STUDENT PROGRESSIONS IN SCIENCE AND LANGUAGE DEVELOPMENT

Progress in Developing Science Practices and Thinking Skills

The Integrating ELD (English Language Development) and Science program, a partnership between the Exploratorium and Sonoma Valley Unified School District (SVUSD), offers elementary students wide-ranging opportunities to interact with and make meaning of natural phenomenon through science inquiry. In turn, students' individual and collective investigations create rich and varied opportunities for using language. The kind of student-centered and student-generated learning produced by the Integrating ELD and Science program happens in deep and complex ways, but often "below the radar screen" of what can be detected through formal standardized student assessments.

What Is the Partners in Innovation: Integrating ELD and Science program?

The goal of the Partners in Innovation: Integrating ELD and Science program was to enhance K-5 students' English Language Development and science learning. Over five years the program promoted the implementation of an integrated ELD and science instructional approach by providing concrete supports to teachers in four critical dimensions: curriculum, professional development, professional learning community, and district backing. With its focus on learning language in the context of hands-on science, the program aimed to establish a robust, districtwide elementary science program as well as to accelerate the language development of its English Language Learners.

As an alternate construct to achievement testing, the concept of ***student progressions*** provides a view of how children build their knowledge over time. The ***student progressions*** lens can illuminate specific critical dimensions of ELD and science learning that are essential precursors to students' academic success and that contribute to robust lifelong learning. The ***student progressions*** concept is presented here to show how SVUSD students both <u>learned and used</u> skills and practices focusing on higher forms of thinking rather than just rote learning. Called for most recently by the Next Generation Science Standards (NGSS), but originating much earlier in the mid-1950s with Bloom's Taxonomy of Cognitive Learning, these intellectual skills and practices are widely accepted as the *raison d'être* of high-quality education and exemplify the academic achievement of successful students. The data used to illuminate how students acquired and utilized these skills and practices is gathered from a range of sources: classroom observations conducted by researchers from both Inverness Research and the Research Group at the Lawrence Hall of Science; teachers' survey responses; teacher reflections from interviews and written testimonies; as well as exemplars of student work, both oral and written.

How does the Integrating ELD and Science program help students develop science practices and thinking skills?

The chief curriculum designer at the Exploratorium, who was responsible for developing the kits and teacher guides that supported teachers in implementing the Integrating ELD and Science program, explained the central focus of the program and how the activities were intended to help K-5 students understand and use science practices and thinking skills.

- ✓ *The Integrating ELD and Science program began before NGSS was even out... so, as we had for many years at the Institute for Inquiry at the Exploratorium, we worked with the term "science process skills." The process skills we identified were similar to the science practices from NGSS. While the names are different, our conceptualization of their use was aligned to current thinking of how science practices are utilized to develop scientific understanding.* ***We also conceptualized the process skills as the key bridge between learning science and developing language.***

What are the eight practices of science that NGSS identifies as essential for all students to learn?

1. **Asking questions (for science) and defining problems (for engineering)**
2. **Developing and using models**
3. **Planning and carrying out investigations**
4. **Analyzing and interpreting data**
5. **Using mathematics and computational thinking**
6. **Constructing explanations (for science) and designing solutions (for engineering)**
7. **Engaging in argument from evidence**
8. **Obtaining, evaluating, and communicating information.**

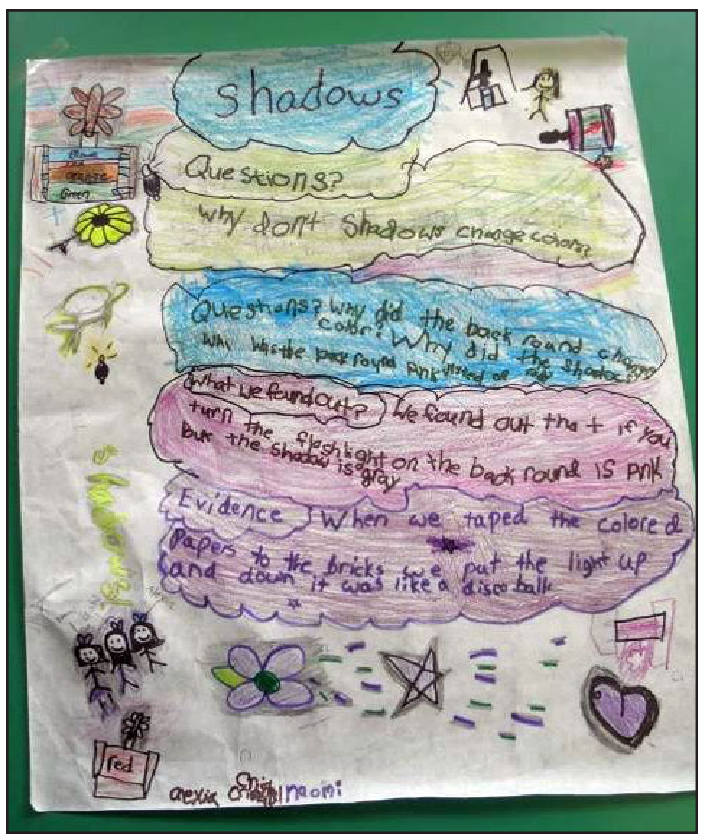
Although all the Integrating ELD and Science units employ several of the NGSS eight practices of science simultaneously and in conjunction with one another, the curriculum designer offered illustrations from specific units of how they successfully engage students in particular skills or practices:

