Developing Language in the Context of Science: A View from the Institute for Inquiry®

This paper presents the Institute for Inquiry's approach to integrating science and English language development. It illuminates key features and foundational principles that underpin the design of our professional learning experiences. The Institute for Inquiry's work is based on the premise that inquiry-based approaches to science require increased communication and sophisticated uses of language, thereby engaging students in linguistic work that can support their English language development. All students—particularly English language learners and others with limited literacy development—encounter language and literacy challenges and opportunities as they engage in doing science. Our conceptual framework takes this into account by recognizing that both science learning and language development can be promoted by providing particular kinds of experiences and supports as students engage in doing science.

Traditionally, schools have considered science learning and language learning to be very different subjects. However, recent research suggests that the integration of these seemingly disparate areas is advantageous to both. The direct and engaging experiences of inquiry-based science can provide a rich context for the development of language as students communicate about their observations and discoveries. Similarly, the use of language to communicate about ideas is essential to the development of scientific understanding.

Making sense of the world involves using and developing language to communicate meaning. Increasingly, as states adopt or develop new standards in English language acquisition, math, and science, there's an acknowledgement that content areas are important arenas in which both academic language and language skills for "everyday use" can and should be developed. There's a growing recognition of the importance of developing "language for use," with the purpose of fostering understanding and communication of ideas, rather than a primary emphasis on isolated, decontextualized skill development that focuses on grammar and vocabulary.

> *"meaningful 'language for use' learning occurs in contexts where students are required to communicate (speak, listen, read and write) about science. A practice-oriented science classroom can be a rich language-learning as well as science-learning environment, provided teachers ensure that ELLs are supported to participate. Indeed it is a language learning environment for all students, as the discipline itself brings patterns of discourse and terminology that are unfamiliar to most of them. In this context, teacher knowledge about language and language learning support strategies can improve the overall science learning experience of all students, especially of ELLs."*
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> Helen Quinn, Okhee Lee, Guadalupe Valdés. "Language Demands and Opportunities in Relation to Next Generation Science Standards for English Language Learners: What Teachers Need to Know," *Understanding Language*, Stanford University.

For most teachers, this represents a major shift, challenging them to think differently about the nature of science learning and language acquisition and to develop new classroom practices that effectively take advantage of their intersections. Given that teachers are often already overextended in their daily activities, and focused on meeting existing curricular demands, extensive support—in the form of professional learning experiences and classroom materials—is needed in order to help them make this shift.

The integration of English language development and science holds great promise for advancing the achievement of English language learners (ELLs), as well as providing connections to literacy that support English-only students. Recognizing these benefits, IFI embarked on a seven-year project (2008–2015) designed to experiment with the implementation of a district-wide professional development program for integrating science and ELD at elementary schools. For this project, we partnered with the Sonoma Valley Unified School District—a five-school, semi-rural district located about 45 miles north of San Francisco. The district's student population is approximately 55 percent ELLs, most of whom are native Spanish speakers.

Through extensive collaboration between educators with different expertise and backgrounds (elementary school teachers, district administrators, museum-based science educators, and a university-based teacher educator specializing in ELLs),the Institute for Inquiry (IFI) has developed a conceptual framework where science learning is at the center and language development is contextualized within making meaning of science experiences. This framework serves as a foundation for the design of our professional learning experiences.

If you were to observe the classroom of a Sonoma teacher who participated in IFI's professional development, you would notice many teaching practices that appear ordinary. For example, you might see a teacher asking their students different types of questions, introducing vocabulary, or charting and posting students' ideas from a discussion. You might see students talking and working in groups. Though these practices may seem unremarkable in and of themselves, they are in fact instances of a deliberate approach designed to help ELLs develop language within the context of science.

What follows is a description of the elements of IFI's framework: Guiding Principles, Signature Experiences, Essential Supports, Contextualized Mini-Lessons, and a Spiral Model for Science as a Context for Developing Language.

GUIDING PRINCIPLES FOR INTEGRATING SCIENCE AND LANGUAGE DEVELOPMENT

A set of guiding principles has come to reflect IFI's philosophical and pedagogical stance towards science learning and language acquisition. These principles address potential misconceptions about language development and have implications for classroom practice. They are introduced to teachers to serve as a foundation and touchstone throughout the experiences that make up their professional development.

