and making choices.

Program One: Urban Engineers

The following excerpted transcript is taken from the same *Engineers* session described in the first section in this Chapter where twelve 6th grade students are working on issues related to designing and racing their steel can rovers. The transcript picks up the conversation about 5 minutes after the earlier excerpt. Mr M and Mrs S were continuing to lead the children through a homework assignment that they had been given to complete. The homework assignment had asked children to isolate the variables, and the relationships among the variables, involved in their steel can rovers' performances with regard to speed and distance traveled. They have moved on from the first question (addressed, in part, in the earlier excerpt) to the second question.

As has been already demonstrated, the patterns of interaction and participation structures in this program are quite school-like. However, the particular dialogic nature of this classroom, while following an IRE pattern, takes place within positive social and developmental conditions that are less evaluative and less time-pressured than in many school classrooms that are challenged to cover curriculum and prepare for testing.

The transcript picks up with Mr M turning to question C on the homework assignment. "Wind-up turns" refers to the number of twists of the film canisters (hooked to rubber bands) that children made before releasing the canister. The released canister would unwind, thus propelling the ballast, which makes the coffee can roll. The audiotape of this session did not pick up many of the children's statements, who spoke very quietly, and they need to be inferred from

the teacher's responses. Luckily, as noted above, Mr M tends to repeat student statements, and thus students' stated ideas, if not the wording, can be discerned.

13:12

Mr M: So let's get right into the next question, which is 'What effect does the number of wind up turns have on how the rover moves?' [He looks at a child who had just made a comment in relationship to question B on the homework assignment] You said the more wind up turns, the faster it went?

Child 1: Yes.

Mr M: [writes it on chalkboard] Did anybody notice something different? Like you had less wind up turns and it went fast? The opposite of that? A contradiction to that? [9 second pause] Uhh. Why do you think the rover sometimes moved back and forth? When it stops sometimes it stops abruptly. That was one of our vocabulary. "Abrupt." Abrupt stop. And sometimes it oscillated, meaning it went back and forth before it stopped. Paul?

Paul: [inaudible]

Mr M: Ballast had to [stop moving?]. So it had something to do with the ballast. [16 second pause] Anything else? Anybody have something different? [4 second pause] What did you have?

Child 2: [inaudible]

Mr M: Say that again

Child 2: [inaudible]

Mr M: The rubber bands you were winding up were loose? [5 second pause] We are not exactly sure what is going on yet but we are still discovering. We're still exploring. That's the job of an engineer. That's why I wanna I want to hear, I want to hear as many different answers as possible. OK, anything different? I'm going around seeing similar answers: Because of the rubber bands. Because of the ballast. OK, what did you guys have? Why did it go back and forth?

Child 3: [inaudible]

Mr M: Do you have anything different than that? You have a rubber band on the movement of the ballast? How about you ladies? Do you have anything different in terms of why it's moving back and forth? We're going over these questions that we had for homework. How about 15 right here? Rubber bands. [inaudible] And the last question: Did you have any observations that you wanted to add? Everybody take two minutes talk to your team-mate and give me one observation that you noticed. This is probably the most important question

right here. Observations. Number 15. I want an observation from each team.

16:12

As he does regularly, Mr M asks children to talk to their team-mates to help to isolate and later articulate their observations. This strategy reinforces the relationships among team members and also serves as a reminder that the substance of the conversation is supposed to be coming from the children, not from the teacher.

17:29[24]

Mr M OK. Well what did you notice when you were testing it? What was the result of your testing?

Child 4: We noticed that.

Mr M: [inaudible]

Child 4: We noticed. We noticed that uh when we tested it. We noticed that when we twisted it [inaudible] it goes fast but it goes the wrong way, and so we [inaudible]. But it still going the wrong way but it's still going faster and further with more.

Mr M: So you're saying with more wind up turns it was going faster, or longer?

Child 4: Yes, faster, longer, farther.

Mr M: [writing on the board] I'm going to abbreviate wind up "WU"

Mrs S: So you said with increased windups you had increased speed and increased distance?

Child 4: Uh-huh

18:28

[24] I have excised 77 seconds of dialogue where two children share their observation but their comments are not audible.

Mr M writes this observation on the board, using symbolic notation (*WU* to mean wind up turns) to abbreviate the statement. He writes "more WU → more d, more speed." Mrs S verbally underscores the child's statement so that the rest of the children can be sure to have heard and understood.

18:30

Mr M: Good. Alright other team members. I want to hear from everybody. Observations. Observations. Right here.

Child 5: Mine's broken.

Mr M: It's broken? It's broken now? Or it was broken then?

Child 5: It was broken then.

Mr M: Remember the first week when we were testing it? What did you notice from testing it the first week and then we came back the second week, and then everything was moving and the rover was going [inaudible]. What were some things you had to do to kinda get it go right?

Child 6: Untangle it.

Mr M: You had to untangle the rubber band. Rubber band [writing on the chalkboard]. "RB." Rubber band. Must be untangled. And I think also that the screws had to be tightened. So everything has to be up to specification, everything has to be in order. You can't. You can't have moving and grooving or it's not going to work. It's not going to work properly. It has to be up to specification. That's what they call it. OK, good. Yes?

Child 7: Too many washers would stop the rover from moving.

Mr M: Say it again one more time.

Child 7: Too many washers would stop the rover from moving.

Mrs S: Oh. On the number 31 rubber band it would stop movement altogether? You had too many washers? Like how many washers was it?

Child 7: 15

Mrs S: 15? So when he had 15 on the 31 rubber band, yours stopped running altogether. Did anybody else use that many washers, 15, on the 31 rubber band?

Mr M: Did you notice the same thing? Did it move or did it move a short distance? Did you have a contradiction? What I mean by

Child8: [inaudible]

Mr M: OK. So what you did you notice with the 64 rubber band?

Child8: It went faster.

Mr M It went faster. It went far? OK. But you're saying with the 31 rubber band with the 15 washers it didn't move. It didn't move at all?

Mrs S: Now what did you get?

Dana: Me? Oh. I'd like to add a comment to his. I think um the 31 rubber band. I think it's because of the washers, because of the weight of the washers altogether, because [inaudible] so it stops its movement.

Mrs S: Ok, that's a good observation.

Mr M: Excellent. This is what. This is what we are trying to get out of this discussion here. You're making observations. You're making conclusions.

Mrs S: Tell me your name again?

Dana: Dana

Mrs S: That's right Dana. Did you all hear what Dana said over here?

Mr M: One more time.

Mrs S: Carl, do you want to repeat it Dana?

Dana: I said that it probably it uh it probably did that because the rubber band weight. You add them all together. The rubber band he used was the lighter one so it kind of stopped it. If he had used the 64 rubber band it probably wouldn't have done [inaudible].

Mrs S: He's saying that because of how thin that 31 rubber band was compared to the 64. He's saying that because all of these washers probably kept it from moving when he turned it. Once you got it turned it's kinda locked because that weight holds it down.

Mr: H: [inaudible] That was a good conclusion. We are going to be making more conclusions after we test the rovers today.

22:31

In this extract we can see that teachers are trying to highlight several features about the nature of science, mathematics and engineering: that part of an engineer's job is to discover, to consider multiple variables and findings, to identify patterns and relationships, to collect and record and report data, to use symbolic notation in recording data, to make sense of data, and to design to specifications. For example, towards the end of the transcript one child puts forth

a theory that lighter rubber bands can be slowed down by too many washers. From the teachers' responses it is clear that these types of theories or pattern recognitions are what they are hoping to elucidate from the children.

Mrs S: Ok, that's a good observation.

Mr M: Excellent. This is what. This is what we are trying to get out of this discussion here. You're making observations. You're making conclusions.

The transcript continues with Mrs S taking the lead on helping children to think about how to organize their data. For the next eight minutes, she asks children to tell her the best times and distances they received for different rubber bands and different numbers of washers.

24:58

Mrs S: So. Was there anybody else who had a good run with the 31 rubber band? So, I got now an 8, 10 and you got 5. OK. 8 and 10 are kinda [inaudible] cause they're probably [inaudible]. And you got 8? So. And what was yours?

Child 10: Five

Mrs S: 5, ok? So those are the things you want to make note of. You know, your best runs. Your best speeds. What about distance? Now you said yours was distance and yours was distance right? OK So. What about the 64, number 64. How many washers for your best run for the 64?

Child 11: Nine

Mrs S: Nine? Nine washers was your best run for the 64? That's where you got the most distance?

Child 12: Ten

Mrs S: Ten? OK. Let me give you a marker so you all can mark so that you can kind highlight those runs.

Mr M: And that's why it's important that we observe the data in different ways. Because of course you have different wind-up turns and different amount of washers. So we changed two variables. And this is why we are fortunate to have the [inaudible] where we can observe two variables at the same

time. And we also have the classroom data where we can kind of look for um certain patterns. Because the yellow. The yellow I believe is 64 rubber band, and the orange was the 31. So we can kind of take the class data and see if there are some patterns. Paul you had a question on [inaudible]?

Mrs S: [to one of the children as she hands him a highlighter pen] I am handing you this so you can highlight it.

Paul: [inaudible]

Mr M: One more time, Paul. What was your question or comment?

Paul: [inaudible]

Mr M: With yours.

Paul: [inaudible]

Mrs S: Oh, OK, did you hear what Paul was saying? What Paul was saying was. This is an observation that he noticed. And correct me if I'm saying it wrong Paul. What I am hearing Paul say is with the smaller washers I mean the smaller rubber band, the fewer washers, the further the distance. With the thicker 64 rubber band, the more washers, the better the run. Is that what you said?

Paul: [inaudible]

Mrs S: Ok, he's saying you are using about half the number of washers than he would with the less, half of the washers or less than you would with the thicker with the number 64 rubber band. Right?

Paul: [inaudible]

Mrs S: OK.

Paul: [inaudible]

Mrs S: OK. OK. Well that's. Yeah. Did you all. Did you all kinda understand that? So. You might want to kinda make note of that, just to have that observation now. Because it may hold true or it may not. But it's an interesting observation. But let me say it again, what he said was [she writes on the board]

The #31 rubber band: if the # of washers is half the number used for the 64# rubber band the distance is further.

30:08

Tools and Disciplinary Practices of Science. In this transcript, we can see that the teachers often have to work to get the children to speak, and when children speak what they say is short in duration and delivered in very quiet voices, such that not only does the tape recorder not pick it up, but the teachers

frequently have to ask students to repeat their statements. At the same time, as was shown in the prior section, the children's statements are consistently welcomed and validated. The developmental conditions are supportive but the IRE structures of the session appear to shut down full engagement and participation.

Science is positioned in this lesson as a field of activity that involves making observations, identifying variables, noticing patterns, and applying the patterns to engineering designs. Two children (Dana and Paul) voluntarily advance their theories of the relationships between the washers, the rubber bands, and the distance traveled. Dana notes that a pattern has emerged where too many washers on the light rubber band seems to be slowing down or halting the steel can rovers:

> Dana: Me? Oh. I'd like to add a comment to his. I think um the 31 rubber band. I think it's because of the washers, because of the weight of the washers altogether, because [inaudible] so it stops its movement.

