Doing and Talking Science: A Teacher's Guide to Meaning-Making with English Learners

Authors

Rita MacDonald, Wisconsin Center for Education Research
H. Gary Cook, Wisconsin Center for Education Research
Emily C. Miller, ESL/Bilingual Resource Teacher, Madison Metropolitan School District

Consultants

Melissa Braaten, Assistant Professor, School of Education, University of Wisconsin-Madison
Okhee Lee, Professor of Education, New York University
Helen Quinn, Professor Emerita of Physics, SLAC National Accelerator Laboratory, Stanford University

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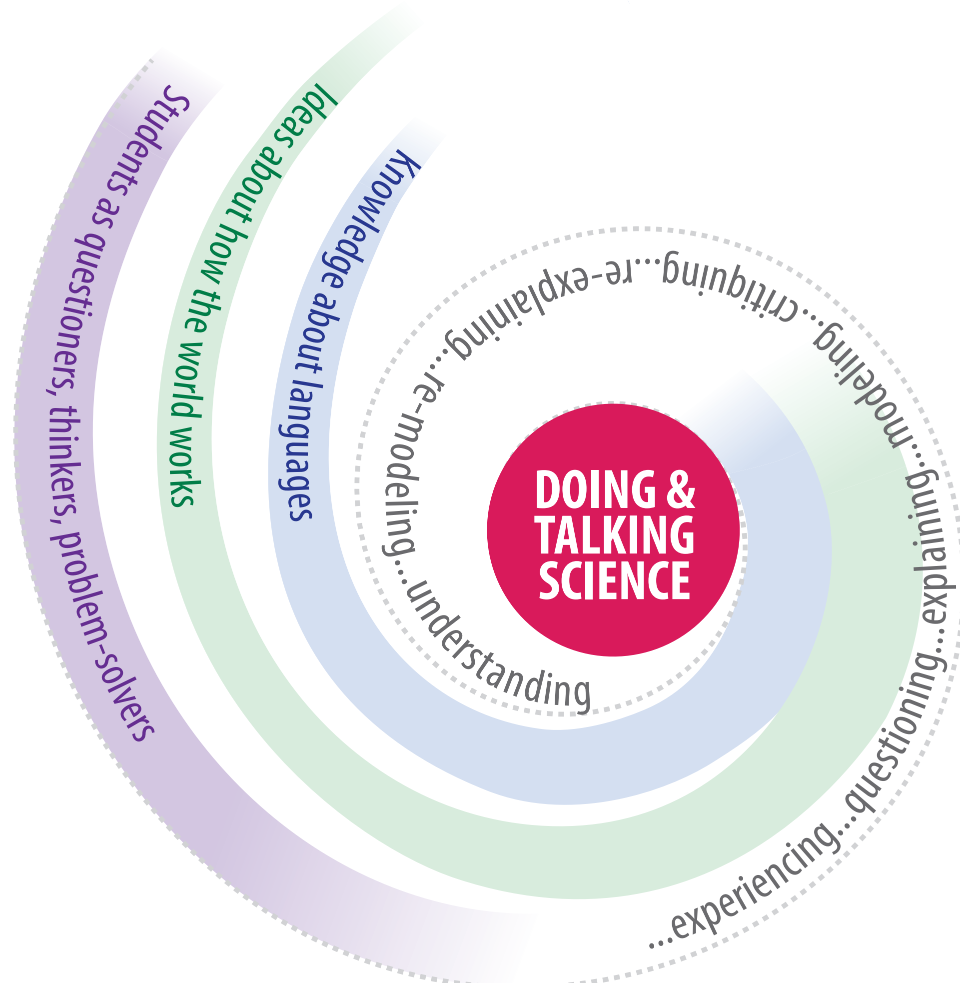
Introduction

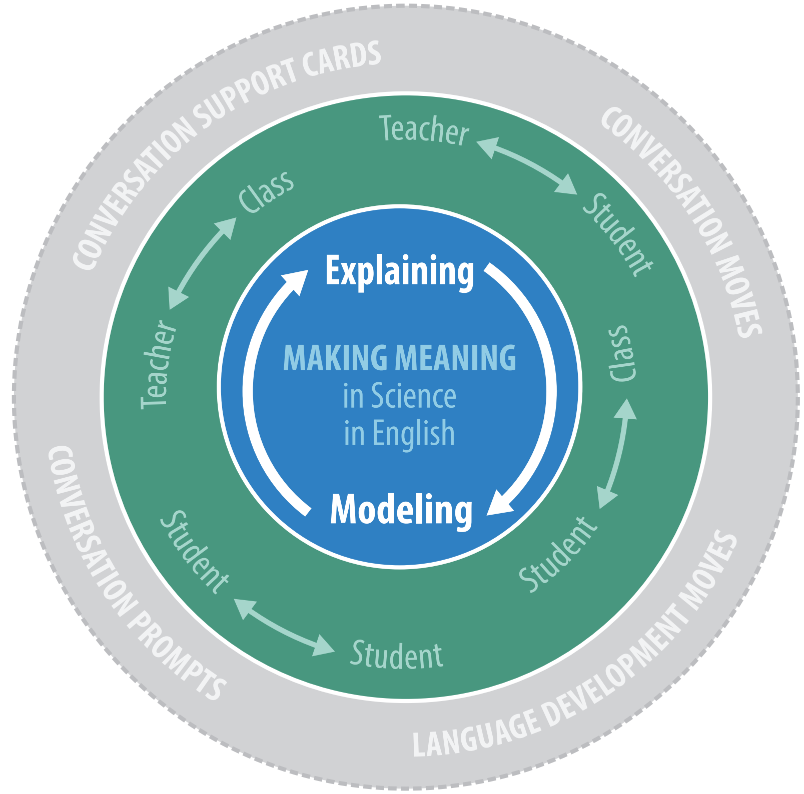
Across the United States, educators are changing the way they teach science. These changes affect all students, including English Learners. New science standards have led to an increased focus on meaning-making. For many, this means learning science through collaborative inquiry about the seen and unseen forces that shape the world around us. For English Learners, this scientific meaning-making is coupled with their emerging ability to make meaning in English. The interplay between meaning-making in science and meaning-making in English can strengthen students' ability in both areas, as shown in this spiral graphic.



Like all students, English Learners come to school with rich experiences and ideas about how the world works, ideas shaped by their cultures and discussions with family. And like all students, English Learners are learning how to frame their ideas in increasingly precise language. With their classmates, they will learn through collaboration and experience the specific style of English used to communicate their growing understanding of science ideas and also what it means to *do* science.

This guide was developed to help science teachers tap into the knowledge and experience that ELs bring to their science classrooms, and to help all students develop the language to be successful collaborators and meaning-makers in science. Information, guidelines, and tools are shown in separate sections on *Teaching for Meaning, Meaning-making in Science,* and *Meaning-Making in English,* but none of these operates separately. The figure below shows a model of science learning in which teachers support students as active and collaborative meaning-makers.

