Equity and Access for All Students

Reprinted, with permission and with edits, originally from the book "Navigating the Common Core with English Language Learners" by Larry Ferlazzo. Chapter 9 (page 315), on Science, was written by:

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As many states shift science instruction towards NGSS, it is imperative that educators look closely at whether equitable opportunities to learn and do science are available to all of our students. In Appendix D of the NGSS, "All Standards, All Students[1]," the writers make the case that these new standards and expectations are intended for every child in each of our classrooms. This means that no student shall be denied the experience of actually doing and learning science. To achieve this, we must teach in equitable ways.

A student's opportunity to learn science can be examined in several dimensions: Are teachers prepared and given adequate class time to teach science? Are high-quality materials and curriculum available to all students and teachers throughout the school year? While these are crucial questions to consider in light of the heavy focus on ELA and math, just increasing time spent on science instruction and placing science materials in classrooms are not enough to provide these expected equitable learning opportunities. The *quality* of science teaching and learning must also be examined. Are students coloring worksheets about science, copying concepts "learned" off the board, conducting "cookie-cutter" labs, or perhaps only experiencing science through textbooks or videos? Or are they truly engaged in the practices of science, as called for in the NGSS?

Equity, however, goes beyond making sure that all students have access to standards-aligned science instruction. To teach in an *equitable* way means that educators understand, value, and teach to the strengths, challenges, prior knowledge, and life experiences that each student brings to the classroom. It means holding high expectations for all students and believing that every student can succeed.

Science and Language

The three-dimensional teaching and learning aspect of the NGSS present both significant challenges and opportunities for ELLs. Providing equitable science instruction requires more than "sheltering" the science experience for ELLs in order to make the content comprehensible. Each and every student must have the opportunity to do the heavy lifting—to struggle with ideas and the means to express them. Although a student may not possess the language resources in English to express their thoughts, all students have a wealth of ideas and explanations to contribute to discussions and learning tasks. There needs to be a classroom culture of discourse, where all students can contribute to the conversation regardless of their "flawed" language. The NGSS were developed to ensure that all students, including ELLs, be afforded equitable opportunities to develop and share their own ideas, interact with the ideas of others, and arrive at a deeper understanding of science concepts as a result of rigorous meaning-making processes.

Many students in Oakland Unified School District (OUSD) are emergent bilinguals, and we consider their bilingual status to be a great asset that brings diversity and richness to our classrooms and will serve them well throughout their lives. There is a history in many urban districts of denying ELLs access to science learning opportunities due to extra time being spent on explicit language skills development—like grammar and vocabulary, often void of rich context and meaning making. Fortunately, many teachers know that language development can be best accomplished through content learning since language is about communication.

Because of the focus on real-world materials and activities, not to mention the high-interest topics and potential for disciplinary language-rich discussions, science classes are ideal learning environments for English language development. Much of this work is supported by the new California English Language Development Standards (CA ELD). As stated in the CA ELD Standards, "A key goal of the CA ELD Standards is to support EL students to develop advanced proficiencies with academic English as they are also developing content knowledge across the disciplines[2]." (California Department of Education, 2012, p. 6).

MAKING IT HAPPEN

Meeting the challenges of the NGSS requires identifying the language demands necessary for students to fully engage in the science and engineering practices— especially those that are highly language dependent and involve complex thinking processes such as argumentation, developing and using models, and constructing explanations. It is, therefore, necessary for all teachers of science to pay as much attention to language objectives as they do to content objectives when planning and implementing three-dimensional science instruction. In addition to answering the question, *What will students know?* the learning objective should also answer questions about the language demands of the instruction, such as:

1. **How will students be engaging in the science experience?**

2. **What are the language functions required when engaged in these practices? What vocabulary and language structures will students be using?**

3. **Where are students now in terms of these language functions? What are the language expectations as a result of this instruction? What literacy supports will students need?**

Answers to these questions will inform teachers of the need for explicit language instruction achieved through designated ELD to support content learning.

LANGUAGE OBJECTIVES FOR SCIENCE

Once the science and engineering practices for the lesson have been identified, the next step is to think about the language functions students will be using to engage in those practices. Knowing where students are and where you want them to be will inform the language objective. The *Student Engagement in the Science and Engineering Practices Chart* below provides examples of how to support ELLs with the language demands inherent in each of the science and engineering practices. These strategies and scaffolds can be used regularly to provide access for all students and/or as supports for ELLs to attain a higher level of language use. As with any scaffold, they should be used strategically on an “as needed” basis.