Paul notes that there is some kind of relationship between the weight of the rubber bands, which are 31 and 64, and the number of the washers. He seems to suggest that the class needs to take into account the doubling of the rubber band size and the doubling (or halving) of the washers to achieve the same results. Mrs S records this idea on the chalkboard in the following way:

The #31 rubber band: if the # of washers is half the number used for the 64# rubber band the distance is further.

Thus in this transcript, we see opportunities for the tools of science (particularly noticing, measuring, recording, analyzing, and theorizing) to be used and taken up in the context of participating in a teacher-led classroom discussion. We might infer from Dana and Paul's statements that the process of collecting and recording data on the worksheet has provided a structure for children to theorize about the relationships among different rubber band weights, washers, and wind up turns, as well as resulting distance and time traveled.

In addition to asking children to share their observations and explanations of what is going on, the teachers provide opportunities, in their probing with children, for children to experience and come to understand several other aspects of the nature of science. For example, when asking children about the number of washers they had for their longest or fastest test runs, they are clearly not looking for a "right answer," but instead are stressing that the goal is to get several different data points, from which conclusions will later be drawn. They also stress the tentative nature of scientific knowledge, when Mrs S remarks on Paul's observation about the relationship between the weight of the rubber band and the number of washers:

> Mrs S: OK. OK. Well that's. Yeah. Did you all. Did you all kinda understand that? So. You might want to kinda make note of that, just to have that observation now. Because it may hold true or it may not. But it's an interesting observation. But let me say it again, …

We also see that throughout the conversation teachers are introducing different technical terms, perhaps words that have not been encountered outside of the context of this investigation: words like, *oscillate, ballast, specifications*. It is not clear if and how the use of these words advances the children's work or ideas, but the use of these words provides opportunities for the children to encounter the kinds of knowledge or information that are associated with being knowledgeable about science in school.

Inquiry and Agency. The worksheet investigation described in this transcript suggests that children did systematically change variables, test run their rovers, and record results. These are elements of scientific investigation, or processes of scientific inquiry. It also seems clear that the questions driving these investigations were generated by the adults. The parameters were defined, and the children followed directions in terms of their investigations for testing and recording the variables. While these processes provide children with firsthand experiences in the disciplinary practices of obtaining and recording data to answer questions, they appear to provide limited opportunities for children to change directions based on unexpected results or new questions that might arise. (It is not known whether or not any of the children in fact found or created such opportunities for themselves.) While the classroom discussion, as noted above, does not suggest that there is one right answer, there does appear to be one right pathway to completion. Agency is exercised within the proscribed pathway for completing the worksheet. Some children might have opted to conduct multiple tests, others fewer, thus exercising agency in their level of

commitment to the assignment. This limitation on the opportunities for children to identify or create their own directions points to an interesting tension in this program: The investigations and discussion position science as “inquiry.” But the experience of the investigation (following direction) repositions science as “knowledge” in that there is a proscribed correct pathway, just as the scientific method suggests that there is a proscribed correct approach to understanding the natural world. In this sense, the *Engineers* science investigations may limit opportunities for students to exercise inquiry and agency.

How does the conceptual positioning of science provide children opportunities for engagement and learning?

Children in the *Engineers* program participated and contributed to an experience in which school-oriented science and mathematics, and their capacity as productive science students, was valued and pursued on weekends, in the context of a dedicated STEM learning community. In this sense, science and the program itself were positioned as tools to support the development of practice-linked identities pertaining to being committed and capable students. There was an expectation that all children can and would succeed.

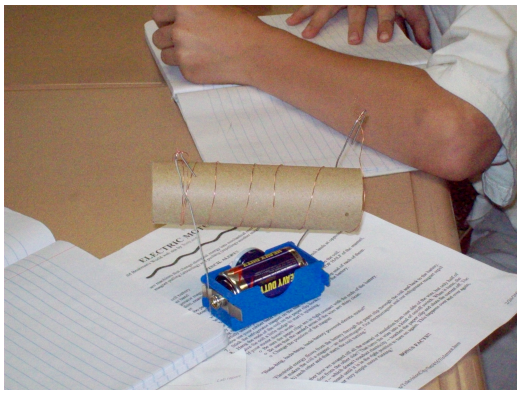
As shown in the transcripts, the *Engineers* program provided students with experiences with science as knowledge and also with science as inquiry. The inquiry processes of science were experienced and discussed through highly structured investigations and teacher-led conversations. Most of the program time was spent in teacher-centered IRE patterns of participation. While this

approach created opportunities for children to develop and share their conceptual understanding, through practices of being good students, there were fewer opportunities for children to engage in science through processes of being and becoming – that is, their roles and actions were largely proscribed by the program leaders, independent of particular interests, dispositions, life goals, or concerns the individual children may have had. There were fewer opportunities for children to appropriate the tools of science towards their own meaningful purposes

The program provided children with opportunities to develop conceptual understanding, to develop their interest and commitment and identities with respect to being science students, and to develop a vision of choices they might make in their lives (as to careers, school, etc.). The *Engineers* program has a high success rate in getting children into and graduated from postsecondary engineering programs. Science is positioned as a tool for agency in the world with respect to pursuing academic and professional pathways for social competency. It may be that for children who have already committed to being students, and to being science students, such approaches are successful in providing, as Mr M put it, a leg up in terms of their schooling. Such approaches may possibly be less appealing to children who have not already made this commitment: children who find science alienating or school irrelevant. The *Engineers* approach to science-as-knowledge, and science-as-inquiry may make it difficult for such children to find a meaningful purpose, to see science as a tool

that they can use to affect change in themselves and their world, and thus drive their learning.

Program Two: Energy Explorers



I now turn to the way in which science is positioned in the *Explorers* program. This transcript picks up shortly after the previous *Explorers* transcript ended. The teachers have passed out the investigation instructions for how to build a motor. The children are provided a copper wire, paper clips, a cardboard tube, and a D-cell battery. The instructions are to spiral the copper wire around the tube, and to connect one end of it to the D-cell battery terminals. The children read the instructions out loud together before starting. Included in the instructions is a set of three trouble-shooting points in case the motor doesn't work. These include making sure that the paper clips are tight, that the sanded wires are clean, and that the magnet is in the right place. Because children work individually, the amount of whole class talk that my tape recorder picks up is minimal during these twenty minutes. However, my field notes describe the investigation:

> 3:40pm
> The kids are reading through different sections of the motor building instructions. Mrs R points them to the materials up front and asks each child to come up and get their materials. They are short one set of materials so two girls are asked to team up. Mrs T tells the children that

> they don't need all of the materials listed in the sheet. For example, they don't need sand paper because the wires are already prepared. They don't need rubber bands because they have battery holders instead.
>
> The children get their materials and begin to work quietly and diligently to follow the directions. There is a low level of chatter and giggling throughout the investigation. The teachers are also chatting with the kids. The energy is very positive and absorbed.

It turns out there are problems with the investigation. The children work diligently, trying to coil the copper around the cardboard rolls but it keeps springing off. They try to connect the paper clips to the battery nodes but the clips keep slipping. The teachers move through the classroom, working one-on-one with the kids to try to help. Multiple conversations are occurring throughout this time. Here are some samples of statements that are not preceded or followed by a response or sustained dialogue, but reflect the nature of the discussion at this point (as I observed it and as my recorder captured it) which was fragments of dialogue focused around trying to get the investigation to work. In the following excerpt Mrs R and Mrs T are trying to help Lucas with his investigation as they work with others at the same time. Therefore several seconds pass between the utterances, however they are all concerned with wrapping the wire around the tube:

> 1:00:04
>
> Mrs T: What can hold that on here? What could you do to the end of your wire to hold it on here?

and

> 1:01:00

Mrs T: This is your lead wire right here. That's your lead wire. Wind the lead wire around the coil two times. [inaudible]

and

1:01:52

Lucas: I think you need to like tape it here cause it keeps coming off. I already rolled the thing around here.

and

1:02:15

Mrs R: Now it's going to stay on right?

and

1:02:42

Lucas I uncurled it and it keeps coming off. See?

Mrs T: Whatever you did here, you did it correctly.

Lucas That's what I did and it [inaudible]. I did that, and I rolled it up twice and it won't stay.

1:03:00

A few minutes later, the teacher who introduced the activity says to the whole class:

1:05:43

Mrs T: What could be. If yours is not working and you followed instructions. First of all you need to look into trouble shooting. Those three things. And then I want you to think about [one second pause] what could possibly be something else that's wrong?

Mrs R: We say operator error. Operator error. [adult laughter]

Mrs T: But if you think. If you got all these parts, and if it's not working correctly. What could be wrong? Well you could start thinking well maybe the battery's dead. I mean that's something you could say right? There's gotta be a reason. Now. [trails off. multiple conversations occurring]

1:06:38

The children continue to work on their investigations, following the same pattern of individual work on the investigation, accompanied by running chatter, and with the ongoing help and commentary of the teachers. About 20 minutes later, with nobody able to get a motor to work, the following exchanges begin. I include this excerpt to note Lucas's response in particular:

1:28:20

Mrs R: You know what I think? That [inaudible] you should write what's going on in your journals now. And we'll put your materials away. Alright.

[children continue to work on their motors, chatting, noody picks up journals]

Mrs R: And Joe when you get ready go ahead and write in there [in your journal]. You can draw it. Put the name of the electrical motor …

[multiple conversations occurring]

Mrs R: You guys go ahead and write in your journals about this [be]cause it's 4 almost 4:20.

Child: [inaudible]

Mrs R: It was though. It was. So we were on the right track.

Mrs R: We're going to try it again.

Mrs R: OK. What happened? Why do you think it happened? What would you do differently?

Lucas: Nothing happened.

Mrs R: Why did nothing happen?

Child: Cause we didn't do it right.

Mrs R: Well, let's have a look at your instructions and see what we might have done.

Child: Cause it's not working.

Lucas: Cause we didn't do it right.

1:30:02

Lucas is the child that earlier in the session was not able to provide the teacher with the statement "follow the directions exactly" despite his successful replication of a menthos and coke experiment. In this excerpt Lucas's complaint

echoes the very point that Mrs R was trying to make earlier in the day: without "doing it right," the results would not be correct.

A half minute later, Mrs T says to the class:

1:30:44

Mrs T: Well we're just going to have to redo it again on Thursday. And maybe just start from scratch. And I think we're going to come in right here rather than we are running around that paper. I mean there are so many things that can go wrong with that. You can wind it too tight. They could be touching each other. They could be too far apart. I mean I don't know. So we're just going to have to work this.

Mrs R: [to the children] Did you guys hear all the variables that Mrs T is talking about?

Mrs T: And of course the battery could be dead. The magnet may not be strong enough.

Mrs R: There you go.

Mrs T: It's just a little bitty thing. So I'm thinking these magnets. These are pretty strong magnets that you bought. Very strong. So I thought that was definitely going to.

PM: We're missing something here.