- ✓ *All of the units in various ways involve investigations, which always have* **Asking questions** *(#1) at their core. The investigations are meant to answer questions. In many units the students come up with questions themselves, but in others the questions are given to the students sometimes as a precursor to helping them understand the kinds of questions that can be answered through investigations. A good example of that progression from having a question modeled for students to inviting them to ask their own questions is the 3rd grade Shadows unit. The first investigation is a guided one where the questions are given, but then later students are encouraged to ask their own questions about shadows and to design and plan their own investigation to address the particular question they had.*

- *Again, the Shadow unit is a good one for illustrating* **Developing and using models** *(#2). The last lesson in the unit involves a demonstration with the whole class using string to model what light rays are in order to give students a tool to predict exactly where shadows are going to fall. So while light rays are actually an invented construct—there is no such thing as a light ray, the light ray is itself a model—the way that we physically represent that in the demonstration is to use string in straight lines. We want to help students conceptualize the relationship between the light source and the edge of the shadow maker and where the shadow actually falls on the screen.*

- **Planning and carrying out investigations** *(#3) is exemplified yet again in the Shadows unit. The students are given a plan for the first investigation so they have a model for what a plan looks like and what its key elements are. Then in the second investigation, they are asked to come up with their own plan in small groups.*

- *For* **Analyzing and interpreting data** *(#4), the 2nd grade Magnets unit is a good example of how we incorporate the science practices into the instructional material. There is an experiment where students see how many washers a single magnet or two magnets or three magnets will hold. The question they are trying to answer is: Is the force from two or more magnets stronger than from just one? As they conduct the experiment they gather a lot of data on the relative strengths of these different numbers of magnets, and they have to construct a graph showing the numbers of washers all of the magnets have picked up. Then they look at that graph showing the results of their investigation and they must interpret their data. It's always a "Wow!" Then they can make some statements about the relative strength of different numbers of magnets.*



- ✓ *You can see how the Magnets unit is also a good example of* **Using mathematics and computational thinking** *(#5), as the students have collected numbers and graphed them to show their relative strength in 3 different investigations. They are using graphing and numbers, that is, math and computational thinking, to make sense of their results.*

- ✓ *Now for* **Constructing explanations** *(#6)***,** *which is showcased in the Shadows unit again. Early on in the unit there is a very quick experiment where children outline their shadow with chalk on the schoolyard, wait half an hour and then repeat the process. Obviously the shadows are different even though the students are charged with standing in exactly the same place. "Why do you think your shadow has moved?" is the prompt for generating students' thinking and their explanations for what happened.*

- ✓ **Engaging in argument from evidence** *(#7) is a practice that is prominent in the Stream Table Investigation unit. Students do several investigations with stream tables—they change the slope of the stream table, the amount of water flowing through it, and the size of the particles. In each case they are looking at which conditions change the amount of erosion, i.e., the amount of sand moved from one place to another. They are asked to write claims and evidence statements after each part of the investigation, responding to a prompt, for example, "Do I think that bigger slope caused more erosion, and what is my evidence for that?" Throughout the process of the investigation they are developing their arguments, and in conclusion in a class discussion they talk about which arguments seemed to be the most compelling.*

- ✓ *The 3rd grade Snails unit is a very good example of the practice of* **Obtaining, evaluating, and communicating information** *(#8), because at the end of that unit and at the end of the investigation on food, the students make posters. They talk about what food the snails preferred. They have to show the rest of the class what they found out about which foods their snails preferred and they do that in a poster format and so they not only have to explain it, but they have to represent it in a way that really shows their findings.*

What are the connections among science practices, thinking skills, and language development? How are they all related in the classroom?