Student Engagement in the Science and Engineering Practices Chart

NGSS Science and Engineering Practices	**Corresponding Language Functions**	**Strategies and Scaffolds**
Asking questions and defining problems	Inquire, identify, define	• Provide an engaging context that peaks student curiosity (discrepant event, interesting scenario, hands-on activity, relevant situation, authentic problem). • Keep class chart for student questions and/or students record questions in their science notebooks. • Sentence frames for oral and written discourse:*I wonder...What, where, when, and how? What would happen if...?* • *What causes…? What are the effects of...?* • Questions/Prompts: • *What is the problem we are trying to solve? What are the criteria? What are the constraints?*
Developing and using models	Represent, predict, explain	• Model for students how to develop and use models to explain their thinking. • Regularly have students draw a model to use as an artifact for discussion. Encourage students to revise their models based on new information. • Example: Draw a model that explains how an electric circuit works. • Sentence frames for small group/ one-on-one discussions:What does your model show/predict/explain? My model shows/ predicts/explains . . .What does . . . mean? What could you change in your model to make it better?
Planning and carrying out investigations	Design, sequence, evaluate, describe, organize, com-pare, classify, draw, label	• Model the process for planning an investigation. Ask guiding questions: *What are you trying to find out? How could you find out . . .? Is there another way? What materials will you need?* • Provide structures for sequencing procedures: *first, second, then, after*. • Teach a mini-lesson on ways to record and organize data in student science notebooks (e.g., T-charts, lists, technical drawings, labeling). • Introduce equipment and procedural words beforehand (*separate, pour, measure,* etc.) and post on a class Word Wall or chart with images. • After coming to a class or group consensus on a procedure for an investigation, document the steps on the board with illustrations so that all students have access to them.

		• Have students work in small groups. Encourage and make collaboration a focus.
Analyzing and interpreting data	Compare, represent, classify, sequence, analyze	• Model ways of organizing data in class charts and student science note- books (graphs, charts, Venn diagrams, graphic organizers). • Provide sentence frames for oral and written discourse: My data show... A pattern I see is... ...and…are similar because they both…and…are different because…
Using mathematics and computational thinking	Enumerate, measure	• Use opportunities in science to engage in math practices when appropriate. • Help students see the connections between what they are learning in math to how it is applied in science. • How did numbers and patterns help us understand what is going on? • How does the quantitative data support your explanation?
Constructing explanations and designing solutions	Infer, explain, provide evidence	• Teach a mini-lesson on language structures and norms for engaging in academic discussions. • Discussion mats • Sentence frames: • Based on… I think... • I think...because... • We think . . . is the best solution because…
Engaging in argument from evidence	Discuss, persuade, synthesize, negotiate, suggest, critique, evaluate, reflect	• Provide norms and structures for students to discuss in pairs, small group, and whole class. • Model and discuss expectations for argumentation. • Sentence frames: I claim... My evidence is...I agree/disagree with . . . because… What about...? I used to think...but now I think...
Obtaining, evaluating, and communicating information		• Reinforce vocabulary by using pictorials (review key concepts by illustrating and labeling on chart paper in front of students). • Provide ample opportunities for students to talk, write, and read about their science experiences. • Use reading and multimedia to deepen students' understanding of the phenomenon. • Model and provide scaffolds. (Use reading strategies such as: close reading, jigsaw, guided reading, graphic organizers, and visual literacy strategies.)

Our students demonstrate that they are capable of doing high-level work in science, while also developing their academic language. Through high expectations, engaging content, appropriate and flexible scaffolds, and formative assessment, students' science conceptual understanding and language abilities flourish.

Fifth-Grade Vignette: Where Does the Water Come From?

This vignette describes how a fifth-grade teacher enhanced her science lesson on condensation to (1) increase student engagement in three-dimensional learning and (2) attend to the demands and the opportunities for language development for her ELLs. However, the strategies demonstrated in this vignette can be applied to science lessons in any grade.

The focus of this lesson is: NGSS Performance Expectation 5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact[3].

