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Abstract

As the Next Generation Science Standards (NGSS) are language intensive, they present both opportunities and challenges for all students, and English learners (ELs) in particular, who are developing language and disciplinary knowledge and practices simultaneously. To support students of varying levels of English language proficiency in the NGSS science classroom, an important role of the teacher is to gather information about student learning that can be used to advance students' language proficiency in the service of learning science. Formative assessment can be a powerful means of gathering such information and using it to provide ongoing and contingent support. This article focuses on formative assessment of language proficiency in the context of NGSS-aligned science instruction. First, we provide a framework for language use in the science classroom in terms of modalities and registers. Second, applying this framework, we articulate language proficiency descriptors across four language proficiency levels aligned to a fourth-grade NGSS modeling task. Third, we provide illustrative examples of student models at each of the four language proficiency levels. Finally, we offer recommendations for how teachers can leverage the power of formative assessment to support the language proficiency of all students, and ELs in particular, in the NGSS science classroom.

Formative Assessment of English Language Proficiency in the Science Classroom

In a linguistically diverse fourth-grade classroom, students carry out an investigation to answer the lesson question: How are we able to see objects? Working collaboratively in groups, students are given a lidded box with an eye hole and a flap. They make predictions about what they will see when they peer into the box and then develop models using drawings, symbols, and text. What's inside the dark box? It's a mysterious beginning to the lesson.

"Doing" science and engineering according to the vision of the NGSS is language intensive and offers both opportunities and challenges for all students, and English learners (ELs) in particular, who are developing language and disciplinary knowledge and practices simultaneously (Lee, Quinn, & Valdés, 2013). As students engage in three-dimensional learning to make sense of phenomena and build their science understanding over time, they grow in their ability to use language and other meaning-making resources (e.g., symbols) effectively.

To support ELs of varying levels of English language proficiency as they *use language to "do" science*, an important role of the teacher is to gather information about student learning that can be used to advance students' language proficiency in the service of learning science. Formative assessment can be a powerful means for gathering such information and using it to provide ongoing and contingent support (Harris, Krajcik, Pellegrino, & McElhaney, 2016). This article focuses on formative assessment of language proficiency (shortened to "proficiency" hereafter) in the context of NGSS-aligned science instruction.

Framework for Language Use in the Science Classroom

For formative assessment to be successful, it must begin with a clear picture of *what* language is used in the science classroom and *how* students progress in their language use across proficiency levels. Our framework focuses on two key aspects of language use in the science classroom: modalities and registers.

Modalities refer to the multiple and diverse channels through which communication occurs (e.g., talk, text, graphs, charts, symbols, equations). Whereas traditional notions of "academic language" tend to focus exclusively on linguistic modalities (i.e., talk and text), our framework expands the definition of language to include nonlinguistic modalities (e.g., symbols), as these are essential meaning-making resources of the science disciplines (Lemke, 2002).

Registers are varieties of language associated with particular contexts of use (Biber & Conrad, 2009). Whereas an everyday/colloquial register is common in day-to-day communication, a specialized/disciplinary register affords the precision and explicitness necessary to communicate ideas with exactness and with "distant" audiences. Unlike traditional notions of "academic language" (defined in terms of vocabulary and grammar), a register perspective views language as a product of, rather than a prerequisite to, science learning.

Table 1 illustrates how ELs use modalities and registers across proficiency levels. As students develop a more expansive repertoire of modalities, they combine these modalities in increasingly strategic ways to communicate their ideas. They also grow in their ability to use a more specialized/disciplinary register, as they require the precision and explicitness that this register affords.