Mrs R: Do you think those paper clips are made out of the right material? Those paper clips [inaudible]

1:31:54

The statements that Mrs T makes suggest that the problem with the investigation might not be the children's inability to follow direction as much as it is problems with the materials. The adults' verbalized trouble-shooting – considering the different variables involved in the investigation – model particular ways of thinking about scientific investigations. However, this conversation occurs in tandem with the children's running chatter and their continued work on their motors, while meanwhile some are packing up their things and preparing to leave.

Tools and Disciplinary Practices of Science. In this investigation science is positioned as a process for completing a task (building a motor) that each child is asked to undertake at his or her desk. It turns out that the materials assembled for the investigation are problematic in ways that mean that nobody can successfully complete the assigned task. Children persist in their efforts to follow the directions, perhaps reflecting their commitment to the group identity as science capable learners. While the teachers make comments to the group about the need to figure out why something doesn't work, there is not a structured opportunity – time during the session – to lead children through a reflective process of thinking about the variables, assumptions, and decisions that might have led to the failure of the motor investigation. The teachers mention some of the variables, thus modeling disciplinary practices of science related to isolating variables, but they do so while the children are still talking with each other informally and focusing on trying to make the activity work, so it is not clear if the students have heard their statements. Thus the opportunity to use the disciplinary practices of identifying and trouble-shooting different variables is implicit in the activity, and children may well have been engaged in such practices, but the adults do not organize the opportunity in ways that ensure that all of the children avail themselves of the opportunity, or to work as a group to make sense of what they have done and found.

Inquiry and Agency. Leading up to the investigation, Mrs R engaged the children in a broad conversation that identified and drew on their prior knowledge

and experiences with motors. As can be seen in that earlier transcript, children actively participated in this teacher-led conversation. She did not have to ask the same question many times to get a response. The teacher introduced elements of her personal life (her preference for her portable classroom, her interest in cars, etc.). She invited children to share their own knowledge as well as to digress and discuss television shows or what they knew about different parts of motors, as well as about the economy and the environment. These proximal processes of interaction created supportive social and developmental conditions such that the children dove into the investigation with some excitement, and persisted for more than 45 minutes in the face of frustrations resulting from the wrong materials having been assembled. Theorizing inquiry as processes of asking and pursuing questions, this investigation provided rich opportunities for children to ask questions about what was not working and why. However, because the conditions were not such that any child could determine what was not working, and there was no group processing of the situation, this inquiry might have been frustrating to the students. Agency in this investigation was enabled by providing opportunities for children to ask questions of the materials and to persist in their attempts to make the motor work. However, because the investigation had one “right answer” which would be a working motor, and because the materials or directions were not appropriate to help the children reach that right answer, and because of the social norms of the class (including the time constraints) which engaged children in following the directions and seeking to get to the right answer (as opposed to using the materials to achieve

some other purpose) opportunities for agency was limited. Children did exercise agency as students, to ask for help, to make observations about why their motors were not working.

How does the conceptual positioning of science provide children opportunities for learning?

In both parts of the session, science was positioned as knowledge. In the first part, children were asked to name parts of a motor. In the second part, children were asked to follow step-by-step procedures to produce a motor. Although motors were something that all of the children would be familiar with in their everyday lives, their need or desire to work with motors did not drive the investigation. In this sense, considered from a transformative activist stance, science was not positioned as an historical tool invoked to realize some valued purpose. As in the *Engineers* program, science in *Explorers* was positioned as an activity for social inclusion in a voluntary afterschool program. As such, it was positioned as a part of a toolkit for being a capable member of an afterschool academic community.

From a transformative activist perspective, the opportunities for agency and inquiry were constructed not around the pursuit of learning about science (or the natural world), but rather to deepen participation in a social group organized around science. (Of course, individual children may indeed have exercised inquiry and agency with respect to science, but this is not how the opportunity was structured by the adults.) Children's opportunities for learning in and through

science were limited to how the teachers defined successful student participation (answering questions, following directions, participating productively in the social group). Science was positioned as knowledge. Opportunities to gain that knowledge arose from listening and contributing to classroom discussions, and by following step-by-step procedures.

Program Three: Environmental Researchers

During the 2-week *Researchers* summer institute, students went on several field trips to places ranging from natural to industrial settings. On June 23, 2008, I observed a field trip to a park on the coast of Lake Michigan, about an hour's bus ride from the college. The field trip began with a short walk, guided by one of the college science education faculty members (who was also a co-PI for the *Researchers* program), along a nature trail through the woods. Walking at a brisk pace, the faculty member called the children's attention to different aspects of the environment along the walk, including particular species of trees, birds, spiders, and plants. When we came to the clearing where we could see the lake, as well as the back of the tall sand dunes that lined them, he provided some background on the particular formation of these dunes. The dunes line the lake for about three miles, and rise to elevations of about 30 meters.

After lunch, the children gathered around some picnic tables where the afternoon's project was described to them by the faculty member who had earlier taken them on the guided walk. The children were going to split into teams and fan out across the dune cliffs to measure and document its topography. The data

would be submitted to a professor at the college who was doing a long-term study of dune erosion. The faculty member said that his colleague “come[s] out here regularly. So we’re adding our data to her study to try and figure out how much [the dunes are] changing and why.”

The faculty member introduced the children to a number of tools they would need to carry out this investigation, including a standia, compass, measuring tape, a viewer, etc. The roles that students were assigned included viewer, standia holder, tape measurement holders, data recorders, and compass direction setter. The task was to systematically measure the changing height of the dunes at distances of every 10 meters. The children were bussed back to the dunes where they began their measurements. They began their measurements 10 meters from the lake’s shoreline. Every 10 meters they took another measurement, and noted the differential between the last and the new measurement. They had to contend with very sleep slopes at points, or with small perturbations in the landscape, which sometimes meant that they had to reduce their measurements to every 5m or even 3.3m to capture changes in the elevation. At places the dunes dropped back down before they rose back up again. Their measurements at these stages were negative numbers.

The next day, each of the teams was tasked with converting their elevation measurements to a visual representation of the dune’s topography.

Each team handled this task differently. The team I had observed gathered around a chalkboard to create a table and then Cartesian graph of the dune's topography. This decision was made by the coaches (coaches of other teams did not use chalkboards but instead sat around tables with lab books). The male coach stood at the chalkboard, the children sat right next to the coach at an adjacent lab table, with their lab books open on the table. They used their lab books both to call out the data they had collected the previous day, so that the coach could enter it into the table, and to copy the table they were jointly constructing on the chalkboard back into their books. My field notes[25] remark that the children were attentive, despite a great deal of classroom chatter coming from the other groups, which was occasionally distracting. The team developed the following table over the course of about 45 minutes:

Distance (m)	**D Height (m)**
10	+0.7
20	-1
30	-.25
40	-.27
50	+.5

They then turned to creating the visual representation:

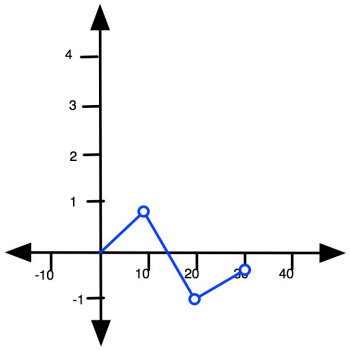
CoachM: Let's graph these numbers.
Child 1: I know how to do a coordinate graph.

[25] This session was not taped, but I collected detailed descriptive observations, including quotes of things that people said, although they need to be considered as paraphrases.

CoachM: OK, but we're going to do a different kind. [Coach M draws an x and y axis on the board. The boy shrugs.]

CoachF: Which one is the dependent and which is the independent axis, the x or y axis? [Children say different things.]

As they begin to graph, kids read off the numbers from the Delta column (marked Height) and Coach M starts to plot them on the x and y axes. For example, at the distance of 10 meters on the x-axis, he puts a point at .7m height on the y-axis (10, .7). The next point (20, -1) is entered. After plotting three points the coach stops and stands back to look at the graph, which is clearly not looking like the terrain of the dune, particularly with respect to the negative dip. He stares at it without speaking, while the children watch along. Then the coach realizes that the numbers are not converting to a topographical map because the height numbers (from the table they had constructed) are not actual elevations but differentials between elevations. Once he realizes this he erases the plotted points and turns to the children:



CoachM: What do these numbers tell us? [Pointing to the Height column of the table]

Child 2: The amount of meters the height is increasing.

CoachM: So we need to take the elevation height and add the delta number to get the next number we need to plot.

Another child asks:

Child 3: What is the triangle?

CoachM: It's a symbol that scientists use to mean change, it's called delta.

The coach begins to reconstruct the graph by asking the children to tell him what the y-axis height/elevation numbers should be by adding the differentials to the previous measurements. The children call out the number of meters the height is changing (up or down). The coach starts to plot out these points, and then he stops. He adds a new column to the table titled "real height" by which he means the actual elevation as measured at each distance, and not just the differential. He asks the children to call out what the real height should be at each distance point. He also adds a row for "zero" distance. Together they adjust the table to read as follows:

Distance	D Height	Real Height
0	0	0
10	+.13	.13
20	+.7	.83
30	+1.0	1.83
40	-.29	1.54
50	+.5	1.59
…		
100		21

One of the children starts to add the numbers to get the real height, but he trips up at the negative number, not sure whether to add or subtract it.

CoachM: Careful… [he explains how to subtract the height using the negative numbers]. … Now we have x and y coordinates.
Child 2: Now, we have to make our graph.
CoachM: Yes, we've done all the hard work, now we just have to draw it.

Child 2: How do we graph the negatives?

CoachM: We don't. See there are no negatives in the real height column. … [starting to map out the grid for the topographical chart.] How high do we need to make this chart?

Child 4: 21.

CoachM: OK, so what kind of scale should we use?

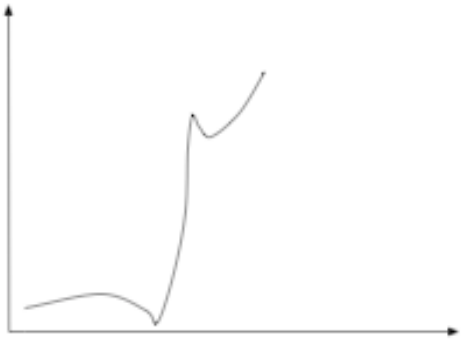
Child 5: Twos.

CoachM: OK. [He enters 2-hatch marks on the Y axis]

CoachM: What do we have to do on our chart? Remember? We need to label axes and give units. [The children discuss different options.] What measure will give us a good representation of the dune?"

He starts to draw out the hatch marks and plot the data points; the children copy the drawing in their journals. When the coach is done the drawing looks something like the adjacent figure, which again does not look like the dune the children had walked on the previous day. The coach says to the children:

Coach M: We have an effect called vertical exaggeration because the scales are different. See, we have 10 meters on the bottom scales and one meter on the y axis.



Tools/Disciplinary Practices of Science. The two-day investigation described in this section involves the investigation and documentation of an actual physical place for an ongoing university-based study of dune erosion. The children visit the dunes, where they are given the same tools that scientists would use to make the same measurements. Some are probably familiar (like a compass); others are probably unfamiliar (like the standia, which is a stick used

to measure elevations). The students are given different roles in the investigation (such as spotter, holder, measurer, recorder). In this way, the science and scientific tools that children use are linked to authentic places, questions, and activities. However, the goal of the investigation (to measure the dunes and produce data for a scientific study) has been developed by the program leaders, and did not come from the children themselves.