IFI's Guiding Principles for Developing Language in the Context of Science
as shared with teachers participating in IFI professional development

1. The learning and doing of science supports the development of language skills.
2. The learning and doing of science requires the use of language skills.
3. Inquiry-based science provides a multitude of affordances to use language in authentic and meaningful ways.
4. The development of language skills requires teachers to encourage, support, and create intentional opportunities for language participation in speaking, listening, reading, and writing.
5. Language participation can be "flawed" and still support language development.
6. All children, regardless of language background, are capable of learning and engaging in complex and rigorous science instruction.
7. Inquiry-based science requires sophisticated language practices and skills. The development of these language practices and skills through inquiry-based science supports teachers in meeting new standards for English language arts and science.
8. Learning science and developing language require social, collaborative interactions.

Developed in collaboration with Sarah Capitelli, Assistant Professor, University of San Francisco

SIGNATURE EXPERIENCES

To give Sonoma teachers classroom resources for exploring inquiry as a context for language development, IFI designed a set of 12 hands-on instructional units based on earth, physical, and life science topics. Within those units, we embedded three types of "signature experiences": inquiry-based science, science talk, and science writing. These signature experiences serve as mechanisms to engage students in the science practices critical to doing inquiry, including asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information. Signature experiences act in concert with each other and provide affordances for the meaningful use of language—and consequently, the development of language. By engaging with the signature experiences, students build their conceptual understanding of science as they communicate their ideas through speaking, listening, reading, and writing.

Extended oral and written interactions require students to think about what they're saying and writing, which involves a deeper processing of language. The expression of ideas makes students' thinking visible, giving the teacher insights into students' understanding of science concepts, what language they have to communicate their thinking, and the supports that they might need to further both.

The three signature experiences are described below, with attention given to how they support science learning and language development.

Hands-on, inquiry-based science is a pedagogical approach designed to give students firsthand experiences with phenomena in order to study the natural world. The experiences provide a context for developing an understanding of scientific ideas, as well as an understanding of the process in which scientific knowledge is developed. A critical aspect of engaging in hands-on, inquiry-based science includes providing opportunities for students to reason about their experiences in order to explain what they've found out.

Hands-on, inquiry-based experiences are especially valuable for ELLs because they provide rich opportunities for communication to happen. Interesting phenomena draw out students' curiosity and are catalysts for sharing. While investigating, pairs or small groups of students have informal conversations and "think aloud" about their observations and discoveries. Because talking is related to the experiences, students' productive and receptive language is encouraged and supported in a meaningful context.

Science talks are discussions that help students develop their understanding of science ideas and clarify their thinking together through negotiation (e.g., argumentation, summarization, elaboration, rephrasing, repeating).

Science talks can be structured and facilitated in various ways—whole class, small group, peer-to-peer—and can serve various functions, giving students the opportunity to share observations, raise questions, plan investigations, make meaning, and draw conclusions. Science talks are integrated throughout a unit so students can frequently hear and use spoken language as new learning takes place.

Science talks value the contribution of ideas rather than emphasizing correct explanations or perfect grammar and vocabulary. They are particularly important for English language learners because they provide multiple avenues for hearing and producing language that is contextualized in relationship to science experiences. They are focused on giving students of varying language proficiencies an opportunity to express their ideas using the language they have.

Building a culture of science talk takes time. Individual students' participation in science talk can develop gradually, and their responses may range from just a few words to an extended discussion; they may include everyday language as well as academic language. Understanding students' varying language proficiencies, accepting "flawed" language, and providing supports so that all students can participate is foundational to encouraging successful science talk.

Given its critical role in learning science and developing language, science talk has been a focal point of IFI's work with Sonoma teachers. The project motto, "Let's give them science to talk about" has come to symbolize the prominent place that science talk has occupied in Sonoma classrooms.

Science writing is a tool students can use to capture observations, questions, and data about their investigations and provide analysis and interpretation of their experiences. Science writing helps students clarify thinking, synthesize ideas, and communicate with others.