One of the great challenges of "hands-on" science teaching is to facilitate students' interactions with materials in ways that go beyond "just having fun," that actually develop both students' science practices, and their thinking skills and intellect. An additional challenge the Integrating ELD and Science program faced was to ensure that students were not only learning science content and practices, but also learning, using, and expanding language in the context of science. The central pedagogical paradigm around which student experiences were designed was the Exploratorium's model of the Inquiry Process, described below.

What Is Inquiry? [1]

- **The inquiry process** is driven by one's own curiosity, wonder, interest or passion to understand an observation or solve a problem.
- **The process begins** when the learner notices something of interest that stimulates a question.
- **The next step is to take action**—through continued observing, raising questions, making predictions, testing hypotheses, and creating conceptual models.
- **The student must find** her or his own pathway through this process, which is rarely linear, but rather more cyclical. Teamwork, collaboration, and communication are all essential.
- **As the process unfolds**, more observations and questions emerge, providing for deeper interaction with the phenomenon and progression of understandings.
- **Along the way,** the inquirer collects and records data, makes representations and explanations of results, and draws upon other resources.
- **Making meaning from the experience** all along the way requires reflection, conversation, writing, comparison of findings with others, interpretation of data and observations, and the application of new conceptions to other contexts.

The units provided all of the materials teachers and students needed for firsthand inquiry lessons. Organized around "signature experiences" that repeated throughout the program, each of the units intended to immerse the students in an inquiry frame of mind and to give them multiple opportunities to use tools and strategies for systematic investigation. The signature experiences included: open and guided hands-on inquiries, activities that elicit students' prior experiences, collaborative group tasks, science talks, science notebooks for drawing and writing, and "public" reports to communicate what students observed, learned, and still wondered about.

A third grade teacher explains the synergy among science practices, thinking skills, and language development, and how the dynamic plays out in the classroom:[2]

> ***Kids have a natural curiosity, a desire to socially connect, and an inclination to seek out fun, engaging activities. The trick with teaching is to lasso all three of those things together into learning experiences that are open-ended enough to allow real discovery and conversation. In 16 years of teaching I have not seen a more successful way to accomplish this than through our Integrating ELD and Science program. The program allows teachers***

[1] Excerpted from the Institute for Inquiry website, https://www.exploratorium.edu/ifi/about/philosophy.html.

[2] Quotes are taken directly from interview transcripts and edited for both grammatical correctness and readability. The integrity of the quotes has been maintained; intent and meaning have not been altered.

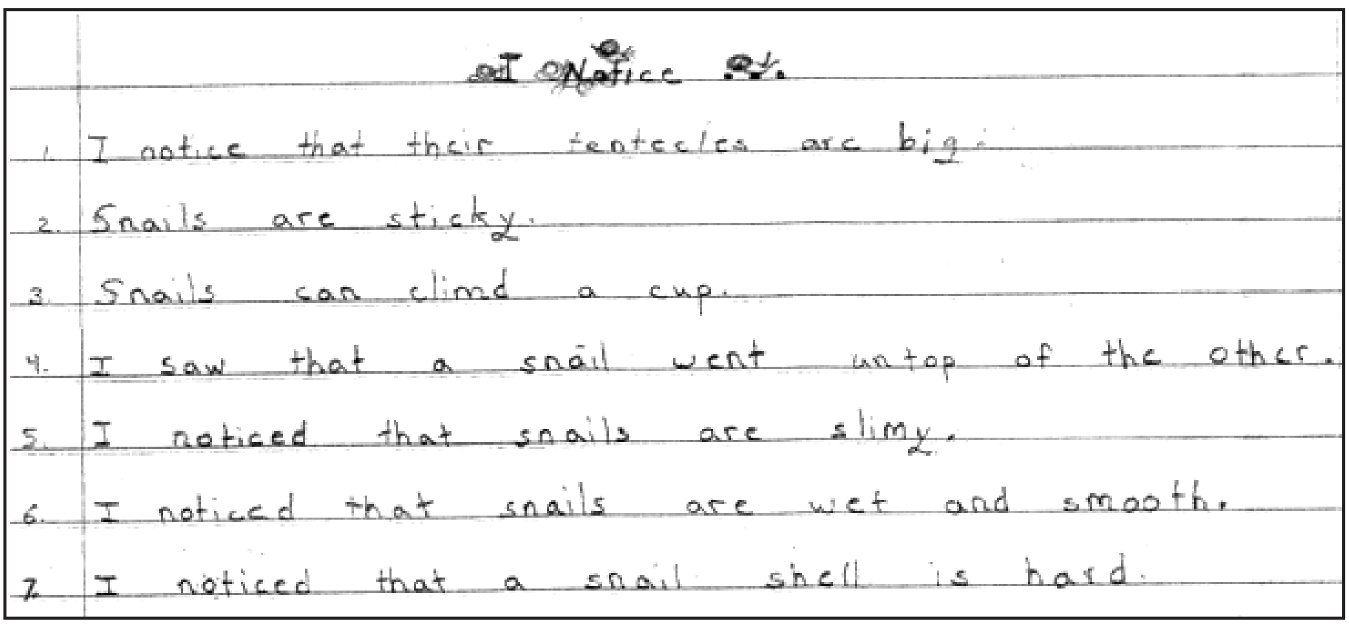
to consistently create environments where kids learn reasoning, communication, and teamwork skills by <u>doing them</u> in an authentic and rigorous way. These 21st-century skills are practiced in context every day through hands-on, inquiry-based science projects where the emphasis is placed more on creating shared understandings <u>through</u> language than it is on the science content. The science experiences get kids talking and sharing. With a bit of teacher questioning, students begin explaining what they are doing and seeing, they begin to write and draw about their experience, engage in debate about what they see, generate thoughtful questions, and design investigations of their own to explore possible answers to their questions. Students work in design teams, like real scientists, to plan experiments, test hypotheses, and come to conclusions. Kids share their results and debate why things occurred. They make posters to share their findings with peers.