Science is positioned as an academic field, linked to authentic contexts, to which the children could contribute. A transformative activist stance would suggest that taking the children to the authentic place could operate to generate a feeling of consequence for the students' actions: they were made aware of the dune erosion, and they knew that their data would contribute to better understanding this phenomenon. On the other hand, from the same theoretical perspective, because the goal was imposed on the children, it is equally as likely that children could feel indifferent about the dunes.

The task the next day, to create a visual representation of the dunes based on the data, provides a context for children to understand how science and math can be used to communicate their physical experience of a geographical location. The accuracy of the visual representation might be more consequential to them due to their firsthand experience of the dunes.

The disciplinary practices of science are used in this investigation to determine the best way to represent their data. It takes the team three attempts to represent the data on the Cartesian coordinate graph such that they feel that the representation is accurate (despite vertical exaggeration). Their collaboration,

use of data journals, use of symbolic representations (such as delta), and use of tables are features of the discipline that are invoked to help in thinking and sense-making. Through the inquiry, and grappling with how best to represent the data, children are provided the opportunity to experience firsthand the ways in which science is not just facts or procedures but ways of thinking, representing, and making meaning of real places or objects or phenomena in the world.

Inquiry and Agency. In this investigation children are engaged in an inquiry that does not have one "right" answer, but that needs to "feel right" to them in terms of representing their experience of the dune. This process appears to drive the inquiry, keeping children engaged through the consequential nature of the investigation: how to represent what they saw, climbed, and measured. The opportunities for agency in this investigation are, as in the other two programs, linked to being productive participants in social groups organized around science. Children can take on different roles, advance their ideas, ask questions, and contribute to the development of the accurate visual representation. Because this investigation is led by the coach, children are put in a more passive position than they might have been, if for example they were working in their own teams. The coach is doing most of the trouble-shooting and problem-solving, as well as actually doing the writing on the chalkboard. But this part of the task (the conversion of data to graph) is difficult. The coach's lead role allows him to model disciplinary practices of science (as discussed above) and provide children with insight into ways of being in science. Thus perhaps seeding agency in terms of including the children in the cultural practices of science.

How does the conceptual positioning of science provide children opportunities for engagement and learning?

In this transcript we see adults and children working side-by-side first to collect and then to figure out the way to convert the data to a topographical representation. The participation structures in the investigation were distributed during the actual data collection on the dunes, with children serving as measurers, spotters, recorders, and direction setters. This experience provided students with opportunities to understand and experience how science and scientific practices could be wielded in outdoor and everyday contexts. It gave children opportunities for using different types of tools, and for understanding the need to distribute roles and tools to conduct a complicated investigation. During the data session, the children participated as equal contributing members and problem solvers in the process led by the coach. The goals of the investigation were to work with real data (data that would be contributed to a larger long term study of the dunes) that came from firsthand experiences the day before on the dunes. Thus the expectation was that the numbers could be used to tell a story that the children had experienced on the prior day. Getting the numbers right, and the graph realistic, became important to these children, and sustained their attention and participation. Thus, science was linked to matters of consequence to the children, and this engaged them in the investigation. In this way, the data session provided students with opportunities to be, do, know, and become through the disciplinary practices of using data to communicate their findings.

Summary of How Science is Positioned in the Three Programs

In this section I sought to address the question: How does the conceptual positioning of science provide children opportunities for engagement and learning? Eisenhart et al. (1996) have argued that "reform science" of the 1990s, i.e., "science-as-inquiry," did not adequately reposition science in society such that children from communities historically underrepresented in the sciences would have reason to affiliate with and pursue science as a field of interest and inquiry. In this view, science is too commonly presented as universal truths, arrived at through linear practices of the scientific method. What science is, how it has meaning in everyday and subjective contexts, and why it is of value, is too often not addressed. A transformative activist stance argues for not only positioning science so that it has meaning, but so that it can be used by learners to make change in their lives and their worlds. Such views suggest that science learning investigations must be authentic and provide opportunities for agency – for developing and pursuing new questions or lines of inquiry. In other words, to expand access and participation in science there must be an epistemological reframing of what science is and can be: it must be positioned as an historical and cultural human endeavor, developed to address questions of interest and meaning to actors in society, or as science-as-cultural-practice. This positioning reintroduces authenticity, inquiry, and agency to the experience of encountering science in structured, organized educational activities. The OST setting has potential to serve as a powerful site for such learning because it is not subject to

the constraints of the school day (with curriculum coverage and testing driving much of instruction) and it is organized around developmental features that encourage children to find and make their own meanings (including developing group values and meanings) as they participate as productive members of a learning community. At the core of science-as-cultural-practice is the use of science to advance agency in the world through inquiry. At the developmental core of OST programs is an emphasis on expanding children's agency.

The three programs described here show that science is positioned in a range of different ways in OST programs. In the *Engineers* program, science was positioned as a set of facts, processes, and procedures that were important to master for success in school and professional life. In the *Explorers* program, science was positioned as a set of facts and procedures that related to children's everyday lives and was pursued in the context of school-like activities. In the *Researchers* program, science was positioned as a set of practices and tools for answering questions about the environment. In this sense, the latter program began to position science as cultural practice – not in the ways that much of the science-as-cultural-practice literature has addressed (for example, using funds of knowledge, see, e.g., Basu & Barton, 2007, Furman & Barton, 2007, Fusco, 2001), but rather within the culture of canonical scientific practice: children used a scientist's tools to collect data for a scientific study. A finding of my study is that science is positioned differently in different programs.

A second finding is that it appears to be difficult for the programs to position science as a cultural practice because of the developmental and

structural constraints. It was more manageable to position science as knowledge – with concrete steps to take and facts to be affirmed. But to the extent that science was positioned as knowledge, the goals and participation structures appeared to limit opportunities for student agency and inquiry. There were proscribed steps, and a right or wrong endpoint. Maintaining the locus of control in the adults tended to limit both inquiry and agency, and thus did not involve students so much in the processes of doing science (developing and pursuing questions) as in a discourse community organized around science. A discourse community has its own value, and is of course a core part of scientific practice, but it is equally important that programs articulate how these discourse communities are positioned, and what they are supported to do. Two of the three discourse communities were teacher-led and did not necessarily tie to consequential matters in which science was a tool to advance students' values or concerns, beyond their values and concerns with respect to being productive members of the community. This latter approach is important, but to deepen students' science engagement and learning, another approach would be to organize the discourse community around the *doing* of science that has consequences to the participants, as is done in several of the science-as-cultural-practice programs described earlier (e.g., Fusco, 2002).

In the *Engineers* program, while science was embedded in the context of developing competitive mechanical cars, the majority of the interactions were focused on school-like exchanges around facts, equations, or patterns abstracted from the context of the car making. In the *Explorers* program, children engaged in

STEM in the context of a safe psychological and social space. In the *Researchers* program, the coach did not have the answers for how best to represent the data collected at the dunes. This created an opportunity for children to engage, as a group, in disciplinary science practices. In the *Explorers* program, the adult teachers did not know how the motor was supposed to work, but this did not translate as much to disciplinary practices. One reason for this might be that the science in the *Explorers* program was positioned as either correct (the motor would work) or incorrect (it wouldn't). Additionally, the *Researchers* program provided time and structure to work through the problems, whereas the *Explorers* program did not. In the *Researchers* program, the final representation that the team developed showed vertical exaggeration, but it sufficed to adequately represent students' experiences of the place, showing the major dips and slopes of the dunes. Thus, a third finding of this study is that to support opportunities for children to engage in science as cultural practice, a critical element, especially given the challenges to adequate preparation time or familiarity of adult leaders with science concepts, may be the pursuit of investigations that do not have a right or a wrong end point, but consist of processes in which tools and practices can be invoked and developed. Such an approach would also provide children with more opportunities to develop and pursue their own goals, and possibly expand their agency with respect to science and science learning.

5.6 Summary of Analysis of Structural, Developmental, and Conceptual Features

In this chapter I looked at three types of features of three different OST science programs: (1) the structural features, (2) the developmental conditions, and (3) the ways in which science was positioned, conceptually, in the investigations. I recapitulate here the major features or patterns I found in the data.

My data show, across the three disparate programs, that while structural constraints do shape opportunities for learning – for example, in two cases bringing school-like norms into the OST setting through the use of borrowed school settings and staffing – they do not necessarily destabilize them. The truncated timeframes and attendance, as well as the borrowed settings, constrain the abilities of the programs to provide multi-day or multi-week learning experiences. To accommodate fluctuating attendance, one program modularized its investigations and another used a research team approach that could accommodate children's absences. The low-stakes (non-assessed) nature of the setting appears to facilitate more personal interactions than might otherwise be found in school-like settings, but at the same time in some cases it is possibly linked to a lack of preparation that affects the learning opportunities for children.

The data suggest that the resources and schema that come with school settings and staffing may stabilize the activities and programs, including contributing towards social cohesion, but they also tend to limit science learning

opportunities for children, as understood from a transformative activist perspective, because they place children in relatively passive positions of following directions for answering questions, using materials, or undertaking investigations. The stability of school norms generally includes having all children follow the same or similar pathways, which does not allow for a wide variation of goals, and therefore limits (but cannot preclude) potential opportunities for diverse individuals to find meaning in the goals of the investigations.

These same structures and passive positions may reinforce opportunities to learn how to be students in science. However, when the purposes and processes associated with science investigations are adult-generated and school-like, such programs may be less appealing to children who are not already committed to the purposes and processes of schooling. That is, such OST science programs may not appeal to children who are disaffected from school or from science. The use of undergraduates as coaches, who lacked the same authority as adult teachers, appeared to help in shifting the locus of control to children, although because this was done in conjunction with a research team approach, it is not possible to tease apart the relative effects.

The developmental features of the settings, which include non-evaluative, reciprocal relationships, and complexifying relationships and interactions, appear to create safe psychological spaces where children feel welcomed to express their ideas, to draw on their non-school lives, and to take risks, in terms of being wrong, without fear of repercussions. The work of Bronfenbrenner and colleagues argues that it is precisely these sorts of proximal processes that are

both necessary for development and are also missing in the learning exchanges of many children in school. In this view, the social cohesion that develops in such OST settings may leverage children's interest and participation, which can expand opportunities for learning and development. Transformative activist perspectives suggest that the ways in which the learning activities are structured around goals that have meaning to children and through participation structures that provide opportunities for exercise of agency and inquiry, including through the sociocultural practices of scientific inquiry, are critical to children's development of interest and capacity to engage in science. But another finding of this study is that OST programs are often adult-centered, and the learning goals as well as participation structures are developed by the adults.