Science writing occurs in many different formats, including notebook entries, charts, diagrams, and drawings. It can be shared with others, posted in the classroom, or become a venue for private conversations between teacher and student. A piece of writing can be a repository for emerging ideas (a silent partner in an investigation) or a final product for sharing knowledge. Science writing serves as a permanent record that can be revisited in order to recall information, used as an oral reading exercise to communicate ideas, revised in light of new ideas and responded to by the teacher in order to support the further progression of thinking and use of language. When science writing occurs throughout a unit, it provides an ongoing record that supports the development of science ideas and the progression of writing and language skills that foster communication.

There is a strong reciprocal relationship between science writing and science talk. Talking can be a precursor to writing, and writing can be a precursor to talking. For instance, students can have a science talk before writing so they can listen to others and rehearse their own language and ideas before committing them to print. This practice can be especially beneficial for ELLs whose speaking skills are often more developed than their writing skills. In turn, writing can help students collect their thoughts without inhibitions before speaking. And a piece of writing, like a science notebook entry or posted word bank, can be a resource for students to refer to during a science talk. The combination of science talk and science writing supports the learning of science ideas and, in the process, helps students develop the language to express these ideas.

Scaffolding the Signature Experiences

Engaging in the signature experiences requires students to meet the language demands of speaking, listening, reading, and writing. Scaffolds are supports that help students, regardless of their language proficiency, to engage in these language demands and meet the goals of a lesson.

Scaffolding is often a necessary condition for beginning an inquiry, as English language learners may not comprehend the teacher's initial instructions. As an investigation proceeds, English language learners may have a lot to communicate and only lack the language to do so. Adding scaffolds along the way enables more students to fully engage in an experience, make meaning, and share what they know.

Scaffolding provides temporary support that assists students in engaging in meaningful and challenging tasks, in order to move skills and understanding to new levels. Effective scaffolding involves modifying instruction, rather than simplifying tasks, to make experiences more accessible to a diversity of students. Teachers need to maintain a balanced approach that responds to students' needs and provides cognitively challenging experiences. The goal, over time, is to foster students to become more independent learners as they transfer their understanding to new situations.

Scaffolds can be preplanned or make the most of a "teachable moment." There are many different types of scaffolds that a teacher might use, many of which are subtle in nature and can be seamlessly integrated into the course of an investigation or discussion. For example, in a whole-group science talk, a teacher may include an English language learner who is reticent to speak by asking a "choice" question, such as, "Which of your magnets attracted more washers, the ring magnet or the block magnet?" This type of question can allow the student to respond and contribute his or her thinking even with little productive language. Or a teacher might have students use gestures as a form of a "total physical response" to support their comprehension when teaching vocabulary. For example, when introducing the vocabulary word "attraction," students can clap their hands to imitate magnets sticking together. Drawing can also be used as a scaffold, effectively acting as an emergent form of writing that allows English language learners to easily capture their ideas.

In the annotated classroom videos that accompany IFI's "Educators Guide for Inquiry-based Science and English Language Development," you can see examples of two Sonoma teachers using a variety of signature experiences and scaffolds to create a rich learning environment for their students.

For more, visit: exploratorium.edu/ifi/inquiry-and-eld/educators-guide.

ESSENTIAL SUPPORTS

Essential supports are a set of classroom practices that are critical to ensuring that the active, language-intensive signature experiences provide maximum opportunities for ELLs to learn science and develop language. These practices include the use of prior-experience conversations, environmental print, collaborative groups, and vocabulary development. They orient students to new topics and provide multiple access points for engaging with those topics. They also aid understanding and the expression of ideas by making words and ideas visible in the classroom, strategically introducing vocabulary, and drawing on peer-to-peer interaction to provide language models.

Prior-experience conversations are a specific type of science talk designed to elicit knowledge and insights about a new phenomenon or topic that students may already have encountered in their daily lives or in school. These conversations serve as a foundation for motivating interest in a new topic and building new knowledge while honoring the ideas that students have. They give teachers important insights about students' thinking and understandings related to their background and culture and serve to provide connections to the new work.

Environmental print is imagery and writing (charts, posters, diagrams, word banks, etc.) posted in the classroom to create a shared public representation of students' thoughts and the language used to express these thoughts. Environmental print serves as a resource to draw from during investigations, science talks, and science writing. Even if understanding comes later, the familiarity of seeing the written word on a daily basis can offer multiple pathways for making meaning as words are used and reused within the context of new experiences. Environmental print is an important part of creating a language- and literacy-rich environment and serves as a bridge between using familiar language and new language.