How do students develop science practices and thinking skills in their classrooms?

Camilla Studied Snails

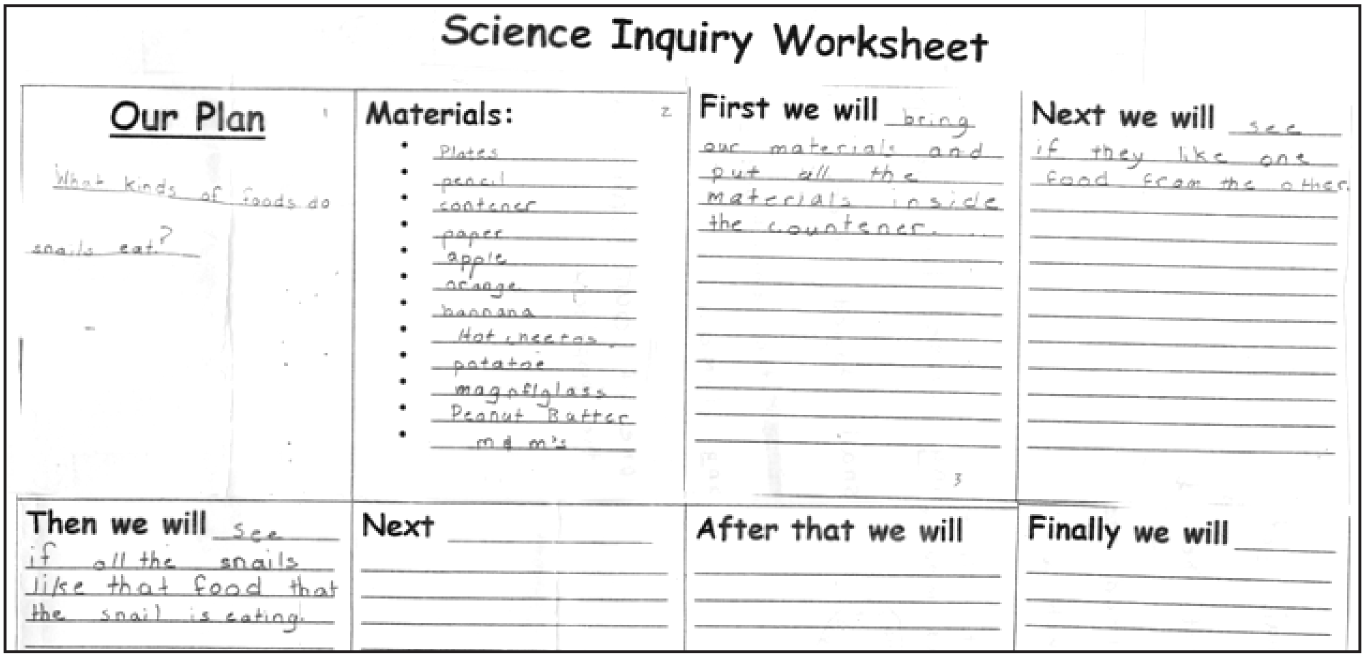
In the following vignette, which highlights a second grade classroom early in the school year, an ELD student writes about what she notices, does, and learns about snails. Several selections of Camilla's work demonstrate the progression in her learning as the Snails unit progressed. Highlighted, albeit at a second grade level, are a handful of the 8 NGSS practices of science: observing, asking questions, planning and carrying out an investigation, constructing explanations, and engaging in argument or explication from evidence.