Science is positioned differently in the different programs, and is related to the structural and developmental features of the programs. For many reasons described in the preceding pages, it appears to be difficult to position science as cultural practice in OST settings. As the programs are designed and implemented through adult-centered interactions, science is more easily disconnected from the questions and concerns that have meaning for the children, and that vary among children. It tends to become abstracted from its use in society, and thus not fully experienced as a cultural-historical tool that assists in pursuit of authentic goals. While social cohesion that is developed appears to sustain children's positive participation, the opportunities for learning, as defined by transformative activist views, is limited to the extent that adult-centered programs limit students' agency.

From a transformative activist stance, children move from engagement (spanning peripheral to full participation, see Figure 6) to learning as they begin to develop meaningful goals that drive their active contribution and transformation of goals, tools, activities, and selves. My data suggest that the way in which science is positioned may serve as the tipping point for whether or not these settings can move children from *engagement* with science to *learning* in science where children can use scientific practices and knowledge to contribute to valued endeavors. When science is positioned as a series of facts and procedures, student agency is limited, as in *Engineers* or *Explorers* program. When science is positioned as a set of inquiry practices and processes, as in *Researchers*, children are able to engage more fully intellectually, physically, and emotionally. This affirms the analysis and recommendations of Eisenhart et al. (1996). Children not only can participate in the investigations, but they can take on roles that allow them to contribute to the shared and valued activities. There is greater opportunity for the development and transformation of their own goals and the goals of the group as their engagement and contribution deepens.

The data I have presented suggest that the three analytical features – structural, social, and conceptual – operate reciprocally to invite in and encourage children's engagement, but also to potentially place limits on the possibilities for deep and agentive learning, by importing school norms, fragmenting the learning activities, and positioning science as an ends rather than as a means that can be taken up by individuals to advance their own and shared and valued purposes. In the next and final chapter I extend this analysis

drawing specifically on the theoretical frameworks cited in Chapter Three and situating this analysis in the research literature on OST science discussed in Chapters Two.

Chapter Six

Answering My Questions and Raising New Ones

The need to answer my research question – How is the OST setting positioned to support children's science engagement and learning? – is driven by the increasing academicization of the OST space (e.g., Halpern, 2006), which threatens its vitality as a developmental space for children. This academicization has resulted, in part, from (1) an underspecification of the OST setting and (2) a failure to conceptualize how learning and development relate to one another in the OST setting. My dissertation attempted to address these two issues. In this chapter I draw on my data to show how the OST setting is positioned to support engagement and learning in science, and I make recommendations about ways in which OST science learning can be expanded and enriched. These recommendations will serve as the basis for my future research.

6.1 Specifying the OST Setting

My study contains nine findings that pertain to specification of the OST setting:

1. The use of school settings and staffing can lead to the importation of school-like norms, including teacher-centered instruction.
2. The use of school settings and staffing can support program stability and can help to build social cohesion among program

participants that can signify to children that they are legitimate participants in science practices and science learning communities.

3. The low-stakes (non-assessed) nature of OST settings can create more flexible uses of time that can allow for more personal interactions that can contribute to social cohesion; the low-stakes nature also may contribute to a lack of planning and preparation which can affect learning opportunities for children.
4. The adult-centered nature of OST programs can be associated with adult-generated goals and participation structures that can affect opportunities for student agency with respect to science learning.
5. The proximal processes that characterize the OST setting can build social cohesion and children's sense of belonging, in the context of a science learning community.
6. OST programs have varied goals for children's learning, some programs and some investigations emphasize school knowledge, others emphasize the everyday or authentic nature and use of science, and others stress disciplinary practices and fields. Most emphasize all three of these features in different ways and amounts.
7. Science is positioned differently across and also within programs: sometimes as knowledge, sometimes as inquiry, sometimes as cultural practice.

8. It appears difficult to position science as cultural practice due in part to the adult-centered nature of instruction in the OST setting.
9. Programs that position science investigations with one "correct" way through, and one "correct" end-point to reach, may limit opportunities for students to find and create consequential learning goals. This may be a common approach in OST settings, especially given the growing role of schools and school stakeholders in the OST field.

These findings show how the three features I explored – structural, developmental, and conceptual – inter-relate to shape the programs. Others have explored how physical and developmental structures fundamentally shape practice and agency in the classroom (Tobin & Roth, 2006; Tyack & Cuban, 1995). Less has been done in the OST literature.[26] Research on science in OST settings has primarily focused on the nature of the science learning activities, and the nature of children's experience, and less on an analysis of the setting per se. Indeed, if anything, this literature has tended to make generalizations about the nature of the OST setting as being inquiry-based (Hussar et al., 2009), led by student agendas (Basu & Barton, 2007), guided by student "choice and voice" (Furman & Barton, 2006), and organized around project-based learning

[26] See Bevan, 2010 for one example of a structural-developmental analysis of informal science education programs.

(Coalition for Science After School, 2007). These characterizations can certainly be found in many excellent programs, including in the programs that are the subject of the studies that make these claims. However, as can be seen by the data I have presented here, such characterizations of OST settings are not universal. Sometimes children have little voice and little choice.

Taken together, and viewed through the lens of a transformative activist theoretical perspective, these findings do not paint a coherent or consistent picture of what the OST learning setting is; but they do point to three relevant conclusions:

1. School-like norms in the OST setting (which result in part from borrowed spaces and staffing) contribute to program stability, to social cohesion, and also to passive student participation structures that are well suited to science-as-knowledge conceptions of science.
2. Providing opportunities for students to experience science-as-inquiry requires stable attendance, adequate time to engage in processes of inquiry, storage and other material structures, and time for reflection and meaning-making; some OST programs may be well positioned to provide such opportunities, and some may not be so positioned.
3. Efforts to position science as cultural practice seem to require significant shifts in the power structures that accompany school-like

norms imported through school-like structural and developmental features.

The theoretical perspective that I invoke – that posits agentive efforts to make change in one's self and one's world as the fundamental mechanism of development (Stetsenko, 2008) and that envisions learning (which entails processes of being, doing, knowing, and becoming) as the driver of development suggest that there is great potential for learning in the OST setting because of the social cohesion and sense of belonging that children can find in OST programs (that result from the confluence of features explored earlier). Proximal processes operating in OST settings allow children to engage with science beyond just "knowing" but instead through ways of being, doing, knowing, and becoming. (This can of course also be true in school classrooms, but OST settings, which are not subject to the same time constraints and assessment policies, may be relatively more likely to provide welcoming and reciprocal relationships that allow children to bring themselves to the learning opportunities, to digress, to create, and to take on new roles and stances, than many other educational settings.) This same theoretical perspective, however, argues that learning is driven by the pursuit of meaningful goals, and opportunities for children to find and create meaningful goals (as opposed to pursuing goals established by adults) was not a prominent feature in the programs I studied, at least not with respect to science itself. Therefore, to leverage the full power of the OST setting as a learning space, science programs need to create conditions

that allow children to find and create goals of consequence to them, so that they can act agentively in pursuit of these goals.

From a transformative activist perspective, consonant with the work of Eisenhart et al., 1996, science itself is a cultural tool that has developed historically to address needs and goals of consequence to individuals and to society. Therefore, if introduced and taken up as a cultural practice intended to achieve goals of consequence, it is an ideal context for children's development and learning: it is a tool that they can use to transform themselves and their worlds. From this perspective, re-positioning the OST setting to promote science-as-cultural-practice would create conditions for children to find and create meaningful goals, and provide them with the tools to pursue these goals, and promote their development.

But how to do this given the conditions I described? Taking as a baseline both (a) school-like (adult-led), but low-stakes, conditions and (b) supportive, cohesive social settings organized around science, how can authenticity, inquiry, and agency – features found in the science-as-cultural-practice literature described in Chapter Three (e.g., Fusco, 2002) – be introduced and sustained in the OST setting? Based on some of the findings in this study, including dimensions such as setting, staffing, attendance, goals, patterns of interactions, relationships, and how science is typically introduced and taken up in these programs, I propose that science investigations in these more typical OST settings (more typical than those described in the science-as-cultural-practice literature cited earlier) might be designed to have the following qualities:

- Sparking inquiry, agency and authenticity. Investigations could be designed to use rich and engaging materials (unusual materials or usual materials used in unusual ways) or settings or phenomena that spark questions and curiosity; or designed to relate to real world problems that children are invested in addressing.
- Sustaining inquiry, agency and authenticity. Investigations could be designed with no one “right answer” or end point; to be open-ended; to be designed with multiple pathways through the investigation; to be conceptually rich with phenomena.
- Deepening inquiry, agency and authenticity. Investigations could be designed with structured time for sharing, reflection, and use of scientific argumentation to explain patterns, differences, surprises or other findings; io involve small group work, allowing all children opportunities to share and vocalize experiences.

These suggestions take into account the structural constraints of the OST setting by envisioning programs that may have fluctuating attendance or borrowed spaces. They build on the social cohesion and sense of belonging that students can develop in OST programs by emphasizing the generation of authentic questions, taking up the tools of science to address them, and involving the social group in making sense of them together, thus providing opportunities for being and becoming as well as doing and knowing. They move away from identifiably school-based science activities, which often require structures and

supports like time, materials, and assessments that may not be available in the OST setting. At the same time they do not require taking children out into local communities, which is sometimes difficult for OST programs to do. They do not require in-depth knowledge on the part of program leaders. The open-ended nature of the activities means that they can be done in one afternoon or over multiple afternoons. They provide children with opportunities to take initiative in the development and pursuit of questions that have consequence to them, thus helping children to move from engagement to learning.

I do not propose that these investigations are simple to create or even to find already packaged or tested. I propose that, from a principled theoretical stance, analysis of my findings suggests that these features may be essential for engaging children in science in the OST setting, especially children who may not be predisposed to learn or like science.

6.2 Learning and Development in the Context of OST Science Programs

Vygotskian theories of human development explain how learning and development inter-relate. Learning leads development. Development, in turn, as it is instantiated in changing capacities to act in and upon the world, creates new opportunities for learning. While learning is conceptualized as the taking up, use, and transformation of cultural tools and practices, a broad view of learning means that processes of taking up such tools involve not just knowing (as in transmission models of science learning), nor just knowing and doing (as in inquiry models of science learning) but a co-evolving process of being, doing,

and knowing (Eisenhart et al., 1998; Herrenkohl & Mertl, in press). A transformative activist perspective, with its emphasis on purposeful forward-moving agency, adds the critical concept of *becoming* to this process of learning. Learning does not only involve processes of being, doing, and knowing to afford participation, but also processes of *becoming* that can afford opportunities to contribute to self, as well as the larger human endeavor of science and society (Stetsenko, 2008).

Such views of learning stand in marked contrast to traditional models of learning as knowledge transmission. As such, they require news ways of thinking about educational design, research, and assessment. Learning activities must account for and provide opportunities for the development of these different facets of learning, which always exist in relationship to one another. Complemented by bioecological perspectives that stress the importance of reciprocal, complexifying, and nonjudgmental interactions (proximal processes) for inviting and sustaining participation in social activities, this broad view of learning helps to establish a vision of what strongly supportive contexts for teaching and learning would look like; where children are provided opportunities to move from engagement to learning, from participation to contribution, through authentic, collaborative, agentive inquiries into questions of consequence to the children.