Collaborative groups are ways of combining students that take advantage of the role of peer interaction in developing science ideas and language.

When groups of students work together, they ask each other for information and respond to each other's ideas in their search for understanding. This interaction provides a lot of opportunity for producing and developing language. Groups are organized strategically in pairs or clusters in recognition that mixed language abilities are an asset rather than an impediment to learning language. Engaging small groups of students with varying language proficiencies (combining English-only and ELLs of mixed proficiencies) in hands-on science experiences, science talks, and science writing allows all students to be exposed to a greater variety of ideas, and the language associated with those ideas. Emerging language learners benefit from peer role models, and students with more advanced language proficiency benefit from being challenged to express their ideas in ways that others can comprehend.

In some classroom populations, there may be three, four, or even more languages spoken by students. Grouping ELLs by their native language can allow them to use their first language to support each other to make meaning. In such cases, whenever possible, the principle of retaining a range of proficiencies (and including English-only speakers in these groups) still applies.

Vocabulary development is an approach for introducing new language that differentiates between procedural vocabulary and conceptual vocabulary. Procedural vocabulary is introduced early in a classroom activity to provide students with the terms necessary to use the materials and engage in an investigation. Conceptual vocabulary is typically introduced during or after an activity to help students make connections between everyday language and academic language (i.e., the language of science).

There is a common misconception that students can't learn science concepts or engage in an activity unless they are equipped with the vocabulary in advance (i.e., frontloading). Strategically incorporating procedural and conceptual vocabulary at the appropriate moment in an investigation makes it more likely that students will assimilate new terms and gain a deeper meaning of them through their association with concrete experiences.

CONTEXTUALIZED MINI-LESSONS

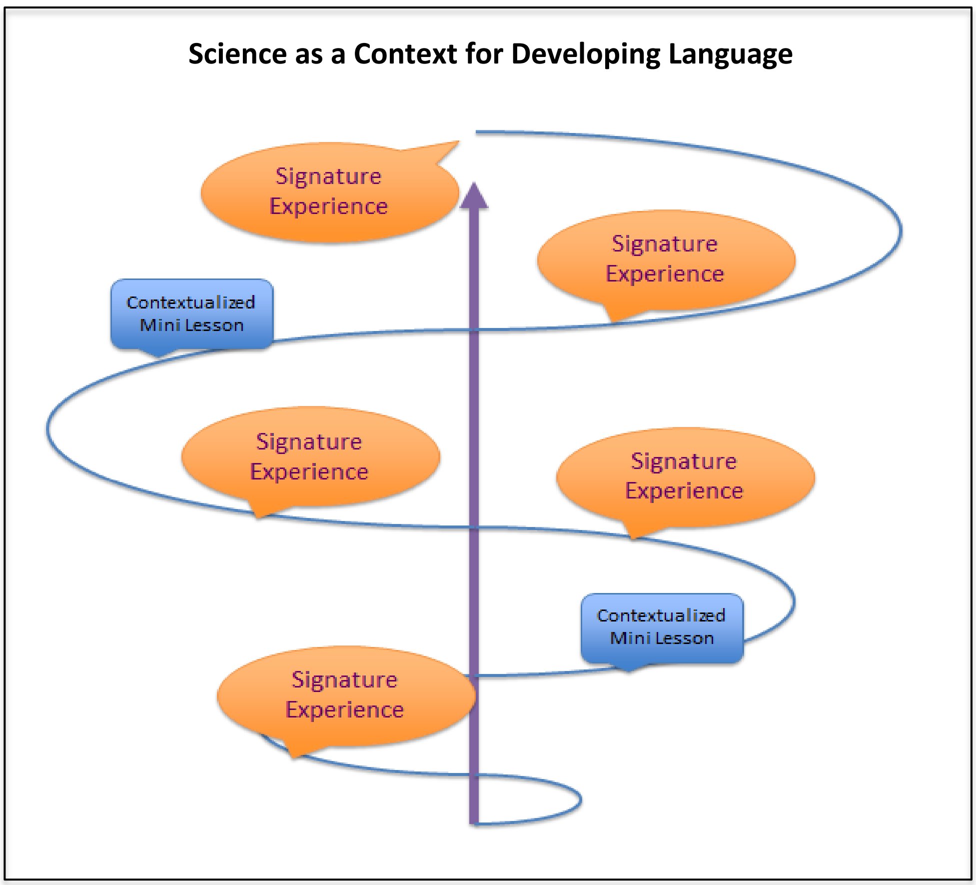
Contextualized mini-lessons (CMLs) are brief instructional moments that take advantage of strategic opportunities within the signature experiences to focus on language conventions. While CMLs might attend to grammatical structures or vocabulary, they are situated within learning science and are driven by the students' need to communicate about the science ideas emerging in an ongoing investigation.