We've centered our work around two important practices in science: **explaining** the seen and unseen forces that shape phenomena, and **developing and using models** to help explore, explain, and predict why those phenomena occur. Experts in science education have nominated these practices as key to helping students learn to reason like scientists. You can read more about the **science practices** later in this guide.



Just as the iterative cycling between these two science practices supports meaning-making, the interaction of the **Teacher Moves** and **Student Moves** outlined in this guide help build productive conversations in which teachers facilitate students' reasoning, while pressing for clarity and deep thinking. This process helps students build ideas together. We've developed two specific teacher tools: **Productive Conversation Prompts** that help facilitate collaborative meaning-making and **Language Development Moves** to encourage students' language development. We've provided two specific tools for students to use, as well: **Productive Conversation Moves** show how students at three levels of English proficiency can use language to engage in seven key interactions as they develop and build ideas together. The **Conversation Support Card** is a resource that students can use in their small working groups to help them clarify ideas and ask and answer questions with one another as they work together to build understanding through the cyclic process of explaining, questioning, modeling, re-explaining, etc.

Constructing an environment in which students operate as meaning-makers requires careful preparation. Elements of preparing to teach for meaning are discussed in the following section. You will also find, in this section, an extensive set of **Classroom Supports** developed specifically to support student engagement in our two science practices. Finally, a **Lesson Scenario** will give you an overview of how these elements are integrated into a science classroom.

Teaching for Meaning

Considering Important Science Practices

The Committee writers of the Framework for K-12 Science Education (NRC, 2012), the guide for the Next Generation Science Standards (NGSS Lead States, 2013), and the foundation of many states' revised science standards, have emphasized the importance of eight Science and Engineering Practices (SEPs). Because the SEPs cut across all grade levels and every area of science, and because they focus attention on what students do as they "do science," we've chosen two of the SEPs around which to center our examples of meaning-making in science and in English. The eight SEPs are shown below, and the two on which we'll focus are highlighted.

The Science and Engineering Practices

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

Source: National Academy of Sciences, 2012

Because these practices work together, most science activities enact several at once, especially the practices of **constructing explanations** and **developing and using models,** which are at the heart of meaning-making in science. When we present students an interesting and puzzling phenomenon to wonder about, the cyclic, repetitive, and collaborative process of questioning and hypothesizing about its cause, constructing causal models, then questioning and critiquing those models to refine the initial explanations and form new questions, leads students deeper and deeper into the science concepts involved, and further down the path to developing the language of science.

Practice 2: Developing and Using Models

In science, models are used to represent a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others. Students can be expected to evaluate and refine models through an iterative cycle of comparing their predictions with the real world and then adjusting them to gain insights into the phenomenon being modeled. As such, models are based upon evidence. When new evidence is uncovered that the models can't explain, models are modified. (NGSS Lead States, Appendix F, 2013, p. 6)

Practice 6: Constructing Explanations and Designing Solutions

The goal of science is to construct explanations for the causes of phenomena. Students are expected to construct their own explanations, as well as apply standard explanations they learn about from their teachers or reading. The *Framework* states the following about explanation: *"The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories."* (NRC Framework, 2012, p. 52)

Meaning is not stored language. Meaning is stored experience.

By exploring, hypothesizing, questioning, and reasoning together as they develop models and causal explanations about phenomena, students strengthen both their science knowledge and their language.

Getting into Position

"Doing science" for meaning-making requires that students and teachers reposition themselves: students as questioners and thinkers, and teachers as guides. Both teachers and students may be nervous when these ways of interacting are unfamiliar. Teachers can help everyone move forward when they steadily uphold classroom expectations that every voice should be heard, all ideas count, questions are good, and "wrong" answers help everyone move forward. Over time, students develop experience and increased confidence as meaning-makers in science.

Positioning students as meaning-makers in science begins with bearing in mind that every student walks into a science classroom with many experiences related to the phenomena they'll study, and that they and their families have important ideas about how the world works. "Doing science" means eliciting those understandings before applying a new set of lenses to those common experiences, and then connecting those everyday, observable occurrences in a new way that shifts thinking. New understandings need not supplant views important to families and cultures, but can be discussed as ways of viewing the world from different, equally valid vantage points.

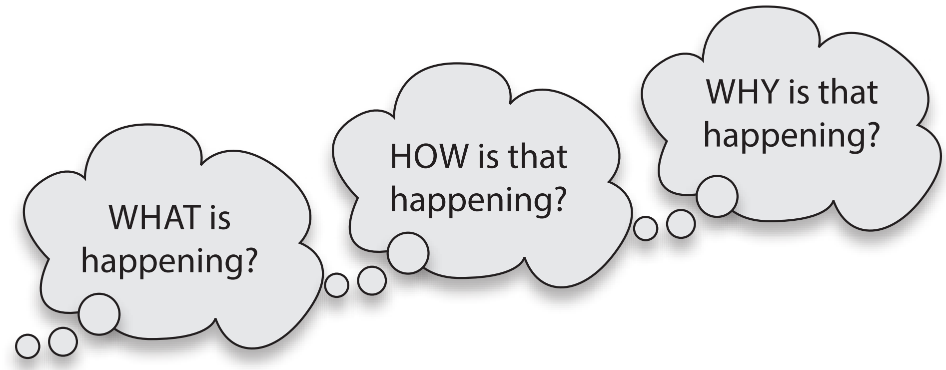
Asking the Right Questions

Questions that provoke productive struggle: big questions. If we want students to reason their way through to the cause of something, it follows that the "something" must be puzzling enough and interesting enough to capture, hold, and be worthy of their attention. Simply stated, the phenomenon or question should connect to a big and generative idea in science, and present the sort of puzzle for which there is no one right or simple explanation.

The Tools for Ambitious Science Teaching website has an excellent set of resources related to choosing a worthwhile activity and supporting and facilitating students' reasoning through careful comments and questions. The website has videos showing teachers using these resources to orchestrate productive discussions.

tools4teachingscience.org/

Questions that strengthen student reasoning. Uncovering the big idea in science—explaining the relationships between the seen and unseen forces that cause the phenomenon being studied—does not happen in one step. Experienced science teachers have several sets of purposeful questions ready to help students clarify their thinking at various stages of exploration. Teachers need to be ready with questions that nudge students past the "what" and "how" questions to the more challenging questions: "Why does that happen? Why does it happen that way?"



Facilitating that progression of thinking takes skill and practice. The **Productive Conversation Prompts** offer examples of how to press students for meaning and clarity, and how to support their efforts to understand. The **Classroom Supports** chart offers a broad array of meaning-making supports for all students.