OST settings are well positioned to support this view of learning. OST settings that are organized as social spaces to provide children with opportunities for belonging in the context of learning about and using science for valued

purposes help to not only develop children's capacities to know, do, and be in the context of science, but also provide them a vision of becoming in the context of science. By this I mean that the programs can be designed, as *Engineers* was, to affirm and sustain children's commitment to pursuing the activities of the program. They can help to create a vision for what students can become (college students, scientists and engineers).

In cases where science is positioned as cultural practices, like *Researchers,* programs support *becoming* in the context of science serving as a tool to transform one's self and one's world. In cases such as *Explorers*, children are provided contexts for being and becoming productive science-engaged learners. Designing and tracking how such programs allow children opportunities to continually deepen their participation, expand their use of cultural tools, and ultimately transform these tools and activities as they take on agentive and purposeful stances will begin to document how learning and development are interrelated in the context of OST programs.

6.2.1 Learning and Development in Varied OST Contexts

There is not one model of science in OST. Different types of opportunities posed by different OST programs are all important for children, and they reflect the values, resources, and needs of local communities. The models I highlighted are neither the rich, agentive vision of community-based science that is discussed in the science-as-cultural-practice literature cited earlier, nor are they experiences with science facts and skills that will necessarily reveal themselves

on standardized tests developed for classroom science. Instead, they are varied but generative spaces for children's learning and development in the context of science. Children develop their selves (their self-efficacy, their resiliency, their problem-solving, their commitment to civic issues, as described in the developmental literature) while engaging in the subject matter of science. Different children need different learning and development opportunities and at different times in their lives.

In the programs I reviewed, the children used the equation for circumferences to optimize their cars, they shared their knowledge of car motors before beginning to build a small battery operated version, they considered the ways in which phenomena of shark attacks could be explained and tested. In all of these activities the children brought and developed their selves, their knowledge and experience with science, to acts of engaging and pursuing science in contexts that were not set up to judge or evaluate them as individuals, but rather to engage and pursue science as a valued field of social practice. Thus they provided opportunities for children to validate who they were, what they knew and could do, and what they might become. They did this in different ways, for different purposes, and to different ends.

Such opportunities can affirm the value that children might have for science and the ways in which they can participate and contribute to science learning communities. Such experiences are essential to expanding access to and participation in science (Eisenhart et al., 1996). They also lay the groundwork for trajectories of future learning (Bransford & Schwartz, 1999). As in

schools, there is no one-size-fits-all in out-of-school. These are the questions that research needs to start to address: Not whether child development is possible (which we see in many studies cited earlier), and not whether learning shows up on test scores (which we should not expect to see), but how these settings create conditions for continued interest and engagement, at different levels, in different communities, and towards different (and always contingent) ends.

6.3 Lessons Learned and More Questions

How is the OST setting positioned to support children's engagement and learning in science? Because of its highly supportive developmental conditions, the OST setting is well positioned to support children's learning and development. At the very least, these programs can engage children in social contexts where science is valued and they are valued as science learners. As such they operate to "keep children in the game" and lay the groundwork for future trajectories of learning. These programs can also build on these social contexts to expand children's agency and inquiry through engaging them with science-as-cultural-practice when the features of the setting are aligned with such goals.

My data and argument would hold that enriching conceptions and representations of science in the OST setting is not impossible if it is a goal. The question remains whether or not it *can* be a goal given the lack of support that teachers and other educators receive to come to know science-as-cultural-

practice and given the narrow view of learning taken by most policy and funding organizations.

The main policy that impinges on OST programs are the provisions of the Elementary and Secondary Education Act that fund the 21st Century Community Learning Centers that serve approximately 8 million children. This Act is currently up for reauthorization and it is not clear how the OST provisions will be decided. There is a debate between moving farther into the academicized model of "extended day" and the developmental model of "enrichment." The ways in which ESEA is shaped will inform the general OST educational policy and funding climate. My findings suggest that it would be beneficial for this policy, and policies of private funding agencies that shape and fund OST programs, to conceptualize the OST setting as a places that are well positioned – and perhaps better positioned than schools – to support ways of being, doing, knowing, and becoming that are essential to full and productive engagement and learning in science. In other words, to eschew standardized test scores (which reflect certain kinds of knowing) as a valid measure of the effects of OST programs and to demand more appropriate indicators that demonstrate how such programs are developmentally supportive for children in science. That is: how they support the development of science-engaged children. It is this demand that will lead innovation in research and evaluation methods for the OST setting.

Today, after 10 years of *No Child Left Behind*, it is hard to imagine policies that could take such a view of development as related to learning. But policies in the 1960s and 1970s, for instance those that funded Head Start, or those that

underpinned the Vermont state standards, did take these views. Those policies were founded in part on experimental studies, such as those conducted by Bronfenbrenner and colleagues, that showed better developmental outcomes for children who were supported in developmental contexts and interactions. Science education reform efforts funded by the National Science Foundation in the 1960s also took such a view. Most of these efforts were undertaken without concomitant investments in assessment strategies. The last twenty years have been dominated by standardized assessments with an emphasis on science (and other subject matter) as knowing. A new era could seek to synthesize: to develop assessment strategies appropriate to broader conceptions of learning and richer conceptions of science. Such policies would:

- Encourage design and implementation of a range of different program types (acknowledging that different communities have different resources and needs).
- Operate from a theory of learning and development that values productive participation in and contribution to communities of learners engaged in science.
- Investigate ways that OST science learning contributes to ways of being, doing, knowing, and becoming that is later taken up in classroom and other settings.
- Encourage collaborations with informal science institutions and youth development programs, organizations that generally take child-directed

views of learning, and might be more likely to operate with science-as-cultural-practice conceptions of science.

Demanding that OST programs show effects on school test scores essentially hijacks their developmental power. Policymakers need to rethink priorities for this OST space and time, broaden conceptions of learning, and encourage investment in exploratory work in assessment methodologies for OST settings.

6.4 Next Steps: Relating Research to Practice

It is my hope that my analysis of the OST setting will be found useful by people who design, lead, and research learning and science learning in the OST setting. For my own work, I intend to use the results of this inquiry in the professional development work I lead for informal educators. Specifically, I intend to explore more deeply what different models of science and different models of learning mean and look like, necessitate and lead to, for informal educators.

Developing the graphic (Figure 6) that maps out the learning trajectory may also be a useful rubric for this work, to start to specify what such stages of engagement and learning might look like with respect to specific contexts, concepts, audiences, and activities. What does contribution versus peripheral versus full participation look like, for instance in the context of the Exploratorium's Digital Bling activity I briefly described in Chapter One? What does it look like in an afterschool program focused on environmental education, or even during an interaction at an exhibit, or a half-day experience at a zoo? Making these

distinctions can challenge educational designers to create opportunities for inquiry and agency, rather than to assume that they are embedded in activities just because they are constructivist or hands-on science investigations.

Finally, spending so much time with the transcripts of the OST educators and children, reading and re-reading, listening to and re-listening, has been a vital reminder about the diversity of people, places, and approaches that constitute what counts as OST learning and development. While I came to this project (and the grant that funded the larger study) with an ideal vision of what OST science *would* (and *should*) look like, I leave the project with an expanded view of what it *does* and *could* look like, and with a richer understanding of how OST experiences can contribute to students' learning and development. It is clearer to me today than it was three years ago that the goal of science education is not to create little scientists, or even future scientists (although future scientists will always be a vital byproduct). The goal is to create children (who will become adults) who see science as a field of practice and inquiry that has meaning to them, in which they can productively participate, and that plays a particular valuable role in supporting and advancing their social world. Such children and future adults will be more likely to question, participate, challenge, and contribute to social discourse that involves scientific interpretations or explorations. It is this relevance of science – marked by inquiry, agency, and authenticity – that can be, and seems to be, the overarching contribution of science education in OST settings.

Appendix A: Adapted Vandell Science Protocol

AYS Observation Instrument
May 2008

Researchers should observe six distinct activities at each site, during two to six site visits.
This instrument draws on elements of Vandell (2007) and includes new AYS elements.

Site Name: _____

First Observation: _____

Date Completed: _____

Using the attached rubrics, complete the activity observation sheets and attach field notes.

For each activity, you will be asked to describe and give concrete examples of:

1. The settings, focus, and resources for the activity (using Vandell et al 2007)

2. The different STEM capacities that observed activity is designed to build (using AYS STEM Capacities Chart).

3. The ways in which the program activities are structured (using Vandell rubrics).

4. The ways in which the activities are facilitated (using the STEM Teaching Addendum) including:
   a. If you see evidence that activities have grown or will grow in complexity
   b. If you see the ways in which the activity relates to previous or ensuing activities; that is how it sustains particular ideas, as well as how it periodically addresses them
   c. If you see evidence that the activities are designed in ways that are reciprocal; that is that children can shape and guide the activities as much as the activities shape and guide children's engagement.
   d. How you see the activities being structured to engage children

FORM A: Activity Context Coding (from Vandell et al 2007)
Complete this form for each activity observed.

Program Name:	Date:	Activity #:	Start time: End Time:	Total Minutes Observed	Observer Name:

A. ACTIVITY TYPE VANDELL		B. KNOWLEDGE/SKILL AREAS VANDELL		E. TOTAL ADULTS/STAFF	# Start	# End
1. Homework assistance		1. Interpersonal		1. Number of adults		
2. Tutoring		2. Physical/athletic		2. Number of teens		
3. Study skills/test preparation		3. Artistic				
4. Reading/language arts enrichment		4. Math/numeracy				
5. Math/science enrichment		5. Reading/language arts		F. GRADE LEVELS		
6. Recreational reading/listening to story/book		6. Problem-solving/ decision-making		K	1	2
7. Computer skill-building		7. Other Academic		3	4	5
8. Computer games		8. Other		6	7	8
9. Sports: competitive and non-competitive games; tournaments		9. None		Other:		
10. Sports: practice/drills/ skill-building		C. TYPE OF SPACE		G. NUMBER OF YOUTH	# Start	# End
11. Fitness/exercise class (including martial arts)		1. Classroom		1. Total # of youth		
12 Arts and/or crafts		2. Specialized studio/lab		2. Number of boys		
13. Performing arts rehearsal/instruction		3. Games/club room		3. Number of girls		
14. Cultural awareness clubs/projects		4. Gym		I. MAIN PURPOSE (circle all that apply)		
15. Board/table/card games or puzzles		5. Auditorium		Deepening understanding of STEM content, process skills		
16. Health/well-being		6. Cafeteria		Involving parents in the program/activity		
17. Service/civic (in community or program)		7. Library		Learning about career options/pathways		
18. Snack		8. Computer room		Taking a field trip to an off-site location		
19. Arrival/dismissal		9. Outside playground/field		Working with/as mentors within AYS program		
20. Other		10. Other		Other (note):		

D. MATERIALS USED					
1. Computers		5. Textbooks and workbooks		8. Games	
2. Art Supplies		6. Writing materials		9. Electronic media	
3. Sports Equipment		7. Musical instruments		10. Other	
4. Trade, reference, research books				11. None	

