Oral Discourse in Teaching and Learning Science in Relation to the Next Generation Science Standards

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The Next Generation Science Standards (NGSS) recently became public in 2013, while implementation of the Common Core State Standards (CCSS) for English language arts (ELA)/literacy and mathematics (Common Core State Standards Initiative, 2010a, 2010b) has been underway since adoption starting in 2010. Because the CCSS and NGSS are academically rigorous, teachers should make instructional shifts to enable all students to be college and career ready. At the same time, because disciplinary practices in the CCSS and NGSS are language intensive, teachers should meet increased language demands while capitalizing on language learning opportunities across these subject areas for all students.

This paper focuses on oral discourse in teaching and learning of science in relation to the NGSS. The paper consists of two sections. The first section addresses science and engineering practices in the NGSS, while the second section focuses on oral discourse as teachers and students engage in the NGSS science and engineering practices. The paper is guided by two fundamental premises. First, students should engage in "doing" science and engineering and "using" language in the science classroom. Second, language demands and opportunities presented by the NGSS and CCSS are particularly important for English language learners (ELLs).

NGSS Science and Engineering Practices

"A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" (National Research Council [NRC], 2011) defines "science inquiry" by identifying a set of science and engineering practices:

1. Ask questions (for science) and define problems (for engineering)
2. Develop and use models
3. Plan and carry out investigations
4. Analyze and interpret data
5. Use mathematics and computational thinking
6. Construct explanations (for science) and design solutions (for engineering)
7. Engage in argument from evidence
8. Obtain, evaluate, and communicate information

Science and engineering practices are language intensive, and engagement in these practices requires science classroom discourse. Students speak and listen as they present their ideas or engage in reasoned argumentation with others to refine their ideas and reach shared conclusions. They read, write, view, and visually represent as they develop their models and explanations. These practices offer rich opportunities and demands for language learning at the same time as they promote science learning.

Across the CCSS and NGSS, these new standards share a common emphasis on disciplinary practices and classroom discourse. These practices raise the bar for content (academically rigorous), raise the bar for language (language intensive), and call for a high level of classroom discourse in both oral and written forms across these subject areas for all students.

The relationships and convergences of disciplinary practices across the CCSS and NGSS are highlighted in Figure 1.