Questions that orchestrate interaction. It will be clear by now that student-to-student dialogue is a key component of sense-making. Placing students into small working groups where they are accountable to one another provides an "All brains to work!" opportunity. Students need instruction and support, however, to leverage the power of shared thinking, since few students come to school knowing how to reason productively together. Some of the **Productive Conversation Prompts** mentioned above are designed to promote students' collaborative reasoning.

Similarly, students need support in learning how to interact as they build ideas. Issues such as turn-taking, responding in connected, cohesive ways to previous comments, following a chain of reasoning, and challenging someone's idea without challenging the person are all important skills that can be learned and practiced. The Productive Conversation Moves show seven common interactions as students respond to one another's ideas, and offer models for these interactions across the range of English proficiency. The **Conversation Support Cards** shown can be used by small groups of students as they work to build meaning together.

> See the bulletin on group work by Lee, Cortada, & Grimm, listed under Additional Resources, for ways to support effective group work for English Learners.

> Chapter 8 in the book by Zwiers, O'Hara, and Pritchard, mentioned in the Additional Resources section, is an excellent source of advice and practical strategies for teaching these interaction skills.

Thinking about English Learners: A few modifications to make

English Learners have more in common with their English-fluent peers than they have differences, but attending to those few differences can help culturally and linguistically diverse students become successful meaning-makers with their classmates.

Although they sometimes know two or three other languages, English Learners start at a different point than their classmates when it comes to English. Those whose proficiency in English is just beginning to develop need ideas presented in multiple ways. Students whose English proficiency is more developed need fewer and different supports, and are more like their English-fluent peers. With their greater ability to express themselves, they too are learning the vocabulary and language patterns to express new and complex ideas, and to make more precise meanings in science. Their interaction with English-fluent peers, as they work out ideas collaboratively, provides the impetus to learn new ways of using English to express ideas clearly. The **Productive Conversation Moves** and **Conversation Support Cards** are designed to assist English Learners at all levels of English proficiency to express their responses to ideas within their groups. The **Classroom Supports** list many ways teachers can support English Learners as they do the extra work they must do to create meaning in an English-speaking context, and many more suggestions are readily available. As always, it's important to think about the principles behind the strategies you use. Here are some that apply to our context:

1. Remember three key words: repeated, multiple, and deep. English Learners need **repeated** exposure to and **multiple** experiences with ideas in order to connect the ideas to the English used to express them. They also need information conveyed in multiple ways—voice, print, pictures, activities—so that language alone does not bear the full weight of meaning-making. And English Learners need **deep** experiences. Rather than present English Learners with new materials to process, it can help to work with the same materials they've just encountered, but to do it more deeply: answer new questions, produce something different, consider the ideas from a different vantage point. Meaning is not stored language; meaning is stored experience, and English Learners will build meaning through multiple related experiences.

2. Provide opportunities to discover and discuss the relationship between meaning and language. Questions such as: *How do you know that's what it's asking? Where does it say that? What makes you think the writer is uncertain? Where does it show that she is considering a counter-argument? What words tell you that? Which writer is more convincing and why?* can help students explore the connection between meaning and language.

3. Discuss the relationship between linguistic choices and the disciplinary purposes it serves. When pressing students to be more precise in their reasoning *(Is it always that way? What if…? How do you know that?),* take time to discuss why you are pushing them to be more precise, or more detailed, or more objective. This provides wonderful opportunities to convey the values of your discipline and to help build the habits of mind students will need.

Student and teacher positioning. Some English Learners, like their English-fluent peers, may come from families in which it is not appropriate for students or children to ask questions, raise doubts, or give opinions. These family views may be supported by cultural patterns that view knowledge as a commodity in the hands of highly trained and highly educated "others" who are responsible for passing on that knowledge. Whatever its source, this view is worth exploring in the classroom. Explaining to students and families that the teacher's role is not to give answers, but to teach students to think, can shift perceptions. Similarly, if some students have been positioned by classmates or families as either "poor thinkers" who can have no worthwhile contributions, or as "brains" who must have all the answers, patience and persistence in helping all students express their ideas and reason collaboratively can help shift those patterns.

Related to this are students' views of science and scientists. Before students from other cultures can feel ownership of science or see themselves as having the right to participate in scientific thinking and conversations, they may need to see examples of traditional and non-traditional scientists from all over the world, and hear of the contributions these scientists made. They will also need to see their own ideas being taken up by others and adding to the evolving understanding of phenomena in the classroom.

Meaning-Making in Science

Science Explanation: a well-reasoned, logical, evidence-supported statement of why a phenomenon occurs

Reasoning and explanation in science are different than they are in everyday conversation. Explain is often used to mean, "Tell me your reasons," as in "Can you explain your thinking?" and "Explain why your group did it that way." But scientific explanation involves a well-reasoned, logical, evidence-supported statement of why a phenomenon occurs. Teaching students just what "well-reasoned, logical, evidence-supported" means is at the heart of science education. Some excellent resources have been developed to assist teachers in this important work. Listed in the Additional Resources section are several such resources. The **Productive Conversation Prompts** presented below are derived from these. Organized by instructional purpose, this chart offers guidelines for orchestrating productive science discussions that focus student attention on the clarification and deepening of student reasoning.

Orchestrating Purposeful Discussion: Productive Conversation Prompts to Develop Student Reasoning in Science

Adapted, in part, from the Tools for Ambitious Science Teaching website and Michael's & O'Connor (2012)

A. Help individual students clarify their thinking

Giving students time to think before they answer questions, and then waiting again after they've voiced their initial comments, promotes deeper thinking and more elaborated and carefully considered responses.

- Use 10-20 seconds of wait time after questions and after responses.
- Use pair activities to help students clarify ideas before speaking to larger group.
- Write, draw/sketch or use materials to support student thinking in partners or individually.

Have students reflect on and explain their thinking, individually or in partners, using whatever combinations of language students wish to use: first language, combination of English with other languages, informal non-science language.

Ask students to identify and reflect on related experiences, discussions in their first languages, and school-related experiences/ideas that they can draw from.

D. Help students listen carefully to and think about others' ideas

"Who can rephrase or repeat?"

"How can you show (gesture, act out) their idea or identify the model or big idea that the student is using in his explanation?"

"How can you draw a picture/sketch of what they are saying?"

"How can you identify the evidence that they used in their explanation?"

"How can you indicate agreement or disagreement with their statement?"

"Whose idea/thinking is most different from your own?"

"How can you show or tell us a way their idea changed your questions or your thinking?"

B. Make ideas and thinking public and available for discussion, analysis, and agreement or disagreement

Press for additional info: ask for students' reasons or support for ideas

- Ask for example.
- Ask to fill out or extend explanation.
- Manage silence--extend wait time, after both questions & responses.
- Ensure clarity of ideas expressed.
- Clarify/repair how idea is expressed, without overriding student's ownership of idea; ask student for confirmation of your paraphrase.
- Re-voice to connect everyday expression to more precise academic language.
- Ask students to explain other classmates' thinking in whatever language or combination is accessible.