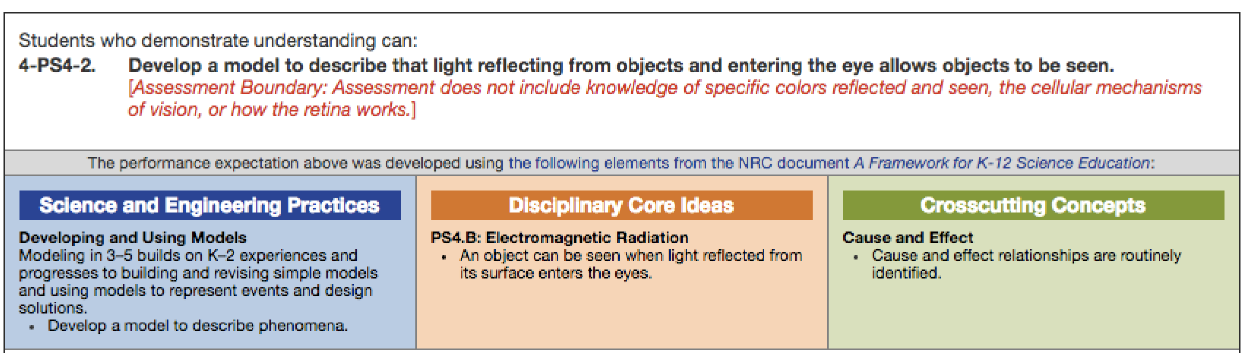
Table 1

Students' Use of Modalities and Registers Across English Language Proficiency Levels

	Level 1	Level 2	Level 3	Level 4
Modalities	Increasingly strategic use of multiple modalities appropriate to the discipline →			
Registers	Increasingly precise and explicit use of registers appropriate to the discipline →			

Formative Assessment of Language Proficiency in the Lightbox Investigation Task

Based on our framework for language use in the science classroom (described above), we articulate a set of language proficiency descriptors aligned to an NGSS task[1]. As shown in Figure 1, the relevant NGSS performance expectation (PE) in physical science for fourth grade incorporates a science and engineering practice (SEP; "develop a model"), disciplinary core idea (DCI; "that light reflecting from objects and entering the eye"), and crosscutting concept (CCC cause and effect; "light . . . allows objects to be seen"). The combination of the dimensions of SEP, DCI, and CCC represents NGSS three-dimensional learning.



Students who demonstrate understanding can:

4-PS4-2. **Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.** *[Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]*

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. • Develop a model to describe phenomena.	**PS4.B: Electromagnetic Radiation** • An object can be seen when light reflected from its surface enters the eyes.	**Cause and Effect** • Cause and effect relationships are routinely identified.

Figure 1. NGSS performance expectation for fourth-grade physical science (4-PS4-2).

[1] The lightbox investigation task is based on a similar task for middle school science in the Investigating and Questioning our World through Science and Technology (IQWST) curriculum units (http://www.activatelearning.com/iqwst-units/).

Students in small groups were given a box with two holes (a light hole covered by a flap and an eye hole) and a toy turtle inside (Figure 2). Peering into the box, they made observations of the turtle under several conditions (i.e., flap closed, flap open, flashlight shining through the flap). When students were unable to see the turtle with the flap of the box closed but were able to see it with the flap open and even more clearly with the flashlight shining through the flap, they began to understand that light causes an object to be seen (CCC) when it reflects off the object and enters the eye (DCI). After developing initial models of how they could see the toy turtle in the box, students revised their models by engaging in related investigations until they individually produced their final models (SEP).

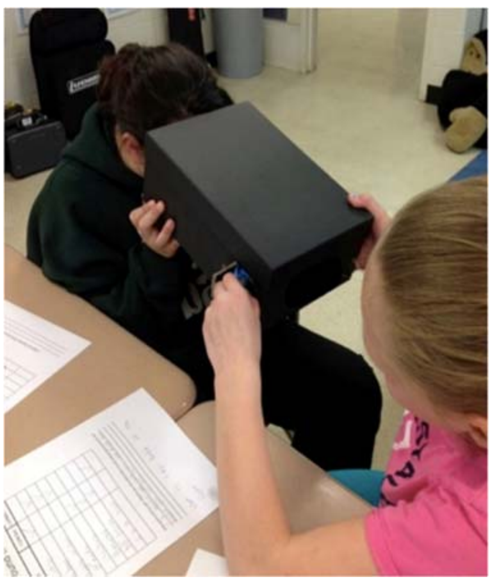


Figure 2. Lightbox investigation task.