H. STEM CONTENT AREA (check all that apply)					
Astronomy/Space Sciences		Ecology/Environmental Sciences		Mathematics	
Biology/Life Sciences		Engineering		Physics	
Earth Sciences/Geology		Health/Food Science/Nutrition		Technology/Robotics	

J. WHAT ARE PARTICIPANTS DOING? (Circle all that apply)			
Attending lectures/demos/tours	Participation in authentic, professional STEM	Tabletop/Hand-on experiments	Web/library research
Design/build engineering activities	Reflection/discussion sessions	Tech-based/Simulations	Other (note):
Field-based data collection	Presentations of work	Worksheets/textbooks	

Form B: Activity Descriptions (from Vandell et al 2007)

Complete this form for each activity observed

ACTIVITY

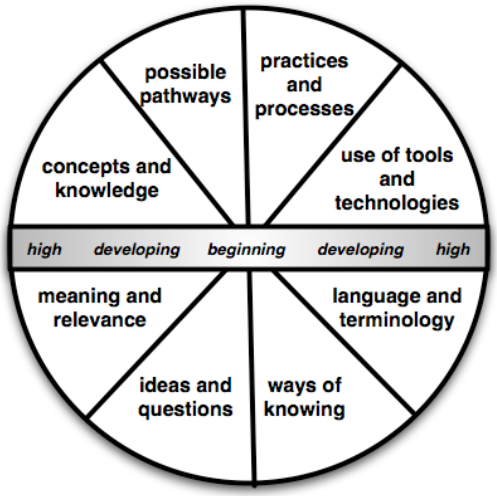
1. **"Name" of activity:**
2. **Location:**
3. **Date:**
4. **Time:**
5. **Activity Type (from the Coding Context form): _____**
6. **Description (summarize in one paragraph and attach field notes):**

For instance:

⇒ What are youth doing?
⇒ What kinds of materials are used?
⇒ What kinds of instructional processes are used?
⇒ Who is leading the activity? What, if any special skills to lead the activity do they have?
⇒ What is the overall affective tone?
⇒ To what extent are youth engaged?
⇒ Describe observed promising practices as appropriate and raise concerns about quality, if there are any.

FORM C: BUILDING CAPACITIES TO ENGAGE IN STEM

Provide descriptions and specific examples of the ways in which the activity builds children's capacities to engage in STEM. Note whether children are already working at a beginning, developing or high/accomplished level.



Capacities	Concrete Examples (expand as needed)
Ideas and Questions	
Concepts and Knowledge	
Practices and Processes (eg, inquiry, analytical, & representational skills)	
Language and Terminology	
Tools and technologies	
Ways of Knowing (inquiry, evidence-based, falsifiable)	
Meaning and Relevance	
Possible Pathways Careers/Academics	

FORM D: PROGRAM CHARACTERISTICS.
For each activity, provide concrete examples, referencing the Vandell et al 2007 observation rubrics, that illustrate the ways in which the program activity *consistently*, *frequently*, *infrequently*, or *never* (C, F, I, N) addressed the following dimensions (examples should be detailed, expanding this sheet to several pages, as needed:

(1) Program design and implementation	***C, F, I, N***	**Examples**
Peer Relationships		
Adult-Peer Relationships		
Levels of Engagement		
Opps for Cognitive Growth		
Appropriate Structure		
Over-Control		
Chaos		
Mastery Orientation		

FORM E: ACTIVITY EXPERIENCE For each activity, provide concrete examples to support your responses.

1. **Did you see evidence that the activities are growing or have grown in complexity, such that children's thinking and skills are being challenged and developed? Provide concrete examples and explanation of why you answer yes or no.**

2. **To what extent do you know that this activity is a part of a coherent set of learning experiences, before during and after? Does it reflect sustained work in a particular area? Is it something that children return to with regularity?**

3. **In what ways are the activities reciprocally designed so that children are able to influence the activity (the leaders, the activity, the materials or tools) as much as these elements structure their experiences?**

See next page

4. <u>ACTIVITY CHARACTERISTICS</u>. Please provide concrete descriptions of the following examples of ways that the activity was designed to actively engage children (refer to the STEM Teaching Addendum observation rubrics) to *consistently*, *frequently*, *infrequently*, or *never* (C, F, I, N) address the following dimensions (examples should be detailed, expanding this sheet to several pages, as needed:

<u>Student experience of STEM learning</u>	*C, F, I, N*	Examples
STEM related to everyday experiences		
STEM related to school STEM		
STEM presented as accessible, historical human endeavor (possible career or academic pathways are illuminated)		
Engaging students imaginations		
Using STEM tools, language, activities		
Building on students' social capital		
Building on students' prior knowledge		
Allowing time/mental space		
Socially embedding STEM activities		
Providing dimensionality/tactility		
Providing intellectual safety		

Appendix F
PROMISING PRACTICES EXEMPLARS
Spring 2005

The exemplars on the following pages were obtained from *Features of Positive Developmental Settings* in Eccles & Gootman (2002), several observation instruments (SACERS, NSACA, Study of After-School Care qualitative ratings, PSA's TASC observation, Wellesley ASQ), the Theory of Change (Table 1) and the Activity Observation Instrument (AOI) definitions.

SUPPORTIVE RELATIONS WITH ADULTS	
High	**Low**
♦ Staff communicate high expectations and positive norms for student behavior and mastery o Acknowledge students' efforts, accomplishments, and progress o Notice when students are having difficulty-- provide encouragement and alternatives	♦ Staff do not acknowledge students o Do not acknowledge accomplishments, progress, or effort o Ignore youth who are bored, wandering, or inactive
♦ Staff use positive behavior management techniques to resolve behavior problems (or no evidence of behavior issues) o Set age-appropriate limits for students o Communicate expectations and intervene constructively and calmly to address disruptive behavior by redirecting students and/or explaining why the behavior is unacceptable o Aware of, and address, teasing, bullying, or other conflicts between students	♦ Staff do not use positive behavior management techniques o Evidence of yelling, shaming, or disparagement of youth o Correct students publicly in a way that embarrasses or belittles them o Ignore behavior issues of conflicts o Use harsh or rough punishment o Are sarcastic
♦ Staff respond to children in a warm, supportive manner o Use a positive tone of voice—and offer encouragement such as "You're doing great" or "That's great" o Offer specific suggestions to youth for improving skills and performance, providing examples of what they like about the work in progress o Offer encouragement to students who are frustrated o Are relaxed and cheerful	♦ Staff are flat or negative o Appear bored, tired, or distant o Show disrespect for students o Disapprove or criticize o Use negative voice when speaking
♦ Staff-child conversations are frequent and reciprocal o Respond to students' initiation of dialogue, comments or questions by showing interest and extending conversation, asking questions o Initiate conversations with students o Look at students when they are speaking	♦ Staff –student interactions are infrequent or one-sided o Do not converse or interact with students o Do not assist students o Are directive
♦ Staff are engaged with children o Pay attention and show interest in what youth are doing or how they are working together o Participate in activities without being intrusive	o Not engaged with students o Intrusive, impose own agenda
Rating indicators:	
1 = negative exemplars are evident – where staff are intrusive, bored or distant, yell at or embarrass students 2 = negative exemplars are not evident but neither are the majority of positive exemplars 3 = some indicators of supportive relationships with adults 4 = evidence of many positive indicators, students are clearly comfortable initiating interactions with staff	

SUPPORTIVE RELATIONS WITH PEERS	
High	**Low**
♦ Peer interactions have a positive affective tone o Tones of voice and body language are friendly and positive o Have conversations that are either social or task-oriented o Listen to each other	▪ Peer interactions are negative o Pick on, or belittle, each other o Harass, intimidate, or threaten each other
♦ Students interact well together o Play or work well together o Share materials and space o Help, and accept help, from one another	♦ Students do not work well together o Argue over materials o Exclude one another from activities
♦ Students appear relaxed and involved with each other o Students speak to one another respectfully o Try to make each other feel welcome (e.g., smile at each other)	o Students seem withdrawn or fearful o Show disrespect for each other
♦ Students negotiate solutions in conflict situations with peers o Make compromises with each other o Jointly work out how to approach an activity or situation	

Rating indicators:
1 = students do not work well together; may harass, intimidate or threaten each other 2 = students are not negative with each other or do not hassle each other, but have few positive interactions 3 = some indicators of supportive peer relations 4 = evidence of many positive indicators, no evidence of negative indicators

LEVEL OF ENGAGEMENT (in intended experiences)	
High	**Low**
♦ Students appear engaged, focused, and interested in their activities o Engaged in the focal activity and/or using free time appropriately o Appear to be interested in the activity o Follow staff directions in an agreeable manner	▪ Students appear bored or distracted o Ignore staff who are talking to them o 'Pretend' to listen o Wander aimlessly
♦ Markers of engagement are appropriate to activity (e.g., intense concentration witnessed during computer activity, high levels of affect during sports activities; can be in solitary or group activities.	♦ Markers of engagement inappropriate to activity (e.g., picking flowers while playing a sporting activity)
♦ Students contribute to discussions o Discuss back and forth and offer comments o Ask 'on-task' questions o Are comfortable initiating conversation	o Do not participate in discussions o Do not ask questions

Rating indicators:
1 = most students are not engaged appropriately, may appear bored
2 = students are participating in activities but do not appear to be concentrating or affectively involved
3 = students are focused on activities with some evidence of affect involvement or sustained concentration
4 = students are concentrating on activities, focused, interacting pleasantly when appropriate, and are affectively involved in the activity

OPPORTUNITIES FOR COGNITIVE GROWTH (development of cognitive skills including memory and planning skills) NOTE: Homework "counts" only if staff are actively assisting or teaching students.	
High	**Low**
♦ Activities promote thinking and understanding at higher levels of complexity, integration or meaning o Engaged in writing a story, poem, or piece of non-fiction o Reading a book, magazine, poem or newspaper (or are being read to by someone else) o Practicing or learning math skills o Opportunities for student involvement through inquiry, experimentation, problem-solving and discussion	♦ Students are not engaged in activities that promote skill development or higher-level thinking o No expansion of topic through use of experimentation, analysis, or synthesis
♦ Staff ask students "why, how, what if" questions that require complex answers (not factual, rote, or yes/no) o Ask thought-provoking questions, add complexity to tasks o Ask youth questions that require extended responses o Ask youth to explain their answers, respond to counter arguments and attempt to answer their own questions o Engage in reciprocal discussion in which they take students' ideas seriously	♦ Staff do not question students o Do not ask questions that require complex answers o Do not challenge students to explain answers or position o Staff only want/expect brief, correct response
♦ Staff provide instruction o Review information, explain how to do something o Youth listen attentively to instruction (or instructional video) o Instruction may include a series of simple question-answer exchanges with youth involving brief factual answers	♦ No instructional conversation between staff and students ♦ Staff give incomplete, confusing or incorrect answers to youth questions o For example, in homework or activity assistance they provide the wrong answer or misleading information
♦ Activity requires students to identify and solve problems o Gather and/or synthesize information in order to complete a task or make a decision o The information gathering and processing should have a purpose defined by either the youth or the staff (e.g., internet searches to advance, plan a project or trip)	♦ Students do not participate in problem-solving activities o Activities require short answers or involve not problem-solving ♦ All information needed to complete a task or activity is provided by the staff
♦ Activity requires students to plan, synthesize ideas, or use information to accomplish a goal or make a decision o The activity requires youth to develop a plan or think ahead several steps and anticipate others' responses (e.g., chess)	♦ Students do not participate in planning or decision making
Rating indicators:	
1 = little or no opportunity for cognitive growth 2 = opportunities occur primarily in the context of homework; use of other activities for cognitive growth is limited; staff ask few or no questions requiring complex answers; few or no problem-solving activities 3 = some opportunities within some activities 4 = variety of opportunities and staff are highly effective in facilitating students' learning experiences; many opportunities for planning, synthesis, problem solving	