CMLs need to be deliberately designed in response to the needs of particular groups of students. For example, a teacher may design a CML on superlatives (strong, stronger, strongest; weak, weaker, weakest) for a whole class of second graders to support them in making comparisons and interpreting and communicating data from a magnet investigation.

A SPIRAL MODEL FOR SCIENCE AS A CONTEXT FOR DEVELOPING LANGUAGE

The spiral model is IFI's way of representing the dynamic interplay between science learning and language development. It describes for teachers how the signature experiences, essential supports, and contextualized mini-lessons can be coordinated and used in an ongoing way across a single lesson or an entire unit of instruction. Rather than treating them as isolated strategies, the spiral model illustrates how its components can:

- address language demands through scaffolding at key moments
- enhance the ability of all students, ELLs in particular, to participate
- provide an the armature for progressively building students' conceptual understanding and developing their language



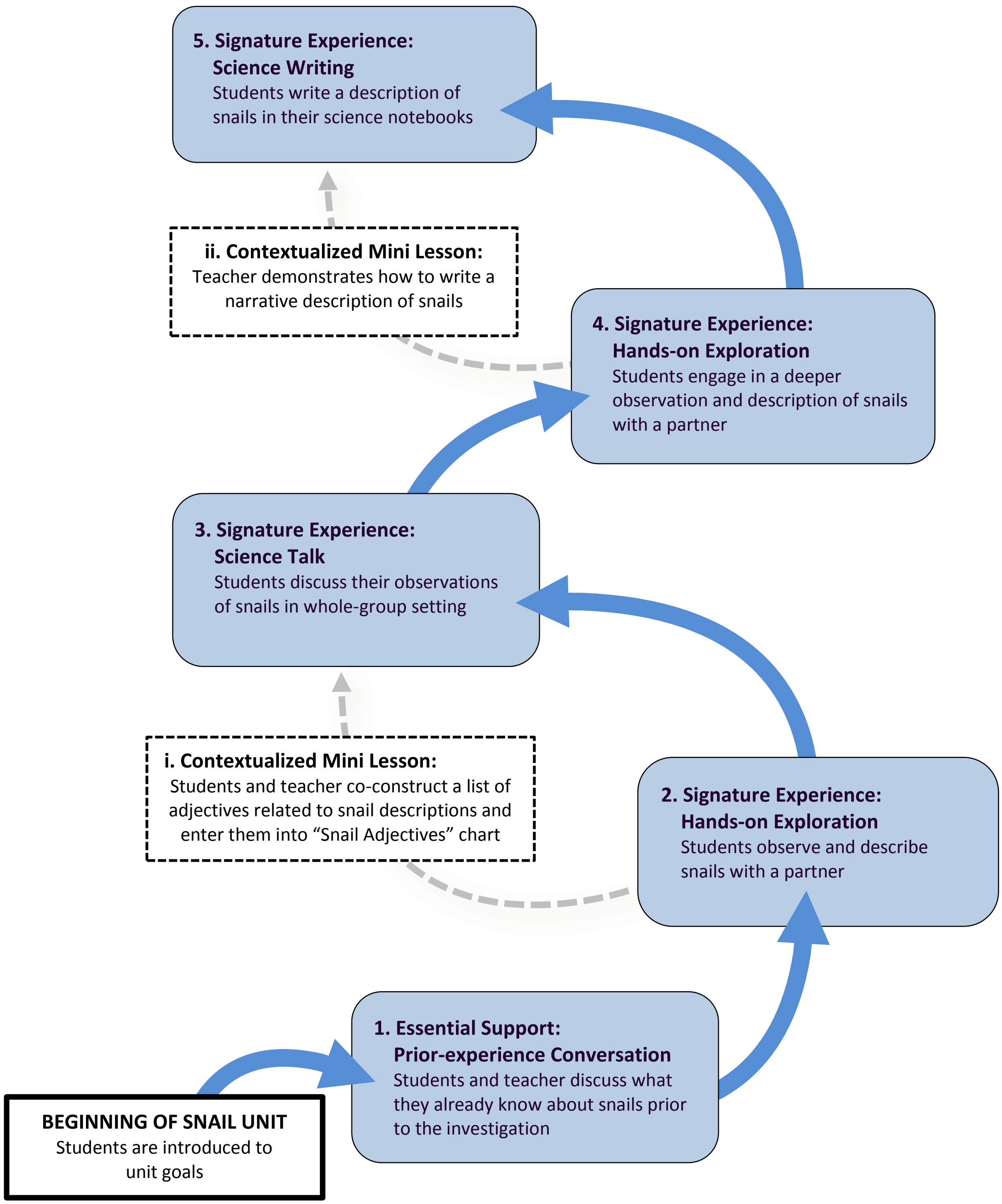
At the core of the spiral model are the signature experiences: inquiry-based science investigations, science talks, and science writing. Teachers have the freedom to determine the combination and progression of signature experiences, and can embed essential supports and contextualized mini-lessons along the way to meet learning goals and address the needs of their students.