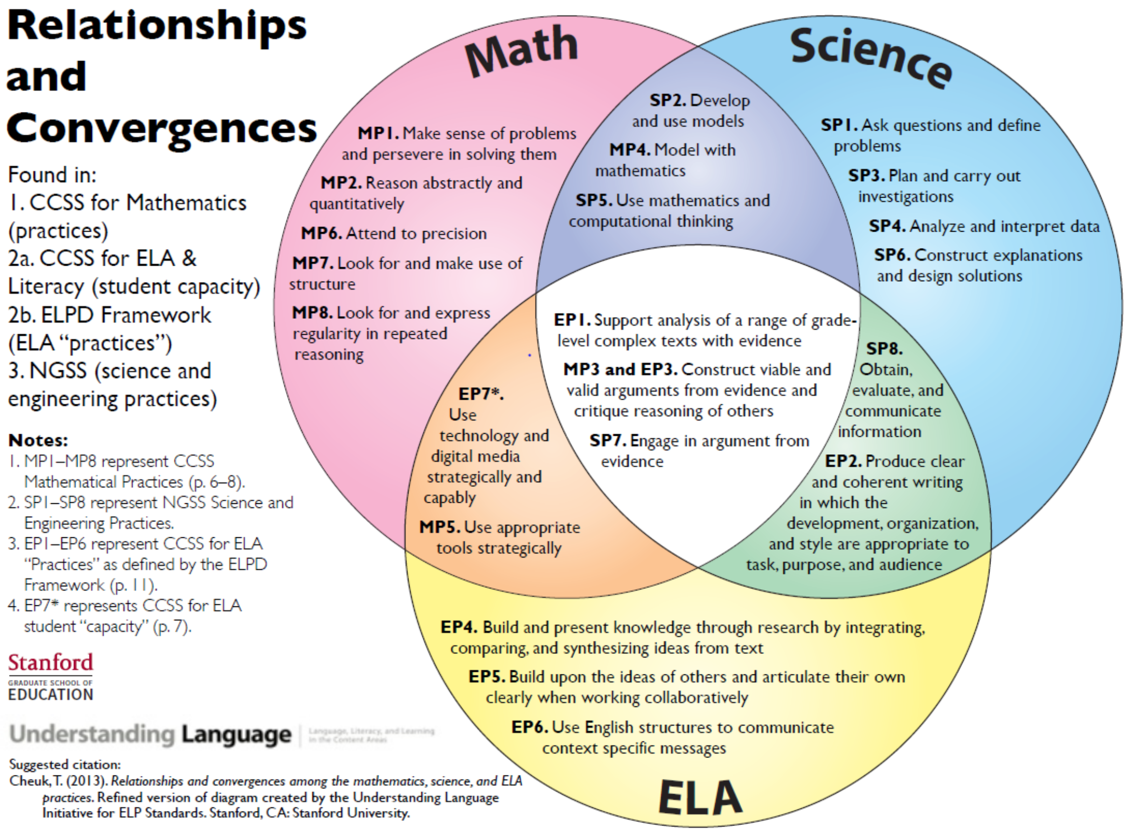

Figure 1. *Disciplinary practices across CCSS and NGSS*

Conceptual Framework: *Language Use in the Science Classroom*

In our paper that appeared in *Educational Researcher* (Lee, Quinn, & Valdés, 2013), we introduce the conceptual framework of *language use in the science classroom* to be explicit about what science teachers and their students "do" with language in science classrooms. Specifically, we address language demands and opportunities that are embedded in science and engineering practices. By examining intersections between the learning of science and the learning of language, we identify key features of language use in the science classroom as students engage in these language-intensive science and engineering practices.

Figure 2 presents one of the eight science and engineering practices as an example. Here, the NGSS practice of engaging in argument from evidence is unpacked into *analytical science tasks* and *receptive and productive language functions.* These receptive (listening and reading) and productive (speaking and writing) language functions are what students "do" with language to accomplish analytical science tasks in making sense of and constructing scientific knowledge. To learn to perform analytical science tasks and language functions over time, ELLs need access to a rich language environment in which frequent examples are part of everyday interactions.

Science & Engineering Practices and Language Functions

NGSS Practice 7: Engage in argument from evidence	
Analytical Science Tasks	• Distinguish between a claim and supporting evidence or explanation • Analyze whether evidence supports or contradicts a claim • Analyze how well a model and evidence are aligned • Construct an argument
Receptive Language Functions	• Comprehend arguments made by others orally • Comprehend arguments made by others in writing
Productive Language Functions	Communicates (orally and in writing) ideas, concepts, and information related to the formation, defense, and critique of arguments • Structure and order written or verbal arguments for a position • Select and present key evidence to support or refute claims • Question or critique arguments of others

Figure 2: *Science and engineering practices and language functions*

Figure 3 focuses on features of science classroom language. Column 1 highlights three key elements of science classroom language, *modality*, *registers*, and *examples of registers*, in an attempt to move beyond grammatical correctness and vocabulary. *Modality* (oral or written modes of communication) refers to multiple features of the oral and written channels through which language is used. The table calls attention to the multiple features of teachers' language use and tasks (column 2) and students' language use and tasks (column 3) while engaged in science and engineering practices. The table also makes evident that language used in the science classroom involves interactions between teachers and students, between students in small groups, by students with the entire class, and by students with various written materials. *Registers* in both oral and written language are viewed from the analytical framework presented in Biber and Cameron (2009). Register is defined as a variety associated with specific situations and communicative purposes, and situational characteristics of registers are considered more basic than linguistic features. *Examples of Register* highlights examples of various registers used by both teachers and students to engage in interactions in the science classroom, ranging from the informal styles used by teachers to provide explanations, to the more formal student-directed written styles used by classroom texts (columns 2 and 3)." In carrying out such language use, students grow in their ability to use appropriate registers.