BACKGROUND

Ms. Lopez's class is working on the Fifth-Grade NGSS DCI Earth Materials and Systems. She is beginning an investigation from the *FOSS (Full Option Science System) Earth and Sun Module* that will include the concepts of condensation, evaporation, the water cycle, and how these systems affect climate. Ms. Lopez's students' proficiency in English ranges from emerging, expanding, to bridging (Beginning, Intermediate, to Advanced). She also has one "newcomer" student whose family just moved to the United States from El Salvador a month ago.

ACTIVATING PRIOR KNOWLEDGE

Ms. Lopez starts every lesson with a prompt or short activity that will help students connect to something they've already experienced or think they know. Usually, she has students share their last science notebook entries with a partner to review what they learned the day before. However, this is the beginning of a new investigation and Ms. Lopez wants to know what ideas students have about the concept of condensation. She asks students to close their eyes and imagine what it looks like when it rains. She adds, *Think about the clouds and the air. What does the sky look like? What can you observe with your senses? Where do you think the rainwater comes from?* Ms. Lopez notices that Mario, her new student from El Salvador, still has his eyes open and is looking around. She points to a picture from the science resource book of a rainy day, closes her eyes and points to her temple, making a face that indicates she's thinking. When she opens her eyes, she sees that Mario is smiling and his eyes are now closed. (Ms. Lopez could have translated the instructions, but instead she is working on supporting Mario to employ learning strategies on his own when appropriate.)

After a minute of silent reflecting, Ms. Lopez tells students to open their eyes and share their ideas with their partners. (Ms. Lopez uses this strategy, *think-pair-share*, often. Students already know who their partners are and what the expectations are for their participation. In the beginning of the year, Ms. Lopez posted and had students practice using the sentence frames, *I observed* . . . and *I think* . . . *because* . . . to share their ideas.) Most students are naturally using the discussion structures; however, she points out the sentence frames to Mario and some of her emerging bilingual students to help them articulate their experiences with and knowledge about rain.

After a few minutes of partner discussion, Ms. Lopez asks students to share what their partner said to the whole group. (This strategy encourages students to listen attentively to their partner's ideas, instead of focusing only on their own thoughts.) Ms. Lopez uses *pick-a-stick* to call on three different students to share out. (Ms. Lopez finds that picking students' names randomly from a jar of sticks with their names on them increases student engagement and helps her to make sure she is not always calling on the first raised hand.)

From the sharing out and what Ms. Lopez was able to overhear in the partner talks, student understanding about condensation seems to be at a phenomenological level, for example, *Rain comes from clouds*; *when it's cloudy it rains,* and so forth. She also heard some ideas such as: *Clouds and rain are made by God*. She makes a mental note to research folklore and mythical stories from her students' cultures about rain to explore and discuss as a social studies and ELA connection (Ms. Lopez incorporates as many home-cultural connections as she can in her instruction to support student engagement and motivation).

SETTING THE CONTEXT

Ms. Lopez reminds students that scientists rely on evidence to support their explanations; therefore, today, they will be making observations and carrying out investigations in order to gather data that will help them explain where rainwater comes from. She explains, *I'm going to pour ice water into a cup on your tables and I want you to observe what happens*. (The desks in Ms. Lopez's room are in groups of four with students facing each other to allow collaborative interactions with materials and to encourage discussions.) She asks, *What do you notice?*

From their conversations, Ms. Lopez determines that all students have noticed the drops of water forming on the outside of the cup. Carolina seems very intrigued and asks, "How did the water get there?" Ms. Lopez smiles and says, "That is our focus question for today." She writes it on the board and, before she has to give the instructions, students have already pulled their science notebooks out of their desks. They find the next blank page and write the date and the focus question at the top of the page, *How did the water get onto the outside of the cup of ice water?* (Ms. Lopez has students write in their science notebooks before, during, and after every science investigation. The notebook gives students a place to record their observations and wrestle with new ideas, and allows each student to process and communicate information at their own level.)

ENGAGING IN THE PRACTICES: DEVELOPING AND USING MODELS

Ms. Lopez has been working with her students on the NGSS practice *developing and using models*. Students have made significant progress since the beginning of the year when they struggled with getting started or with trying to make the perfect drawing. Ms. Lopez asks students to make a model to explain where the water on the outside of the cup came from. She refers students to the class chart Key Elements of a Scientific Model (shown here) and reminds students to remember to include labels, arrows, and the science knowledge they have so far.