The example spiral model below shows a series of hands-on activities, science talks, and science writing that a third-grade teacher planned for three days of lessons that took place early in a unit on snails. She started with a prior-experience conversation to understand and draw on students' existing knowledge (1). The students were then engaged in a hands-on exploration of snails and asked to share their observations with their investigation partners (2). As students began talking about the color, size and shape of their snails, the teacher recognized that they were providing limited descriptions, and saw it as an opportune moment to insert a brief contextualized mini-lesson on adjectives to model language that could broaden students' repertoire for describing the snails (i). During the mini-lesson, the teacher prompted the students to look more closely at their snails, and together they co-constructed a list of more specific adjectives (brownish-grey, striped, slimy, etc.), adding them to a "snails adjective chart." The reciprocal nature of having direct experience observing their snails, and then collectively listing their descriptions—a process facilitated by the teacher—helped students recognize more subtle differences in their snails and encouraged them to communicate those differences further in a whole-group science talk (3). The snail adjective chart also became part of the classroom environmental print and served as a reference students could use while talking about their observations. Taken together, the adjective chart and science talk set the stage for a second, deeper, exploration of snails (4). After the second exploration, the teacher led a contextualized mini-lesson to demonstrate how to write a description containing details about snails (ii). This mini-lesson prepared students to synthesize their observations and new understandings of snails in a session of science writing (5). The language students used earlier in the science talk and the descriptions captured in the snail adjective chart gave them sources to draw on as they wrote.

Example Spiral Model

3rd Grade Science Unit: Snails

What can we observe about snails?
(3 days of lessons at the beginning of the unit)



These lessons laid a groundwork that supported students later in the unit as they experimented, talked, and wrote in order to learn more about snail anatomy, movement, and diet.

Advancing the Spiral Model

Using the spiral model to develop effective experiences for students takes practice and often requires a shift in thinking about science learning and language development. In order to support teachers in making this shift, IFI has designed professional learning experiences to include ample time for reflection on teaching practices and student learning. As teachers develop familiarity with the elements of the spiral model and make them regular features of their classroom practice, they become more adept at recognizing the supports that their students require and develop the ability to scaffold science learning of increasing complexity.

The spiral model represents IFI's current approach to learning language in the context of science as applied to classroom practice. As the IFI staff and teachers work together as part of an active learning community, new insights are gained about the effectiveness of the spiral model in the classroom. Our shared work is advanced by an iterative cycle of experimentation, reflection, and redesign that has implications for future classroom and professional development practices.

The Institute for Inquiry (IFI) is a professional development program that addresses the theory and practice of inquiry-based science education. IFI workshops and seminars are tailored to a variety of participants, including professional developers, administrators, lead teachers, national education reform leaders, out-of-school educators, and educators in the museum and university communities worldwide.

For more information about IFI's program of professional development in Sonoma, see the project website, "Educators Guide for Inquiry-based Science and English Language Development," at exploratorium.edu/ifi/inquiry-and-eld/educators-guide.

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