In the very first activity that launches the Snail unit, the second grade teacher asked students to observe their snails and to document what they noticed. Below is Camilla's response.


I Notice

1. I notice that their tentecles are big.
2. Snails are sticky.
3. Snails can climd a cup.
4. I saw that a snail went untop of the other.
5. I noticed that snails are slimy.
6. I noticed that snails are wet and smooth.
7. I noticed that a snail shell is hard.

After deciding the class would investigate what snails eat, Camilla's teacher introduced a Science Inquiry Worksheet to help students plan their investigations. The worksheet was completed by pairs of students, each pair filling it out in different ways. The worksheet on the following page shows how Camilla and her partner planned and anticipated carrying out their investigation.

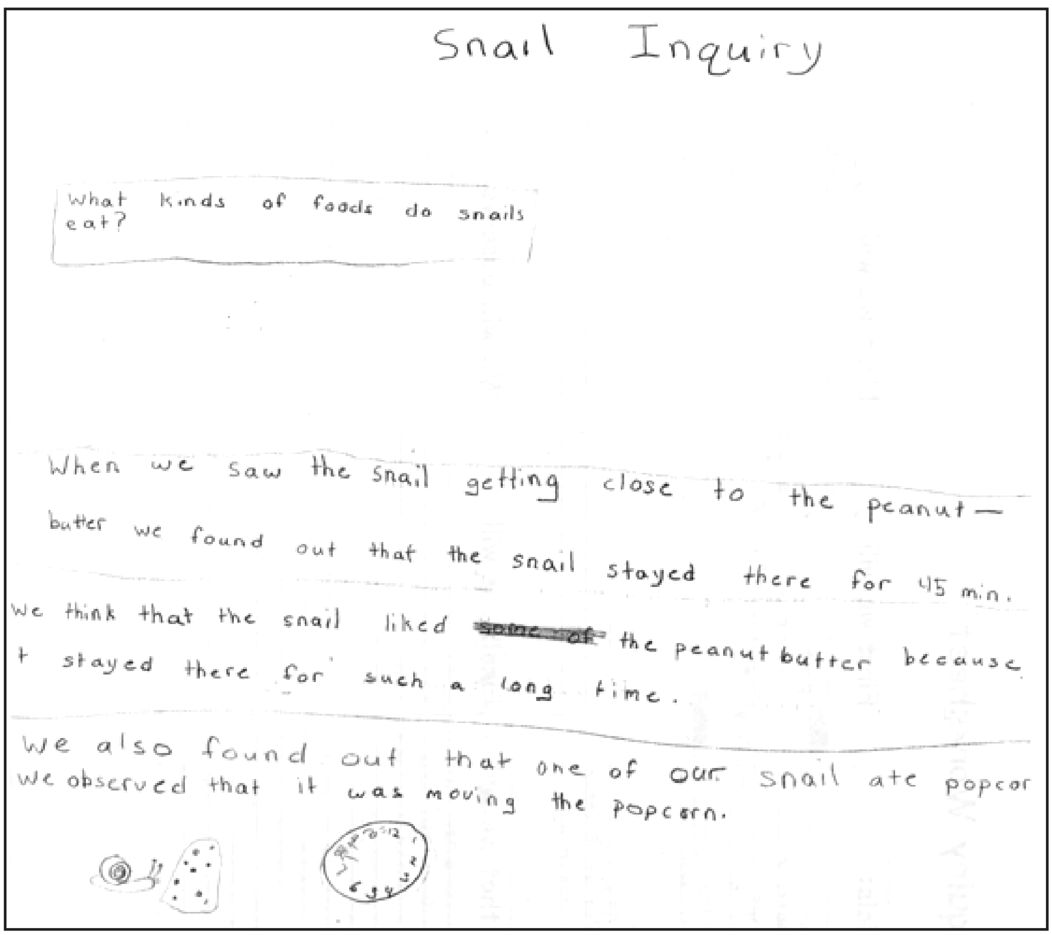


Science Inquiry Worksheet

Our Plan	Materials:	First we will	Next we will
What kinds of foods do snails eat?	• Plates • pencil • contener • paper • apple • orange • bannana • Hot cheetos • potatoe • magnflglass • Peanut Butter • m & m's	bring our materials and put all the materials inside the countener.	see if they like one food from the other.