Table 2 articulates language proficiency descriptors for assessing students' final lightbox models. As indicated at the top of the table, students at all proficiency levels are expected to meet the targeted PE. By holding all students accountable for meeting this PE, the descriptors reflect the NGSS vision of "all standards, all students." However, because ELs are, by definition, still developing the language necessary to access grade-level instruction in English, it is anticipated that they use language with varying degrees of proficiency. Across proficiency levels, students make increasingly strategic use of modalities and more precise and explicit use of registers (see Table 2).

Table 2

English Language Proficiency Descriptors for Assessing Lightbox Investigation Models

	Students at all proficiency levels meet the performance expectation (4-PS4-2) by...			
	Level 1	**Level 2**	**Level 3**	**Level 4**
Modalities	Using drawings, symbols, and limited text	Using drawings, symbols, and some text	Using a strategic combination of drawings, symbols, and extensive text	Using a strategic combination of drawings, symbols, and extensive text
Registers	Using words and memorized chunks of text	Using words and familiar patterns of text	Using colloquial (everyday) terminology and text	Using disciplinary terminology and text

Lightbox Model Examples

We present four lightbox models corresponding to the four proficiency levels articulated in the descriptors (see Table 2). The models offer examples of how language is used at each proficiency level and the progression of language use across the four proficiency levels.

Figure 3. Lightbox model at Level 1 proficiency.

Figure 3 shows a lightbox model at Level 1 proficiency. The model includes all of the components from the investigation, including the object (turtle), eye, light, and open view (open flap). The student uses arrows, which are key meaning-making resources in science disciplines (Kress, 2000), to show the relationships among the components. Specifically, an arrow is used to show the path of light as it originates from the flashlight, passes through the open flap, reflects off the turtle, and enters the eye. The scientific principle of reflection is communicated by the direction of the arrow, which reflects off the turtle and points toward the eye (A common misconception is to draw an arrow from the eye pointing toward the turtle). The arrow thus sets up a causal relationship between the light reflecting off the turtle and the eye's ability to see the turtle. While the model is replete with meaning due to the use of multiple modalities, the student's use of text (i.e., written language) is limited to a small number of labels ("Light" and "Reflection") and a short title in the form of a memorized language chunk ("Turtle in a Box").