APPROPRIATE STRUCTURE (activities are implemented effectively)	
High	**Low**
♦ Transitions are orderly and efficient o Transition times are minimal, students do not need to wait a long time for an activity to start o Activity area is prepared and ready when youth arrive o Materials are accessible and efficiently dispersed to youth o Materials are in a condition that allows them to be used as required (e.g., sports equipment is functional, games have all required pieces, computers work) o There are enough materials to allow youth to participate simultaneously in activities	▪ Transitions are chaotic o Long waits between activities o Materials are not functional or not available in necessary quantities o Staff are not prepared for the activity o Students may not know where they are supposed to go or be
♦ Instructions for activities are clear and appropriate o Staff understand and are prepared to support students in the activity o Explain reasons for rules and structure of the activity o Instructions are easily understandable and easy to follow o Students understand and follow instructions o Students understand their responsibilities o Students know what is expected of them	o Instructions are unclear and not easily followed o Students may not know what they are supposed to be doing
♦ Staff members support each other	♦ Staff members work at cross-purposes or give conflicting information
♦ There are **no** obvious safely hazards (e.g., the area is not too cluttered, there are no dangerous or broken materials around	♦ Activity area is cluttered and materials are broken
♦ External distractions are minimized	♦ Distractions outside the observed activity interfere with students' participation/experience

Rating indicators:
1 = staff are unprepared; poor materials; long transitions; environment is unsafe
2 = a few indicators of appropriate structure
3 = some indicators of appropriate structure
4 = staff support each other; activities run smoothly; staff are well prepared; students have a clear understanding of rules; transitions are smooth

OVER-CONTROL	
High	**Low**
♦ Staff are highly over-controlling o Little or no student talk or involvement o Spontaneity and creativity are not encouraged o Activities are staff-directed o Little time for free choice	♦ Activities and interactions structured in such a way that levels of staff control are appropriate o Staff respond to youth who ask for assistance o Students are not over-controlled o Staff demonstrate respect for students' autonomy and responsibility
♦ Students do not have opportunities for making choices o Do not select own activities o Do not have choices within activities	♦ Students have opportunities for making choices o Help to determine the direction of activities o Have choices within the activity o Make suggestions about how to carry out activities or tasks ♦ Have some choice about who they work with
♦ Staff **impose** solutions to interpersonal problems/conflicts	♦ Staff help youth develop their own solutions and compromises

Rating indicators:
1 = level of staff control is appropriate to the activity; students are free to make choices
2 = level of staff control is appropriate to the activity; students may have some opportunities for choice, but not many; most activities are staff-directed
3 = staff are somewhat controlling
4 = staff are highly controlling; activities are staff-directed, students do not have opportunities for choice

CHAOS	
High	**Low**
♦ Students are engaged in inappropriate, and often disruptive or rude behavior o Are out of control during transitions, activities, or free time o Students misbehave o Students ignore the sanctioned activity o Students misuse materials	♦ Students are engaged in a productive level of functional talk and movement that are part of the activity o There is **no** evidence of disorder, students out of control, or extreme disorganization o Moderate levels of noise, talking, and movement o Talking, noise, and movement not disruptive or distracting to other students
♦ Moderate or heavy amounts of ineffectual control tactics o Staff allow situation to get out of hand before intervening o Staff control techniques are unsuccessful	♦ Staff control techniques are effective o Aware of all situations in the room o Distracted youth are redirected or refocused o Intervene when appropriate and necessary

Rating indicators:
1= no evidence of disorder or chaos
2 = students are engaged in productive level of talk; may be some brief instances of disruptive noise or talking; staff control techniques are effective
3 = some evidence of chaos
4 = students are out of control throughout observation; youth are not redirected; staff control techniques are ineffective

MASTERY ORIENTATION NOTE: The program offers sustained activities and opportunities for practice and skill development. In these activities, the students work toward a culminating project or event. This encourages goal setting, reflection and self-evaluation.	
High	**Low**
♦ Students work on skill-building projects o Engaged in activity that builds to a product or event designed to showcase their work/skills (art show, drama production, recital, service project) o Activity may not build to specific event, but a new skill is learned and built upon (e.g., karate, dance class, music lessons)	♦ Activities do not build skills o Do not require perseverance and sustained attention
♦ Activities challenge students intellectually, creatively, and/or physically in developmentally appropriate ways, without being so difficult that they discourage participation o Involve a graded progression of skills, accommodating multiple skill levels, and allowing students to successfully participate at their own level o Appropriate for students' skill levels—not so difficult that they have trouble participating successfully and not so easy that students master skills quickly and become bored	♦ Activities do not challenge students o Activities are not set up to meet individual skill levels o Activities are too easy or too difficult
♦ Staff encourage students to try new activities o Encourage completion and mastery of activities and tasks by providing assistance and encouragement o Clearly focused on instruction/helping kids learn something new or a new skill	♦ Staff do not encourage students o Do not provide assistance when needed o Do not encourage students to challenge themselves o Do not encourage students to try new activities o Criticize youth work without offering appropriate guidance
♦ Staff demonstrate or model concepts or skills o Explain, provide information, coach, direct instruction necessary for students' progress o Explain specific steps to follow in completing activity/tasks, beyond giving simple instructions to actually **showing** how to do something (demonstrating a dance step, drawing technique, working through a problem) or giving examples in response to questions	♦ Staff do not offer appropriate instruction and feedback
Rating indicators:	
1 = no evidence of skill building or mastery orientation 2 = a few activities focus on skill building or mastery, although not in an optimal way; staff may demonstrate some concepts or skills; activities may offer challenge to some, but not all, students 3 = some activities encourage skill building or mastery 4 = many activities encourage skill building or mastery; staff demonstrate and explain techniques, directions, etc.; staff encourage students to try new activities, skills	

STEM as meaningful enterprise

High	Low
STEM presented as part of everyday experience •activities take place in everyday settings or with everyday materials •activities are designed to address a real-world problem that has significance for participants •participants discuss or reflect on the ways in which the activities relate to their everyday experiences •explicit connections are made between the activity and everyday phenomena or nature	No connections are made between the STEM activity and everyday world, materials, or uses of STEM. •activities use unfamiliar materials and settings that would not normally be encountered outside of the activity •the real-world applications or meaning of the activity is not inherent, discussed or somehow communicated
STEM activity is connected to school STEM •explicit connections are made between the content or process of the activities and the types of content or process students have or will have encountered in school •activities are based on the local school STEM standards •activities are designed to build on and extend student school experiences (such as extended lab or field work) •activities include the use of language, tools, or materials that are commonly found in school STEM	No connections are made between the STEM activity and the knowledge, skills, or features of school STEM. •STEM activities are presented in isolation from the types of STEM experienced in school •STEM activities draw on content or skills that are not addressed in K12 STEM • activities use unfamiliar materials and settings that would not normally be encountered in a school context
STEM presented as an accessible human endeavor (in which students can participate and make contributions) •The problem, purposes, or activities of STEM are presented in compelling and relevant ways that encourage students to value their importance, currency, personal utility, and meaning, and the ways in which students can contribute to/benefit from them, both now and as adults	STEM presented as an esoteric or unreachable field for experts-only •The problems, purposes, and activities of STEM are not made relevant to the worldview of students •STEM is presented as the province of expert or specialized individuals who bear little resemblance to students •Students engage in STEM activities through step-by-step

•students are provided multiple ways to contribute to the STEM activity and outcomes, and the success of the activity (meeting the goals) depends on their individualized and group contributions •students are exposed to different (approachable, accessible) role models engaged in STEM •adults model and scaffold increasing student participation in STEM practices	instructions that do not take into account their individual capacities for contribution.
STEM activities engage students' imaginations to solve, envision, or engage in the activities •STEM problems and activities encourage student questioning and wondering •STEM activities incorporate aesthetic, social, and/or personal elements, decisions, or actions •STEM activities incorporate and/or trigger playfulness, pleasure, and joy in learners	STEM presented as a set of dry facts or procedures •STEM presented as a set of procedures that are indifferent to students' individual ideas or imaginations •STEM activities are close-ended and pre-determined
STEM activities accomplished through use of tools, language, practices of science •STEM activities use authentic tools of science •Adults and students use or learn to use the language of STEM •students engage in authentic STEM practices involved in inquiry and investigations •students engage in authentic STEM social practices such as poster sessions etc.	STEM experienced through means that are non-specific to STEM, such as purely text, purely lecture, purely call and response. • Instructors fail to introduce key terms relevant to the activities , and developmentally appropriate, that can expand student's working STEM vocabulary •Activities are overly abstract or disassociated from actual STEM practices, such as finding pre-recorded measurements of materials rather than asking students to measure themselves.

Personalizing Learning

High	Low
Activities intentionally build on cultural and social capital of participants •activities reference the lives, communities, and/or experiences of participants •activities require students to draw upon their personal experiences	Activities are indifferent to the cultural and social capital of participants •activities do not reflect the daily lives of students (such as proverbial yachting curriculum for urban children) •activities fail to capitalize on opportunities provided by student resources and interests
Activities intentionally build on prior knowledge of participants •activities reference prior knowledge of students by explicitly asking students what they know, and adjusting accordingly •activities are designed in response to prior activities	Activities are indifferent to the prior knowledge of participants •activities do not make connections between the foundations of the activities or the extensions of the activities, and are taught in isolation •students are confused by activities that assume familiarity with ideas or skills that may or may not already exist

Allowing time (and mental space) for…	Program leaders provide time for children to engage in program activities at their own pace, including late arrivals, absences, and time to question, interrupt, elaborate, and digress. This flexibility means that opportunities to participate are not offered on a tightly constrained, limited-time basis, and learning is not presumed to happen according to a rigid schedule.
Socially embedding activities in …	Program leaders embed STEM in social and collaborative activities, where children sit together, talk and plan together, and inquire and act together.
Providing dimensionality/ tactility to…	Program leaders structure STEM activities through children's first-hand engagement with the processes and tools of STEM. For example, children use instruments to measure natural phenomena, participate in whole group discussions to collectively develop explanations, and document what they have seen, heard, and tried in their hands-on activities.

Providing intellectual safety for …	Program leaders keep the consequentiality of participation low-stakes. Children are not at risk of failure; consequences are personally constructed, and are not standardized or systemically imposed.

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