Prompt students to examine/seek out discrepancies of model or explanation.

Ask students to provide reasoning to support or revise models or explanations.

E. Help students deepen their reasoning

Ask for rationale.

Ask how students would test that idea.

Engage students in a phenomenon that is inconsistent with the explanation or model. Ask, "How can we revise the model/explanation to account for this new evidence?"

Compare two student-generated models or explanations and analyze how the class' collective thinking has changed based on the evidence collected. (This can also be done individually, looking over personal work.)

Collectively, sort the available evidence for consistency and inconsistency with model or explanation.

Ask, "What new questions occur to you now after the experience and discussion?"

Ask, "What do you need to know more about now?"

C. Mark/emphasize a particular idea. "Rebroadcast" an idea through revoicing, always making sure that the ownership of the idea remains with the student who voiced it originally, always checking with that students to make sure you've expressed the idea as he or she intended. "Rebroadcast" an idea by asking a student to paraphrase it. This gives the idea more "air time" and gives everyone a chance to hear it and think about it again. Be explicit about putting some ideas on hold to focus attention on the idea you want to emphasize.	**F. Help students build meaning with others by applying their own thinking to others' ideas; prompt peer-to-peer talk** Prompt for paraphrase and confirmation of approval of restatement. Prompt students for frequent use of comprehension checks and clarifying questions. Prompt for clear connections between student's response and previously stated idea. Consistently model valuing others' ideas, experiences and perspectives. Model valuing whatever language combinations students use to build meaning.

Meaning-Making in English

English Learners are important contributors to classroom meaning-making. They may not yet be fluent in academic English, but they can use their own creativity and the supports offered by teachers and classmates to keep up with and contribute to productive science conversations. They bring fresh perspectives and experiences that enhance the understanding of science.

No one is a native speaker of academic English.

No student comes to school knowing what educators call academic English. The English used in school is a specialized version, one of many types of English that we develop to suit different situations, and is different from the English used in everyday conversations. (Just as there is an academic English, there is an academic version of French, Spanish, Arabic and other languages.) The language of science is an even more particular version of that specialized academic English. Science focuses on certain types of relationships between ideas and patterns of thinking that lead to specific ways of using language. Students learn these patterns as they need them, and they develop the language of science by "doing science."

Meaning-Making Tools

- Productive Conversation Prompts
- Language Development Moves
- Productive Conversation Moves for Interacting with Ideas
- Conversation Support Card

English Learners may be able to express complex science ideas in two or three languages, but have different starting points than their classmates when it comes to expressing those ideas in English. Like their classmates, they will learn through collaboration and experience the specific variety of English they will need to communicate their growing understanding of science. The tools shown in this section are designed to help teachers support English Learners' use and development of English as they engage in meaning-making interactions in science. Often, teachers find these tools helpful for many of their students. After all, English Learners are not the only students working to develop precise, sophisticated language.

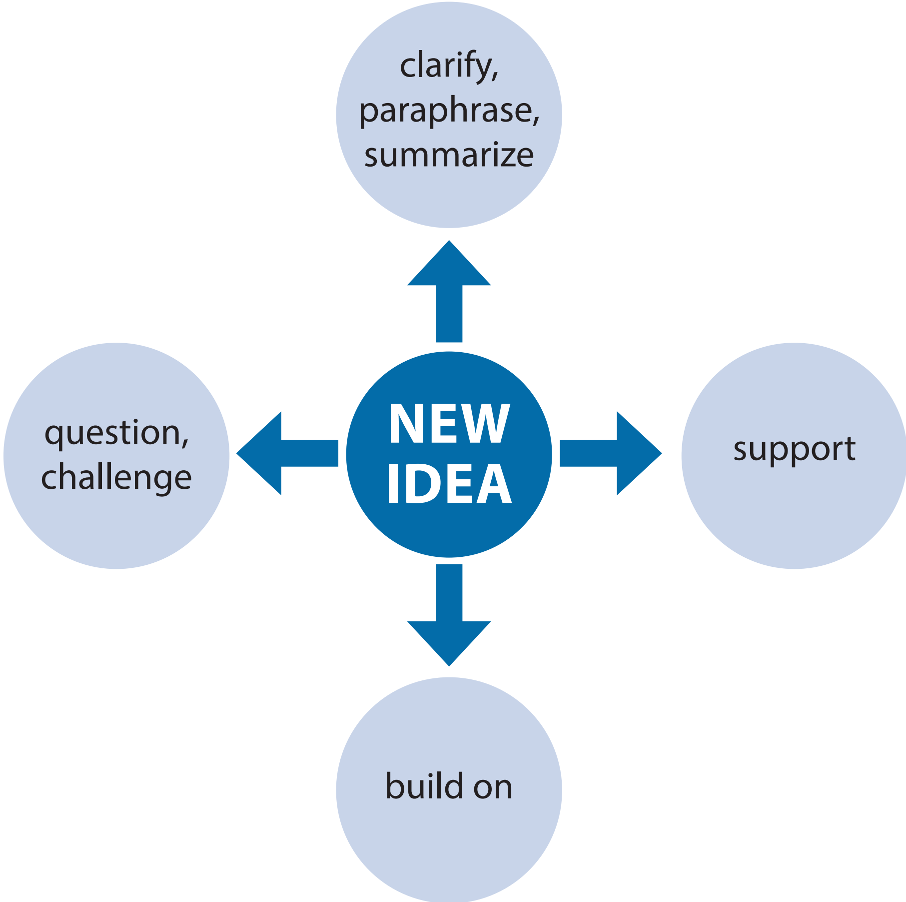
Productive Conversation Moves: How English Learners Can Interact with Ideas

The first section of the chart below lists a few characteristics of students' capabilities in English at three broad levels of proficiency. Although some states categorize English proficiency in five or six levels, the three-level descriptors from which these characteristics are derived are based on, and consistent with, English proficiency descriptors used across the U.S. (Cook & MacDonald, 2014), making it fairly simple to translate across different systems of classification. Whatever system is used to describe English Learners' growing capacity with English, it's important to remember that English development doesn't always follow expected patterns. Words that seem like advanced vocabulary in English may be similar enough to words in students' other languages that they are learned very early. Similarly, aspects of English that are learned fairly quickly by some may be more challenging to others whose first language may just work very differently than English. It is not critical to have a highly accurate rating of students' English proficiency. What's more important is understanding some aspects of English development and how to provide a range of supports to help English Learners contribute their ideas to classroom discussions.

The remainder of the chart is designed for both teachers and students to use. We developed a list of 7 types of responses students would make to interact with one another's ideas:

- Tell and support one's own idea
- Ask for clarification
- Restate or paraphrase an idea
- Summarize ideas
- Support someone's idea
- Build on someone's idea
- Challenge someone's idea

For each of these 7 response types, the **Productive Conversation Moves** below show how English Learners can discuss and develop ideas with others at all three levels of English proficiency. Teachers can use these to provide written or oral prompts for student responses. English Learners can use them to help formulate responses. All students can use them as they learn and practice the interaction patterns of academic conversations.