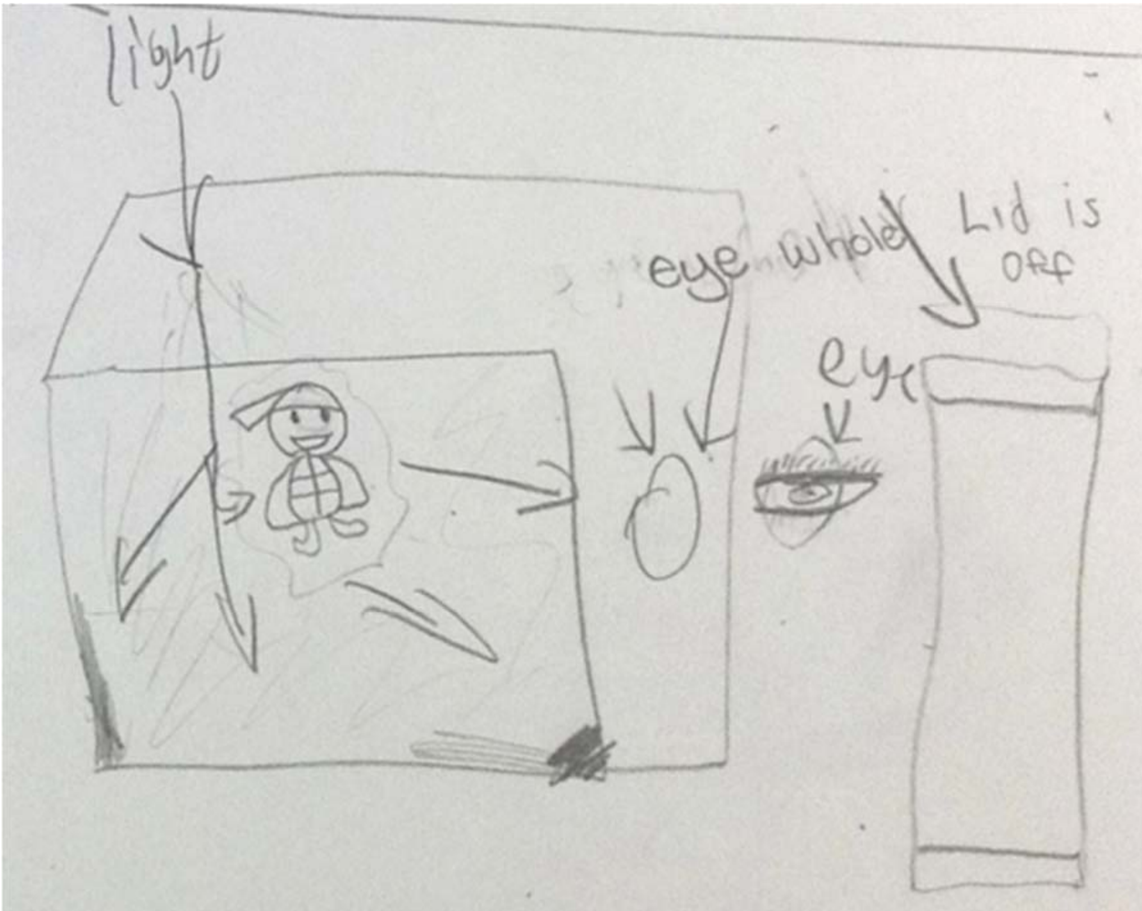


Figure 4. Lightbox model at Level 2 proficiency.

Figure 4 shows a lightbox model at Level 2 proficiency. Similar to the Level 1 model, this model uses multiple modalities to communicate the scientific principle of reflection and to explain the causal relationship. This model goes beyond what is shown in the previous model by drawing multiple arrows emanating from the turtle to represent how light reflects off an object in multiple directions, not just to the eye. In comparison with the Level 1 model, this model provides more labels for components and also includes a simple sentence using a familiar language pattern ("Lid is off") to clarify the condition of the investigation represented in the model. This combination of some text with drawings and symbols serves to enhance the model's explicitness, thus increasing the likelihood of it being understood by someone unfamiliar with the investigation. Still, the model relies heavily on drawings and symbols to convey its intended meaning, leaving substantial room for (mis)interpretation.