Then we will	Next	After that we will	Finally we will
see if all the snails like that food that the snail is eating.			

Students then spent time observing snails on plastic trays along with various types of food. They recorded what they observed the snails doing.



Snail Inquiry

What kinds of foods do snails eat?

When we saw the snail getting close to the peanut-butter we found out that the snail stayed there for 45 min.

We think that the snail liked ~~some of~~ the peanut butter because it stayed there for such a long time.

We also found out that one of our snail ate popcor we observed that it was moving the popcorn.

With simple illustrations and just three statements, Camilla and her partner showed what they had learned. Their snail ate peanut butter—*we saw*. Though they couldn't actually see the eating, the evidence they used for making the claim—*we think that*—was based on sound reasoning, i.e., the long time the snail spent at the peanut butter. They also documented and quantified the amount of time —*45 minutes*. Finally they observed the snail eating popcorn, again citing their evidence—*it was moving the popcorn*. Thus, this pair of inquiring students made a straightforward, but a patiently executed and effective, set of observations and assertions.

The final activity in the unit asked students to complete a reflection sheet, prompting them to tell what they had learned about snails, what they still wanted to learn, and what they would have done differently in their snail-focused investigations. Camilla wrote the following:

Snail Inquiry Reflection

What I Learned...	What I Still Want to Know....
1. I learned that snails don't like hot cheetos. 2. I learned that one snail liked the peanut butter. 3. I leatned that a snails shell is a home for them. 4. I learned that snails eat very slowly. 5. I learned that all the snails didn't like the m&m's 6. I learned that snails don't see colors.	1. I still want to know how snails sleep.

What I Would Do Differently Next Time...

Next time I would want to do something different like get pizza, strawberries, berries, and corn.

Camilla learned and practiced critical science and language skills during her study of snails. As the third grade teacher cited at the bottom of p. 5 explained, “The Science and ELD program allows teachers to consistently create environments where kids learn reasoning, communication, and teamwork skills by doing them in an authentic and rigorous way.” Camilla, like the others in her class, was excited and surprised by snails. She asked questions, recorded and documented her observations and findings, planned investigations, applied what she had learned from her investigations to other contexts, and easily generated more possibilities for further study—all a strong demonstration of learning science practices and thinking skills while engaged in intriguing, accessible topics.

What do school administrators say about how the program contributed to students' progress in developing science practices and thinking skills?

... Even if we didn't have Common Core State Standards adopted here in California, I think the whole idea around teaching students to be critical thinkers rather than having them memorize algorithms or having them learn language outside of the context is important ... in this district we are moving away from the No Child Left Behind mentality of math and English instruction only. It has been at a cost of every other subject area.

... One of the greatest accomplishments of the Integrating ELD and Science program was to show us an instructional model focused on inquiry-based learning ... (In the program) students experienced learning and researching and gathering evidence to either support or disprove a hypothesis ... that model then, that we learned from the Exploratorium, set us on a good course for the work we are doing now with the Common Core.

As for the students, the program has undeniably given them the gift of learning science that they didn't have before ... not just learning science, but doing science, and becoming more like real scientists ... the science was so hands-on ... demanding hard thinking and collaboration ... it's about 21st century learning skills. The program focused on all of those skills ...

~ SVUSD Superintendent

... Five years ago when we began the Integrating ELD and Science program we saw it as a great opportunity to push the envelope with NCLB and to create some space for more hands-on, big-idea things to happen for kids ... we wanted them to have more opportunities to develop their thinking, to be inspired by things, to ask questions, and work to find the answers—all in service to their language development.

The program was an opportunity to find ways to address student achievement, especially for Latino students ... we wanted to make sure they had entrance into the field of science. We knew, however, we were teaching in a way that didn't really transfer well to a bubble-in test because we were opening up the dialogue for kids instead of closing it down, which is what that kind of testing often does.

Thinking now about what the program has accomplished ... First, every teacher used the program, and that meant kids were getting more science ... and it meant we were well-prepared for the Common Core standards ... The other thing is that our students are interested in science. You hear them asking why, and they have the skills to investigate, to collect information, and to plan a presentation—overall I think those kinds of things have improved.