What students can produce in English at three levels of proficiency		
Low English proficiency	**Intermediate English proficiency**	**High English proficiency**
Short, simple expressions with common vocabulary. Some simple connectors (because, so, then) may be used.	More involved sentences that contain more than one idea, with a broader range of logical connectors used to create additional types of logical relationships between ideas.	More concise sentences with ideas embedded within other ideas. Personal pronouns removed to maintain coherent and impersonal focus on concept rather than on actor. Personal opinion expressed indirectly.
Productive Conversation Moves: How English Learners can use English to …		
Tell and support own idea		
I think…My reason is… *My idea is…*	*We should try… because* *Since the pattern is the same, I think we could…*	*The obvious next step would be to…*
Ask for clarification		
Say again, please. (Seeking repetition) *What is … ?* (Seeking more information) *Why?* (Seeking rationale)	*What did you mean when you said that…* (Seeking more information) *Can you tell me why you think that … ?* (Seeking rationale)	*It seems the suggestion is…. Is that correct?* *What is the rationale for that change?*
Restate or paraphrase an idea		
He said "…" (may attempt direct quotation; not likely to produce full details) *It means …*	*In other words, …* *What she means is ...*	*The model was changed to show…* *The suggestion was made that …*
Summarize ideas		
It is the weight. [Statement of main point, not embedded into another framing sentence.]	*So far, everyone's suggestions are ways to deal with the fact that…* *We have 3 different ideas about why this could be happening, and they all relate to…*	*Every idea expressed so far has centered around…* *The problem encountered by every group has been that…* *Our reasoning is most like group A's thinking because….*

Support someone else's idea		
Good idea because… *I agree with Yer because….*	*Remember, it said in the movie that…* *I'm sure that would work since...* *That idea makes sense because last week, we learned…*	*That explanation is a better fit, since it accounts for….* *The advantage of the proposed change is…*
Build on someone's idea		
Let's try that.	*What if we try it this way, instead of…?* *Let's change the model to show that.* *I'm certain that…means that we should...* *Yer's idea made me wonder about…*	*The obvious next move would be to…*
Question or challenge someone's idea		
I think that's wrong because… *It won't work because...* *What is your evidence?*	*But your explanation will not account for…* *Did you think about…?* *How does the evidence support your idea that______*	*Unfortunately, that explanation doesn't fit every situation.* *The situation you've neglected to account for is…*

Note: Sentences described here for the high English proficient level may not occur in the early stages of students' thinking or in a small group context, even for high English proficient students. This more formal expression occurs more naturally in and is better suited to presentations or writing. Nonetheless, students need instruction to develop this high-level English, with strategies such as those described in the **Language Development Moves.**

Classroom Supports for Meaning-Making in Science

Here is an extensive array of strategies to support English Learners' sense-making in science. Fewer and different supports are needed as students gain proficiency in English, but note that even students with high English proficiency benefit from support and instruction.

Classroom Supports for Meaning-making in Science		
Low English Proficiency	**Intermediate English Proficiency**	**High English Proficiency**
Home discussion questions to involve families in discussions of the phenomenon being investigated **List** of graphically-supported key words and their meanings **Student-generated lists** of terms and ideas in English and other relevant languages **Visual/physical model** at hand to support telling of rationale, with teacher assisting as needed to voice as students points, or to re-voice to clarify meaning (Note: focus on meaning, not on correctness) **Sufficient wait time** to allow students to formulate ideas in English **Purposeful grouping:** pair work to help students put ideas into words, progressing to small heterogeneous group work for low-pressure language formulation and peer assistance. Give students a chance to write or draw by themselves for a few minutes before beginning to talk. Have students buddy up with a classmate so the two of them can formulate the words to express their ideas in this low-pressure setting before speaking to the larger group. English Learners can also benefit from speaking their ideas as part of this partnership, rather than individually. **Productive Conversation Moves** that model the use of phrases or simple sentences to accomplish the discourse function. *(See sentence frames specific to each discourse function.)* **Labeled pictures/photos** of evidence collected so far **Timeline** of evolving model/explanation with photos of experiences that drove the changes/revisions in the models or explanations in central location **Continuously revised conceptual webs** labeled in relevant languages, with sketches or graphic supports. **Evolving chart of connections** between past science experiences and related experiences in other disciplines.	**Home discussion questions** to involve families in discussions of the phenomenon being investigated **List** of technical content-area words and their meanings **Visual/physical model** at hand for student to point to or refer to as needed **Sufficient wait time** to allow students to formulate ideas in English **Purposeful grouping:** small heterogeneous group work for low-pressure idea formulation and language experimentation **Productive Conversation Moves** that model more compact expression by combining more than one idea per sentence to accomplish the discourse function. *(See sentence frames specific to each discourse function.)* Charts and reminders to support **periodic tracking of group's collaborative sense-making.** *"Let's stop for a minute. I want everyone to focus on the conversation that Yritzy and Alan just had. What did you notice?"* **Time-out poster** to support students in calling for review of interactions. **Evidence collected** so far in central location with quick sketches of the evidence. **Continuously revised conceptual webs** **Student journal** of experiences in informal or multiple languages with quick sketches. **Evolving chart of connections** between past science experiences and related experiences in other disciplines. *(Remember, we looked for a pattern in math. We found the cause and effect in history.)*	**Visual/physical model** at hand for verbal reference **Productive Conversation Moves** that model a more objective or authoritative expression of an idea to accomplish the discourse function. *(See sentence frames specific to each discourse function.)* Charts and reminders to support **periodic tracking of group's collaborative sense-making.** *"Let's stop for a minute. I want everyone to focus on the conversation that Yritzy and Alan just had. What did you notice?"* **Guided examination** of rich examples of student generated talk (written down), student writing, and professional science writing to examine the linguistic choices made and their effects.

This broad array of supports can be used and adapted in many ways. Some teachers vary the supports provided to different working groups of students. Others choose to make all supports available to everyone, trusting that English Learners—and others—will gravitate toward those that they need. Teachers may note that students may demonstrate different levels of receptive and productive language and the supports they need for one context (i.e., listening for evidence) may be very different from what they may need for another context (i.e., producing an oral explanation).

Conversation Support Cards

When students collaborate to create meaning, much of the interaction occurs in small group discussions, and teacher support is not always available. When students have begun to learn how to discuss ideas together, they can use **Conversation Support Cards** like those shown in this guide. Cards like these, developed to suit specific activities, can be placed at each table as tools to help student groups keep their science conversations moving along productively. Students can be involved in creating cards like these, brainstorming many ways to word various responses.

The book by Zwiers, O'Hara, & Pritchard, listed in Additional Resources, has excellent examples of similar tools.