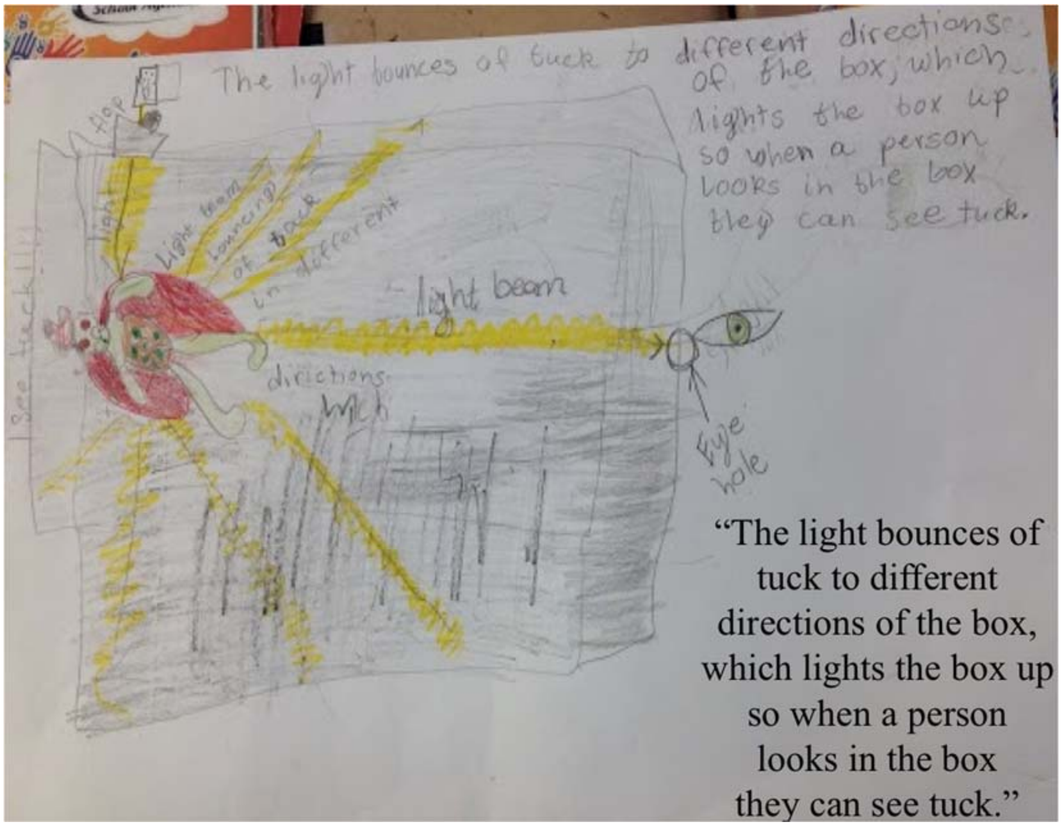


Figure 5. Lightbox model at Level 3 proficiency.

Figure 5 shows a lightbox model at Level 3 proficiency. It contains many of the same elements from the previous two models plus substantially more text. By strategically combining extensive text with drawings and symbols, this model achieves a higher degree of precision and explicitness than either of the previous two. Specifically, the use of text creates a "reading path" that guides the reader through the causal sequence of events represented by the drawings and symbols. The student uses an everyday register ("bounces of[f]") to describe the science idea of reflection and a coordinating conjunction ("so") to explain the causal relationship. Still, the terminology ("bounces of[f]") is imprecise, and the text ("so when a person looks in the box they can see tuck") does not make explicit that light enters the eye. Thus, there is still room for improvement in the precision and explicitness of register.

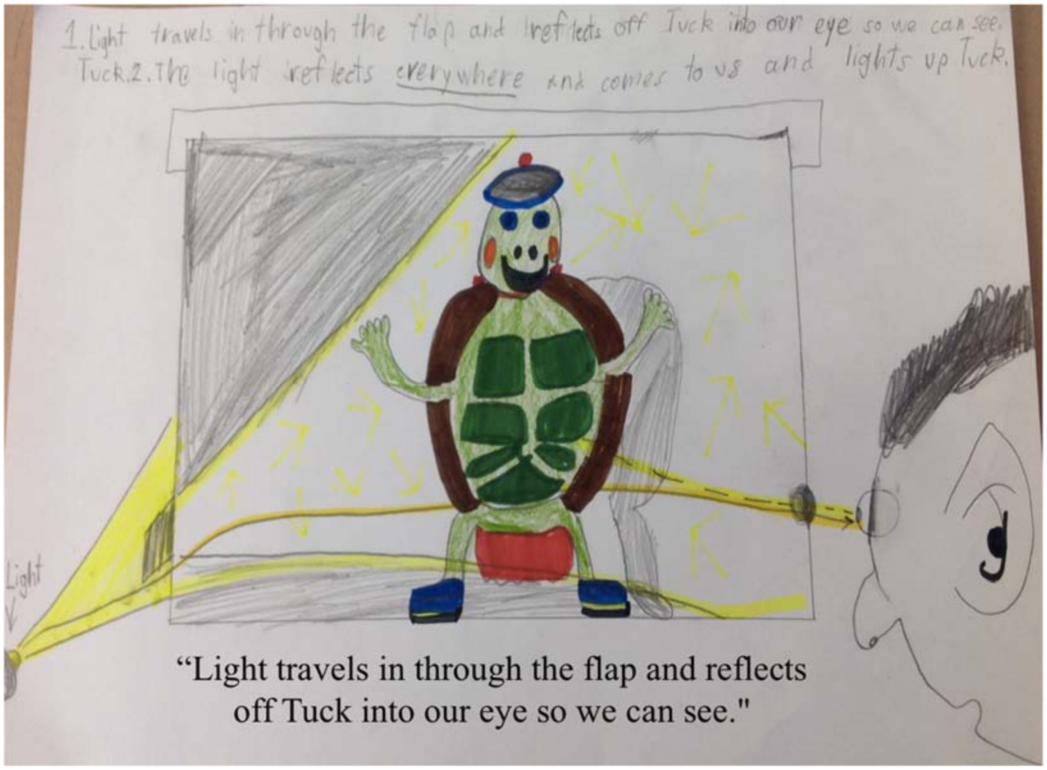


Figure 6. Lightbox model at Level 4 proficiency.