Key Elements of a Scientific Model

- Explains the phenomenon and helps us make predictions
- Involves cycles of evaluation and revision
- Consistent with observational data and established scientific ideas

Remember to use:

Arrows to show force and motion

Lines to label

After students have made their models in their notebooks, Ms. Lopez asks them to discuss their models with a partner. Ms. Lopez's language objective in this lesson is for students to move beyond sharing ideas to building on and critiquing the ideas of others. (This type of academic discourse is both a Common Core ELA speaking and listening standard and essential for the NGSS practice *Engaging in Argument from Evidence*.) To accomplish this, Ms. Lopez wants students to practice active listening, so they can challenge each other's ideas. She writes prompts on the board and asks students to use them to ask and answer questions in their discussions. She explains, Partner A will ask Partner B, "How does your model explain where the water on the outside of the glass came from?" Partner B will answer, "My model shows . . . " Partner A can then ask a follow-up questions, such as, "What does this arrow mean?"

As students engage in the discussions, Ms. Lopez cruises through the room, checking in with students she knows may need additional prompting or modeling to engage in this sort of discourse. Ms. Lopez notices that Mario and a few of her more shy students are not talking, so she reassures them that it's okay to talk in Spanish. (At this point in the lesson, Ms. Lopez's priority is knowing what students are thinking and whether they can understand each other's ideas enough to question or challenge each other. She is confident that if students are able to engage at this level of discourse in their primary language they will transfer these skills to English with a little more practice.)

ENGAGING IN THE PRACTICES: PLANNING AND CARRYING OUT INVESTIGATIONS

Ms. Lopez asks students to share out their claims, and she lists them on the board.

As she expected, students' ideas include: *Water leaks through the glass; Water moved over the top of the glass and dripped down the sides; The glass is sweating*. Fortunately, Carlos adds, "I think there is water in the air." Without acknowledging whether or not these ideas are scientifically accurate, Ms. Lopez asks students to discuss in their table groups how they could find more information to support or refute their claims.Ms. Lopez goes from group to group asking questions and providing prompts to help students come up with an appropriate investigation. She points out the materials students can use in their investigation, and all the groups are eager to use the food coloring in the ice water to see if the colored water leaks through or over the top of the cup to the outside. Students write their plans in their notebooks. Ms. Lopez refers to a class chart on writing a procedure which includes sequence words like, *first, second, then, finally*. Students get to work making colored ice water and pouring it into another cup to see what happens. When they observe that the water on the outside is clear, there are exclamations and questions abound. As Ms. Lopez circulates through the groups, she asks students to record their results and questions they have in their notebooks. She observes some students have already made detailed drawings with labels, some are writing narratives, and others are making simple drawings with a few words. Carlos asks if the same thing (water forming on the outside of the cup) happens with room temperature or warm water. Ms. Lopez suggests they find out and there is a flurry of further investigation. When students begin to make the connection that temperature is a factor, Ms. Lopez calls for attention and refers students to the list of claims they generated before the investigation. She asks, *Has anyone's thinking changed based on what we've observed in our investigations?* Many hands go up and Ms. Lopez goes through the list of claims, asking students to use hand signals to show if they agree, disagree, or are not sure for each one. (Using hand signals gives everyone an opportunity to communicate their ideas and gives Ms. Lopez a quick assessment of where her students are in their thinking.)

Ms. Lopez decides it's time to introduce some academic vocabulary. She draws a picture of the cup of ice water on chart paper and as she draws the droplets of water on the outside, she says, *The moisture you found on the outside of the cup is called condensation*. She writes the word *condensation* next to the droplets. *Condensation can mean making something shorter, like the condensed version of a long story; however, in science we use it to describe the liquid water that forms on a cold surface. Since we are scientists, I would like you to use the word condensation in your discussions and in your writing*. (Ms. Lopez is careful to introduce conceptually coded words like condensation *after* students have had sufficient hands-on experience with the concept. She strategically bridges their own language "drops, foggy" to the science word "condensation" so that they now have a schema to hang this idea onto).