Language Development Moves

Like their classmates, English Learners need instruction to support their English development and participate in science discourse. When students work together to express important ideas clearly, the interactive context helps students push themselves and one another in the direction of more effective exchange of ideas. Working with complex ideas pushes the development of complex language—at least, to an extent. Language is built up in layers and there are some foundational building blocks (English word order, for example) that seem to be needed before others (such as complex sentences) can be added. But, students whose English proficiency has moved beyond the basic beginning stage can benefit from instruction and modeling in additional ways to make meaning in English. Indeed, if the ideas they're working with are engaging, they will be eager to find ways to communicate more easily with their English-fluent classmates.

This section provides an overview of some language development strategies that can be integrated into science lessons. Instruction should always be tied to an experience students have had and to their perceived need for additional ways to clarify, exchange, and build on ideas. It should use real language generated in class. It is also important—especially when students are introduced to the highest level of English proficiency, in which they learn to adopt the voice of a scientist within the context of authentic science purpose—to discuss the advantages and disadvantages of these new ways, and purposes, for expressing ideas. The default academic language expected of science writers and speakers is impersonal, tightly focused on the evolution of complicated concepts, and very concise. It is not engaging, personal, or easy to comprehend—thus, a significant cost to adopting more academic language is the loss of personal connection with listeners and readers. Having students examine various science texts and discuss the different styles of English used can lead to fascinating discussions of how scientific language is shaped by the values of science and by the different contexts in which scientists operate. Students can enjoy debating the advantages and disadvantages of using several styles of English to move across these multiple contexts.

Language Development Moves	
Moving toward intermediate English proficiency	**Moving toward high English proficiency**
• Describing complex things concisely, or building long "things" • Repackaging actions and qualities as things • Compacting ideas	• Expressing ideas objectively • Expressing ideas confidently

Helping Students Move from Low to Intermediate English Proficiency

Describing complex things concisely, or building long "things" in English. One of the first things students may notice when they read science articles is that the sentences are very long and have lots of words in them. Students can learn relatively early in their English development that English can create very long "things" with words. Consider this sentence:

Water that evaporates from millions of leaves in a tropical rain forest helps produce clouds.

What is the "thing" that helps produce the clouds? Not simply water, but *water that evaporates from millions of leaves,* a long phrase that combines two ideas. Separately, and in beginning-level English, that first sentence might be stated as three sentences:

A rain forest has millions of leaves.
Water evaporates from the leaves.
That water goes up and helps make clouds.

Imagine the first answer a student might give when asked what makes the clouds over a rain forest: *The water.* If you imagine next the series of questions to press for additional information *(Which water, exactly? Water from what source?),* you and your student can begin to notice the benefit of knowing how to combine many details into one phrase. Science is specific, and details matter. Science language is also efficient, and putting all the important details together is faster that saying or writing several sentences. It also makes the idea more precise.

These long linguistic things (long noun phrases) have been described as the powerhouse of meaning in English and are one of the first things that students change as they move into using academic English. Spending a bit of time showing students this pattern can help them both comprehend and use this strategy for combining ideas. Simple and quick activities such as asking students to embed the details from Sentence 2 into Sentence 1 (both below) can be fun and helpful.

Plankton are minute marine plants and animals. They drift with currents.

Repackaging actions and qualities as things. As we help students learn the language patterns that create detailed and specific descriptions of entities (the long things mentioned above), another important language strategy known as *nominalization* becomes very helpful: talking about events (verbs) and qualities (adjectives) as things (nouns). When we note that a plant stem is *strong* (a quality), we can later talk about its *strength* (a thing) without having to repeat our statement that the stem is strong. If we discuss how plants *survive* (an event), we can later refer to their *survival* (a thing) without having to describe the event again. Repackaging events and qualities as things allows us to analyze, add information to, and generally go on to discuss those things efficiently.

> *Many foxes* ***died*** *that year due to the spread of disease. Their* ***deaths*** *allowed large numbers of rabbits to* ***survive*** *that summer. Their* ***survival****, in combination with the poor crop output in the valley, led to …*

Compacting ideas. Students can make accurate and important meanings with conversational style English, which usually has just one idea or event in each sentence. The more complex the ideas students need to discuss, however, the greater the number of small sentences they must string together, and the longer and more laborious the exchange becomes. Speakers, listeners, and readers find that it takes less work to make sense of ideas when at least some of them are combined, rather than strung out in long chains. Consider the following sentence, typical of science texts:

> *The high phosphorus levels in local lakes, 20% higher than last summer's levels, are related to neighborhood storm water runoff, which has increased in volume and contamination levels.*

In the conversational style of English, this would probably be expressed in sentences like these five:

> *Local lakes have high phosphorus. It's 20% higher than last year. This is because of the storm water. It's running into the lakes from neighborhoods. There's more of it this year and it's got more chemicals in it.*

Students enjoy and can benefit from occasional practice in deconstructing sentences like the first one into as many smaller sentences as possible, and then repackaging those into another long, but differently structured, sentence.

Helping Students Move from Intermediate to High English Proficiency

As English Learners get more comfortable creating long chunks of language, they experiment with moving them around, inserting those chunks into different places in the main sentence or combining them in different order for a range of effects. The more varied and complex students' language becomes, the more proficient they become in using English. But high proficiency in English is more than complex language. Sometimes, the most proficient language is very simple, using very few of just the right words. High proficiency also involves knowing how to tailor messages to a wide range of very specific circumstances. Proficient users of English consider issues such as: *How close a relationship do I want to create or suggest when I speak to this person? How much detail is needed to be convincing? Will people be reading this or listening to it? Do I need to make this sound very important to me, or is it better if I come across as uninvolved?*

In science, considering these questions is part of taking on the voice of a scientist: conveying meaning in a way that sounds confident, objective, and emotionally uninvolved. These qualities relate to important values in science: objective analysis, and reasoning that can confidently be supported by logic and evidence; and to some of the contexts in which scientists operate: presenting their findings to others, and seeking funding for research. The call to use this particular style or voice does not often occur in the midst of classroom learning activities, so teachers must create opportunities for students to examine and practice this style of English, which they will need in college and career settings. One helpful activity is to show students sets of sentences, each of which conveys the same idea but with differing degrees of confidence or objectivity, and have them discuss which ones are more convincing and why, or which sound more objective and why. Some example sentence sets are shown below:

A. We did this twice and our results are pretty close to theirs.
B. After repeating this, we obtained the same results as Group B.
C. The results, after two replications, were consistent with prior findings.

D. We think our method is better because we can control the air pressure better.
E. The method we used results in better control of the air pressure.
F. Clearly, the improved control of air pressure provided by Method B makes it the logical choice.