~ SVUSD School Principal

What do teachers have to say about how the program contributed toward students' progress in developing science practices and thinking skills?

- ✓ *93% of teachers surveyed said the program contributed to their students exhibiting an inquiry state of mind, e.g., noticing, wondering, questioning.*
- ✓ *94% of teachers surveyed said the program contributed to their students using science process skills, e.g., observation, comparison and contrast, analysis.*
- ✓ *91% of teachers surveyed said the program contributed to their students utilizing prior knowledge in connecting science ideas to other experiences and the real world.*

✓ *83% of teachers surveyed said that the program contributed to their students learning to document, organize and analyze ideas and information that involve making scientific drawings, taking notes, constructing data tables, etc.*

What is a representative example of a student progression toward internalizing science practices and thinking skills?

Lana Studied Shadows

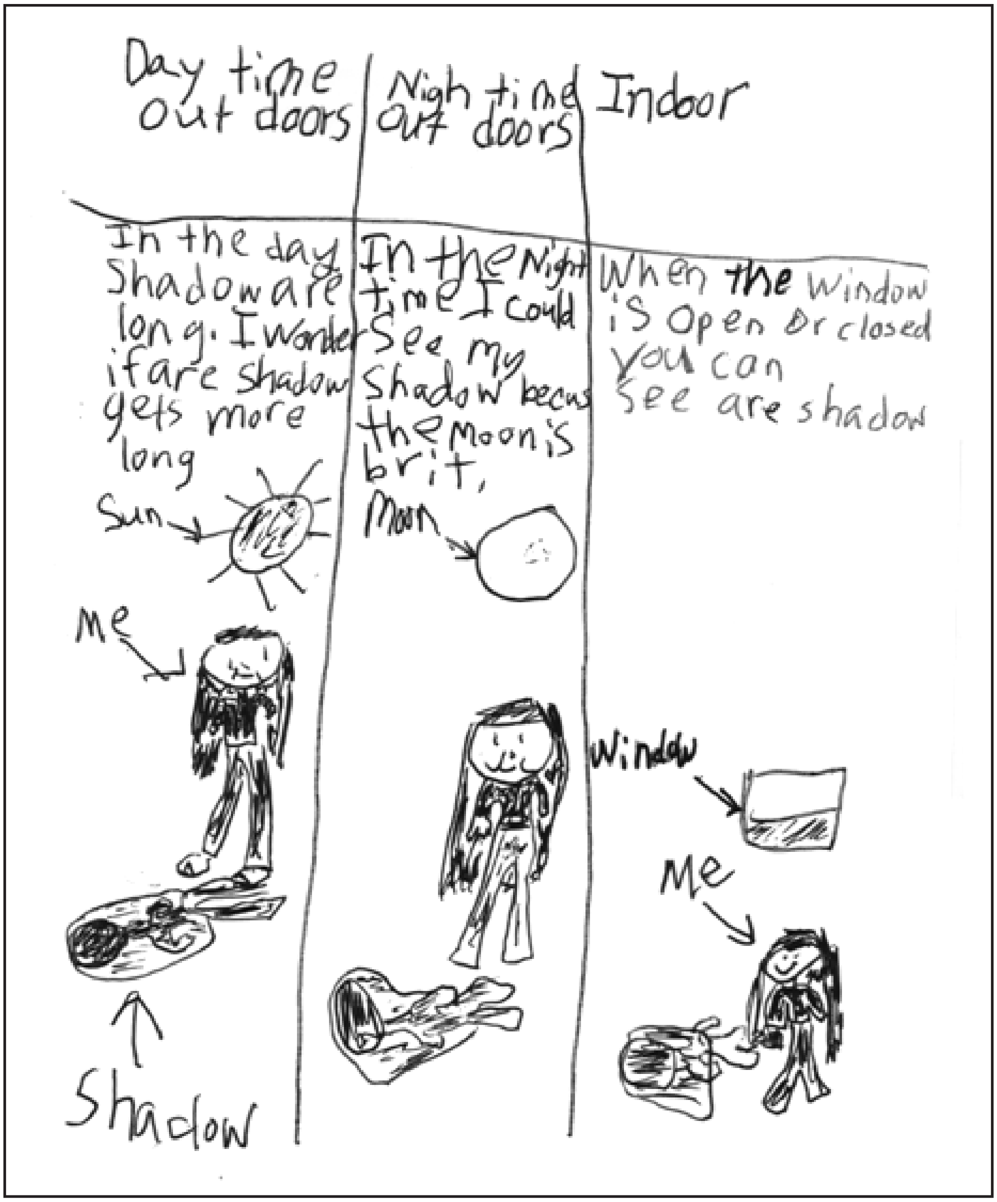
In the spring of 2013, an Inverness researcher observed one of SVUSD's third grade classrooms studying shadows. What follows are excerpts from the researcher's class observation notes and reflections:

> *The Shadow lesson is taking place outdoors on the black top area of the playground. Students are noting and comparing what their shadows look like at two different times during the day. These 3rd grade students seem engaged in the shadow and light activity, and they appear to be in most cases self-directed, the authors of their own lessons, pursuing new questions with their actions as they interacted with inherently interesting phenomena.*
>
> *Following on this initial activity, the teacher later told me this process of individual investigations continues on through the day. She sees the children playing shadow games, or doing more shadow investigations at recess. The teacher also said that the students are interested in looking at and thinking about shadows in other areas … they talked about the shadows and the lights and what they thought was happening in a painting.*
>
> *If the students referred back to what they observed about shadows during the outdoor lesson, the unit may help them pay attention to the natural phenomena around them in ways they haven't before. It also seems to me that by extending the lesson into multiple investigation sessions, students have ample opportunity to engage with the materials. The teacher seems to encourage them to think about what they are learning and tries to relate what they learned earlier in the unit to what they are seeing and investigating currently.*

After these activities the Shadow unit moves into opportunities for students to investigate further, using flashlights and mirrors—taking the class from thinking about shadows to thinking about reflections. However, one student, Lana, continued her blacktop shadow investigations at home.

The artifact on the following page, from Lana's science journal, describes the experiment she conducted at home. Her teacher describes how Lana's journal entry exemplifies the internalization of the inquiry process she and many other 3rd grade students experienced as a result of their shadow study:

> ***In this entry from Lana's science journal, she dated the page and set it up with a double "T" chart labeled with the following categories: Daytime Outdoors, Nighttime Outdoors, and Indoor. She remembered these categories from a Science Talk we had to activate prior knowledge. I love how this child took the scaffolds and made them her own to do some writing at home on the topic.***
>
> ***Under each category Lana made a drawing of herself and her shadow in the conditions with an observation about each.***



She states that the Day shadows are long. She wonders if they can get longer. Her labeled drawing shows the sun as a light source. In the Night she says she can see her shadow because of the bright moon. Her labeled drawing shows the moon as the light source. And for indoors, she writes that whether the window is open or closed, you can still see a shadow on the floor.

This child is applying knowledge from school to her life at home. She's making independent journal entries to make sense of her experiences in a very organized, scientific way. She internalized the process and took it a step further on her own in her own investigation. And the really good news is that this continued as a practice by Lana in other inquiries.

Not only is this student applying what she did in class to design a new investigation at home, but also she has internalized and utilized a score of important science practices and thinking skills.

She has opened herself to noticing and observing scientific phenomena. She has pursued a science topic ever more deeply on her own. Her journal entry reflects that she carefully observed and represented the size and nature of the shadow as the conditions changed, complete with the details of a lighter shade of shadow represented by her hair and the darker shadow showing her head. In addition, she has drawn and labeled her drawings carefully in order to communicate to others. She demonstrates knowledge of an intuitive sense of variables, varying one condition and keeping others mostly the same, even though she doesn't formally articulate the concept of variables. Her documentation also shows that she is standing between the light source and her shadow, a careful observation of cause and effect many students didn't notice or represent in their classroom study.

Lana's science journal entry revealed the progress she made toward internalizing critical science practices and thinking skills—by showing how she duplicated the inquiry process she learned in class and repeated with new questions and under different conditions at home. Lana, representing many of the other 9-year-olds in her class, has fulfilled what the Science Framework for K-12 Education describes as the rationale for why the NGSS eight practices of science are essential:

> ***Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world.*** [3]

---

[3] Next Generation Science Standards, APPENDIX F "Science and Engineering Practices at NGSS," page 1.

Partners in Innovation: Integrating ELD and Science
Exploratorium/Sonoma Valley Unified School District

Project Portfolio

Inverness Research, a national education evaluation and consulting group headquartered in Northern California, has over 25 years of experience studying local, state, and national investments in the improvement of education.

Inverness Research * P.O. Box 313, Inverness, CA 94937 * Ph: 415-669-7156 * Fax: 415-669-7186
www.inverness-research.org