Figure 6 shows a lightbox model at Level 4 proficiency. Of the four models, this model demonstrates the most strategic use of multiple modalities and the most precise and explicit use of register. In addition to representing the components and their relationships, a unique feature of this model is the strategic use of drawing to represent the shadow behind the turtle resulting from the turtle's obstruction of light. As in the Level 3 model, this model also uses a coordinating conjunction ("so") to explain the causal relationship. However, unlike the Level 3 model, the use of disciplinary terminology ("reflects") achieves the precision needed to communicate scientific ideas, and the text makes explicit that light entering the eye causes the turtle to be seen ("into our eye so we can see"). Notably, this model contains fewer words than the Level 3 model but uses those words more effectively. Although a certain amount of language is needed for effective communication, increases in the quantity of language beyond that point can be counterproductive. Because *less* is sometimes *more* when communicating scientific ideas, teachers should attend to the quality, rather than quantity, of their students' texts.

Recommendations for the Classroom

Across the four lightbox models, students make increasingly strategic use of multiple modalities and more precise and explicit use of register, which enables them to more effectively communicate their ideas. The descriptors provided in Table 2 can be a useful tool for formatively assessing students' models at multiple points over the course of instruction (e.g., initial, revised, and final models). What makes assessment truly formative, however, is that teachers and their students use assessment information to guide teaching and learning going forward. Below, we offer three recommendations for how to use formative assessment to promote language proficiency:

1. Engage students in conversation about their models.

Ask probing questions that guide students toward more strategic use of multiple modalities and more precise and explicit use of register (e.g., What does this arrow mean? Is there a more precise way of saying "bounces off"?).

2. Provide scaffolds for students' use of text (i.e., written language).

For example, ask students to number the relationships represented by their drawings and symbols (e.g., use 1, 2, 3, etc. to indicate the sequence of events). Then, ask students to write what is happening at each time point in the model.

3. Create opportunities for students to assess their own and each other's models.

For self-assessment and peer-assessment to be effective, students must have a clear idea of what a "good" model looks like (Harris, Krajcik, Pellegrino, & McElhaney, 2016). One way to do this is to co-construct a set of criteria with the class. Once these criteria are established, set up a “gallery walk” in which students use sticky notes to write respectful comments and questions on each other’s models. Then, students revise their models based on feedback from their peers.

We emphasize that these recommendations are useful for promoting language proficiency *and* science learning. All four lightbox models show evidence of meeting the NGSS PE, although they vary considerably in terms of language use. Of course, this may not always be the case, since, at any given time, students will be at varying points in both their language proficiency and science learning. Formative assessment, then, can be a powerful tool for advancing students’ language proficiency and science learning in tandem and for guiding instruction with all students, especially ELs.

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4-PS4 Waves and their Applications in Technologies for Information Transfer http://www.nextgenscience.org/pe/4-ps4-1-waves-and-their-applications-technologies-information-transfer	
Performance Expectation	**Connections to Classroom Activity** ***Students:***
4-PS4-2: Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.	• develop a model to describe how light reflecting from a toy turtle and entering the eye allows the toy turtle to be seen.
Science and Engineering Practices	
Developing and Using Models • Develop a model to describe phenomena • Planning and carrying out an investigation	• develop a lightbox model with components (object, eye, light source, and open view) and relationships (light originating from the light source, reflecting off the object, and entering the eye). • carry out an investigation to make observations of the effect of light under several conditions: no light, some light, and bright light.
Disciplinary Core Idea	
PS4.B: Electromagnetic Radiation • An object can be seen when light reflected from its surface enters the eyes.	• understand that light is reflected from the surface of an object. The ability to see the object occurs because the reflected light enters the eye.
Crosscutting Concepts	
Cause and Effect • Cause and effect relationships are routinely identified.	• identify the relationship between light and the ability to see an object. The cause is light entering the eye, and the effect is being able to see the object.