Analyzing and discussing these sentences can lead to very interesting discussions about what matters in the various contexts in which science operates. When clear communication with peers is most important, the first sentence in each set would certainly suffice. But when scientists go farther afield, where their objectivity cannot be taken for granted but must be demonstrated, certain linguistic strategies become very useful. The portrayal of objectivity, emotional uninvolvement, and confidence are intertwined, but some specific suggestions related to each are shown below.

Expressing ideas objectively. Notice that in sentences C and F above, no people are mentioned. Clearly, people were involved, so why are they kept behind the scenes here? Two reasons:

1. Ideas seem more objective and more "true" if we gloss over the fact that they were produced by people. That way, we can make it sound as if there's an inherent logic or "rightness" that just naturally leads to the conclusion we've stated—with no possibility of human error or bias involved. Of course that assumption needs to be examined carefully, and helping students look behind an objective-sounding statement to examine the reasoning that does or does not support it is an important part of science education. Showing students this linguistic strategy can make them more aware of it as a strategy, one to be checked closely! But students will need, at times, to portray with language the hard-won objectivity of science, and will need practice with the linguistic choices that produce that objective tone.

2. Not focusing on the human actors allows the speaker or writer to keep the science idea in the most prominent position, which is usually the first part of a sentence. It keeps the attention focused on the idea that is being developed, rather than on the people involved. Consider the difference if the human actors are kept in first position in these three linked sentences:

   We heated the solution to 180 degrees Celsius, and then we added a reagent, and we saw that the color changed to match the …
   Reading all those "we's" gets annoying. The topic is not the people, but the procedure. When the sentences are rewritten without the people,

   After the solution was heated to 180 degrees Celsius and the reagent was added, the color matched…
   attention is focused on the important topic, and it's easier to follow the description of the procedure.

Expressing ideas confidently. Consider sentence F from above and a re-written version of it. Which one sounds more confident?

Clearly, the improved control of air pressure provided by Method B makes it the logical choice.

The improved control of air pressure provided by Method B makes it a better choice.

The use of two words (clearly and logical) infuses a sense of confidence into the first that is missing in the second. A *logical choice* sounds better than a *better choice,* since *better* usually expresses an opinion, and not a "logical" fact. The addition of *clearly* suggests that anyone listening would agree. With the use of these two words, the speaker of sentence F has expressed a great deal of confidence in the idea expressed, and has done it subtly enough that the assertion seems beyond question.

English Learners moving to the high English proficiency level are, like their classmates, learning the specific science version of academic English. They are learning to adopt the voice of a scientist and to portray, through language, the values of a scientist. To gain important understanding and practice with this, English Learners and their classmates can compare different kinds of science texts or oral presentations to identify the differences in the way English is used. Discussing the effects these linguistic choices produce helps students become more aware of the variety of messages and impressions they can choose to construct as they share their ideas in science.

Conclusion

Like the English Learners and their English-fluent peers in our classrooms, teachers learn by doing, and by doing things together. We hope that you will experiment with using these tools in whatever ways fit into your classrooms, that you'll discuss your ideas with your colleagues, and that you'll refine these tools together as you go. As you interact in your own spiral of meaning-making in science education, we're confident that the interactions you support among your students will deepen their knowledge of science and help them make meaning of the world we all share.

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Lesson Scenario

This second grade science lesson is an example of what an interactive, meaning-focused science lesson looks like. It's also an example of how teachers and students can use supports to reason effectively together, even with developing English. The lesson uses many of the supports and strategies in this guide—many more than can be shown neatly—but a few are highlighted to demonstrate how easily and naturally they fit into this science classroom.

Ms. Lozano's second grade students were very familiar with anything to do with the class guinea pig. Even Mai and Axel, her two newcomers, could talk in English about Squeaky's behavior and his daily needs. The 17 students had taken photos and then documented them with simple observations and questions they had about Squeaky. One stated, *Squeaky likes cilantro,* and another, *Does Squeaky like music?*

Classroom supports: Prior knowledge

The students had been observing mealworms for two weeks, and Ms. Lozano decided to use their extensive guinea pig knowledge. She gathered the students together on the carpet. Ms. Lozano began her discussion by silently placing pictures on the floor, one of a student, Isaac, one of the guinea pig, and one of a mealworm. She checked with Isaac, "Do you need water? Do you need food?" And she placed a picture of water and another of the class snack that day, cheese crackers, next to Isaac's photo. Isaac was serious as he watched the class; he was enjoying being the example. She asked her students to bring out something from the cage that Squeaky needed to live. Tom's name was picked. He pulled out a carrot and the teacher placed a carrot picture next to the guinea pig saying, "Squeaky needs food." Next, Mai showed the class the water bottle from Squeaky's cage and she said, "Squeaky needs water."

Classroom supports: Multiple modalities

"People need water. The guinea pig needs water and he gets water from the water bottle. Do you think mealworms need water too?" Ms. Lozano pointed to the picture of the mealworm, paused, and then repeated the question.

Classroom supports: Wait time after a question

Pao answered quickly and definitively, "No, *they* don't need water." Ms. Lozano **pressed for more information: "Why do you say that?"** Pao said, "There don't have any water in there." Ms. Lozano held up the mealworm container so all of the students could see inside." Together the class wrote down and stated everything in the mealworms' container: oats, carrots, and cardboard. Pao peered inside again, demanding, "Do you see water? NO."

Productive conversation prompt to deepen reasoning

Alvin didn't agree, "Yes, they do! All living things need water to drink. Or else they die." **Ms. Lozano waited,** and then said, **"Can you say more** about that? **Can anyone build on** Alvin's words?" Nevaeh said, "Animals and plants die with no water. There was this plant that we had. And it didn't get water for a while and died. If our meal worms didn't have water already they would all be dead." Some of the students were impressed. They whispered, "Evidence!"

Classroom supports:
Wait time after a response

Productive conversation prompt
to build collaborative reasoning

Miguel thought this made sense, but was unsure how to resolve the issue of no water in the container, suggesting, "They can get water from the river." Ms. Lozano said, "Did you take the mealworms to the river?" Miguel shook his head.

Isabella helped out, "Maybe at the beach." Lilia didn't agree, "It would take them days and days and days and they wouldn't like it at the beach. The beach is really cold and sometimes hot." Miguel added, "We didn't take them to the beach!"

New idea, and challenge
to idea, with rationale

Ms. Lozano kept the discussions respectful, and often asked the students to repeat or rephrase what another student had said. She a**sked Seleti to repeat** what Miguel had said. He said, "Miguel said they did not get water from the beach because we didn't go there." Ms. Lozano **checked with Miguel,** "Was that right, Miguel?" He nodded and smiled.

Student paraphrase followed
by check for accuracy

Ms. Lozano checked for consensus that living things need water. **After a turn and talk,** students agreed on this point. Ms. Lozano passed out sentence strips, and asked, "Where do the meal worms get their water?" She **assigned partners** to look in the mealworm containers on the tables and write down their claims on the sentence strips in words or pictures. She gave one member of each group a ***"What's your evidence?"* popsicle stick.** That person was responsible for making sure they all used evidence in their claims.