ENGAGING IN THE PRACTICES: ENGAGING IN ARGUMENT FROM EVIDENCE

Referring back to the list of claims, Ms. Lopez says, *From your hand signals it seems we have some disagreement as to how the condensation formed on the ice water cups. Let's look at our data to see if we have evidence to support or refute some of our claims*. Ms. Lopez writes "Data" on the board and then calls on a "reporter" from each group to describe what their group observed. After compiling the list of observations, Ms. Lopez again focuses attention on the list of claims, *Now, let's look at the first claim, "The water leaked through the sides of the cup." Do you agree or disagree? What evidence do we have from our investigations that we've listed here as data that supports your idea? Talk in your small groups using these prompts: "I agree or disagree . . . My evidence is . . . "*

Ms. Lopez circulates listening in on the conversations. Earlier in the year she would have had to review the class norms for discussions but, at this point, students are naturally looking at the speaker, waiting their turn to speak, and being respectful. She pauses to listen in on one group of quieter students and encourages them to use the prompts for asking each other questions that are posted in the classroom. *Can you say more about…? Why do you think…?*

Ms. Lopez calls for attention and asks the reporters if their table groups have reached consensus. All the groups agree that the water did not leak through the cup based on the observation that the condensation on the cup of colored water was clear. Ms. Lopez wants to make sure all her students are making and can articulate the connection, that is, using reasoning to explain how the evidence connects to the claims, so she asks them to pair up and take turns convincing each other.

CROSSCUTTING CONCEPTS

Next, Ms. Lopez wants to bring in the idea of water vapor using NGSS crosscutting concepts, so she points out the observation students made that there was no condensation on the outside of the cup of warm water. She holds up the cold-water cup and the warm-water cup and asks students *What is different about the two systems and what might be causing the different results?* Ms. Lopez finds that using crosscutting concepts, such as *systems* and *cause and effect*, helps students deepen their understanding and provides a common vocabulary they can all use to help explain phenomena.

Carlos' hand shoots up: *I think the cold temperature causes the condensation*. Veronica adds, *I agree, because it's the only thing that is different in the two systems*. Carolina looks puzzled, *But* *why? How does the cold make condensation?* Ms. Lopez makes motions with her hands around the cups and asks, *What else might be in this system that we haven't mentioned? What is all around us?* Many students shout out, *Air! Yes*, explains Ms. Lopez, *air is part of the cup and water system. What did we learn about the composition of air (what is it made of)?* Students shout out *oxygen* and other gases and some refer back to their notebooks looking for information. Carolina lights up and exclaims, *Water vapor!* Ms. Lopez uses hand gestures as she explains that the liquid water on the outside of the cup came from the water vapor in the air. *Can you think of other examples where you've observed condensation?* From the silence and puzzled looks Ms. Lopez realizes students are not quite able to generalize the concept to their own experiences, so she asks them to take out their science textbooks to look at the photographs of foggy windows and mirrors, dew on the grass, breath on a cold day, low clouds, and so forth. The buzz returns to the room as students excitedly make personal connections.

Ms. Lopez then asks students to think about and share with a partner *What is the same about all the times and places when condensation occurs?* Most students are making the connection to the colder temperature. Ms. Lopez returns to the cup diagram and explains, *When water vapor comes in contact with a cold surface like the cup of ice water, it changes to a liquid. We say the water vapor condenses into droplets of liquid water.* Ms. Lopez adds the words *water vapor* and *condenses* to her diagram. *Tomorrow we'll investigate how this concept applies to rain.*

CLOSING

The science content objective for the vignette (develop a model to explain condensation on cold surfaces) provides the foundational knowledge and skills students will need to successfully execute the NGSS Performance Expectation 5-ESS2-1. To accomplish this, students will need lots of opportunities throughout the year to develop and use models to explain their thinking. The use of models is both a practice that students need to engage with in order to make meaning of their science experiences *and* an equitable means of communicating science thinking.

All students make their thinking visual when they develop a model, which then serves as an artifact for partner, small group, and whole class discussions—everyone has something to bring to the table.

Students also need many experiences in order to develop a deep and flexible understanding of how the crosscutting concept, *systems and systems models,* is applied in science and engineering. It will require many encounters across all disciplines for students to describe and explain phenomena in terms of a system, its components and their interactions. Providing a common and familiar vocabulary for making meaning in science supports a higher level of ELL participation.

The strategies described in the vignette illustrate the five areas that have been identified in the research literature where teachers can effectively support ELLs in language development at the same time they are learning science: (1) literacy strategies with all students, (2) language support strategies with ELs, (3) discourse strategies with ELs, (4) home language support, and (5) home-cultural connections[4-6]. By constructing our lessons with these in mind, we can move closer to ensuring that all students have access to high-quality, language-rich, NGSS-aligned science learning.

Notes

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