Purposeful participation structures
Classroom supports
Effective group strategies

Kurt said to his group of four, "They don't have water in the container, but they have to have water. **Maybe they got it in the carrot.** They eat the carrot but they can get water too. They can get the water in the juice." Axel held up his evidence Popsicle stick, **"What's your evidence?"** Kurt shook his head, but Lilia answered, "There is juice in the carrot. **Juice is kind of like water; it's like a different type of water. That is the where they get the water, in the carrot." Jal said, "I don't get what you're saying."** Lilia took out a carrot to show the group. She scraped at it with her fingernail to show the moisture. "See, water." She said, "Juice water."

New idea
Request for evidence
Clear reasoning with simple language

Request for clarification,
and response

Conversation Support Card adapted from Zwiers, O'Hara, & Pritchard (2014)

RESPONDING TO IDEAS

Clarify, Paraphrase, Summarize

Question Starters

What is…?

What do you mean by…?

Will you say that again for me?

But, what is the main point?

Response Starters

Let me show you.

Another way to say that is…

What she means is…

So far, everyone thinks…

Support

Question Starters

What are some examples?

Does anyone want to try that?

Do you see the link to…?

Have we seen that before?

Response Starters

An example is…

I'm sure that would work, because…

That makes sense, because…

Last week, we learned…

Build

Question Starters

How could that connect to…?

Would it work if we…?

Where could we use that idea…?

How can you add to that idea?

Response Starters

Let's try that.

Let's adjust our model to show that.

If we change this part, it would fit better because…

That reminds me of…

Question or Challenge

Question Starters

Did you think about…?

But, would it only work for…?

What is your reasoning?

Why do you think that?

Response Starters

I don't agree, because…

That ignores evidence of…

I see this very differently.

There's a problem with your idea because…

MODELING & EXPLAINING

DEVELOPING CAUSAL EXPLANATIONS

Language cues for talking about evidence and reasoning

Question starters

What's the connection between….?

What link do you see between…
Why do you think…?

What is our evidence that….

Do we have enough evidence
to make that claim?

But what about this other evidence that shows….?

But does your claim account for…(evidence)

Response Starters

I agree with you because of (evidence or reasoning)

I don't agree with your claim because of (evidence or reasoning)

This evidence shows that…

Your explanation makes me think about …..

DEVELOPING MODELS

Language cues for making internal thoughts understood

Question starters

Which thing in the model is the most important?

Do you think that causes _______ , or
is it happening because of….

How does your model show…?

Does our model show everything
we need?

Could you explain this part of the model?

What is happening here…..?

What is missing from your model? What did you not include?

Response Starters

Are you saying that….?

I think I heard you say…. Is that right?

Can I tell you what I understood from what you said?

Can you say more about….

Additional Resources

The following books, articles, and websites offer excellent resources. Most are specifically related to working with English Learners. Some, such as the websites listed below, are about the teaching practices and discourse practices that help create meaning; these do also address meaning-making with new learners of English.

Council of Chief State School Officers. (2012). Framework for English Language Proficiency Development Standards corresponding to the Common Core State Standards and the Next Generation Science Standards. Washington, DC: CCSSO.

- Analysis of the language demands for English Learners
- Articulates the relationship between Science and Engineering Practices, analytic tasks, and the language needed for their accomplishment

Fang, Z., Lamme, L., & Pringle, R. (2010). *Language and literacy in inquiry-based science classrooms.* Thousand Oaks, CA: Corwin.

- Excellent explanation of the language of science. Simple strategies, popular with students, for developing science language
- Co-published by NSTA

Lee, N., Cortada, J., & Grimm, L. (2013). *WIDA Focus On: Group Work for Content Learning.* Madison, WI:WIDA Consortium.

- Strategies for using group work effectively with English Learners

Lee, O., & Buxton, C. A. (2013). Integrating science learning and English language development for English language learners. *Theory Into Practice, 52*(1), 36-42.

- Excellent discussion of the interplay between meaning-making in science and in English

Lee, O., Quinn, H., & Valdés, G. (2013). *Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics.* Educational Researcher, Vol. 42 No. 4, pp. 223-233.

- Discussion of the importance of the Science and Engineering Practices in language learning for English Learners

NGSS Lead States. (2013). *Next generation science standards: For states, by states. Appendix D: Case Studies.* Washington, D.C.: The National Academies Press. http://www.nextgenscience.org/appendix-d-case-studies

- Series of cases studies that outline science teaching practices helpful to students from diverse backgrounds

Rosebery, A. S., & Warren, B. (Eds.). (2008). *Teaching science to English language learners: Building on students' strengths.* Arlington, VA: National Science Teachers Association.

- Good discussion of how to leverage students' and families' funds of knowledge

- Summary of strategies to support English Learners' comprehension in science classrooms

sites.nationalacademies.org/DBASSE/BOSE/CurrentProjects/DBASSE_0839999
- Videos from a 2013 two-day workshop on Literacy in Science at the National Academy of Science

Science Discourse Resources

tools4teachingscience.org/
- Extensive teacher resources on this "Tools for Ambitious Science Teaching" website
- Tips for designing activities related to the '"big ideas" in science
- Our primary resource on teacher discourse moves to support meaning-making
- Many video clips showing teachers and students using these talk moves

Michaels, S. and O'Connor, C. (2012) *Talk Science Primer.* TERC: Cambridge, MA. Downloaded at inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf

Zwiers, J. (2008). *Building Academic Language: Essential Practices for Content Classrooms.* San Francisco, CA:Jossey-Bass.
- Excellent and practical strategies for focusing on academic language

Zwiers, J., O'Hara, S., & Pritchard, R. (2014). *Common Core Standards in Diverse Classrooms: Essential Practices for Developing Academic Language and Disciplinary Literacy.* Portland, Maine: Stenhouse.
- Many strategies to strengthen students' ability to develop and sustain academic conversations
- Many additional resources on the related website: http://aldnetwork.org/core-practice/resources-fostering-academic-interaction

References

Cook, H.G., & MacDonald, R. (2014). *Reference Performance Level Descriptors: Outcome of a National Working Session on Defining an "English Proficient" Performance Standard.* Washington, D.C.: Council of Chief State School Officers, www.ccsso.org/Resources/Publications/Reference_Performance_Level_Descriptors.html.

National Academy of Sciences. (2012). *A framework for k-12 science education.* Washington, D.C.: The National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, D.C.: The National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states. Appendix F: Science and Engineering Practices.* Washington, D.C.: The National Academies Press.

Zwiers, J., O'Hara, S., & Pritchard, R. (2014). *Common Core Standards in Diverse Classrooms: Essential Practices for Developing Academic Language and Disciplinary Literacy.* Portland, Maine: Stenhouse Publishers.

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