Features of Classroom Language	Teachers' Language Use and Tasks	Students' Language Use and Tasks		
	Oral & Written	Oral	Written	
	Receptive & Productive	Receptive & Productive	Receptive	Productive
Modality	Explanations and presentations (one-to-many, many-to-many)	Whole-classroom participation (one-to-many)	Comprehension of written classroom and school-based formal and informal written communication	Production of written classroom and school-based formal and informal written communication • Written reports • Science journal entries
	Communication with small groups of students (one-to-group)	Small group participation (one-to-group)		
	Communication with individual students (one-to-one)	Interaction with individual peers (one-to-one)		
	Communication with parents (one-to-one)	Interaction with adults within school contexts (one-to-one)		
Registers	Colloquial + classroom registers + disciplinary language and terminology	Colloquial + classroom registers + disciplinary language and terminology	Science-learner written registers + disciplinary language and terminology + disciplinary discourse conventions	
Examples of Registers	Classroom registers: • Giving directions • Checking for understanding • Facilitating discussions Science discourse registers used for: • Describing models • Constructing arguments • Providing written or verbal explanation of a phenomenon or system	Classroom registers: • Comprehending oral directions • Asking for clarification • Participating in discussions Learner-appropriate science discourse registers and conventions used for: • Describing models • Constructing arguments • Providing oral explanations of a phenomenon or system	Classroom, school, and science-learner written registers • Textbooks • Lab or equipment manuals • Writing by other students • Internet materials • Science-oriented trade books • Science press articles • Syllabi • School Announcements • Formal documents (e.g., class assignment, quarterly grades, assessment results)	

Figure 3: *Features of science classroom language*

The *language use in the science classroom* conceptual framework refers to the intersections between both science and engineering practices and language functions (Figure 2) and features of science classroom language (Figure 3). The analytical tasks that are essential to science and engineering practices (e.g., asking questions and defining problems, developing models, engaging in argument from evidence) are carried out by means of receptive and productive language functions (e.g., comprehending oral and written explanations, making predictions, describing observations). These science and engineering practices and language functions take place in the context of the science classroom as teachers and students engage in "doing" science and engineering and "using" language during their interactions.

Recent Policy and Practice Initiatives Grounded in Our Conceptual Framework

Our framework, described above, has made an impact, such as its role in the modifications of English language proficiency (ELP) or English language development (ELD) standards in some states (e.g., CA and NY) and World-Class Instructional Design and Assessment (WIDA). In particular, our framework has guided several initiatives for educational policy and practice.

First, "The Framework for English Language Proficiency Development Standards Corresponding to the Common Core State Standards and the Next Generation Science Standards" (ELPD Framework) was developed (1) to communicate to ELL stakeholders in states the language practices that ELLs must acquire for academic learning in the CCSS and NGSS and for second language acquisition more generally and (2) to provide guidance to states on how to use the expectations of the CCSS and NGSS as tools to create and evaluate ELP/ELD standards (Council of Chief State School Officers, 2012). This document applied our framework for the NGSS (see Figures 1, 2, and 3 above) to the CCSS for ELA/literacy and mathematics.

Second, “The English Language Proficiency (ELP) Standards” are developed to highlight and elaborate on the critical language, knowledge about language, and skills using language that are in the CCSS and NGSS and necessary for ELLs to succeed in school (Council of Chief State School Officers, in press; Shafer Willner, 2013). Extending the ELPD Framework, this work identifies ELP standards that correspond to each of the disciplinary practices in the CCSS and NGSS. States are currently in the process of adopting these ELP standards.

Finally, “A Teacher’ Guide to the Mathematics and Science Resources of the ELPD Framework” is a small-scale development project funded by the NSF Discovery Research K-12 (Cook, 2013-2015). This project has recently begun to develop and validate a teacher’s guide that explains how the resources within the ELPD Framework can be used to generate classroom materials and to design learning activities that support ELLs’ engagement with the NGSS and CCSS for mathematics.

Oral Discourse in Teaching and Learning Science in Relation to the NGSS

The discourse of the science classroom, and of science textbooks, differs from everyday discourse of students and from that of a mathematics or language arts classroom or textbooks (Quinn, Lee, & Valdés, 2012). Among science disciplines, each has different discourse conventions, adapted to what has proven effective and efficient for communication among experts. These differences are reflected in science classroom talk and textbooks, which have registers specific to a discipline and grade level. Students must absorb these differences in register as they work to construct meaning appropriate to the topic at hand. Although science classroom discourse is not the same as the professional discourse or writing of scientists, it mirrors the conventions of the professional discourse more closely as the students advance across the grades.

"A Framework for K-12 Science Education" (NRC, 2011) refines what it means to promote learning science by moving away from prior approaches of detailed facts or loosely defined inquiry to a three dimensional view of science and engineering practices, crosscutting concepts, and disciplinary core ideas. In our conceptual framework of *language use in the science classroom* (Lee, Quinn, & Valdés, 2013), we argued for a parallel redefinition of what it means to support learning language in the science classroom by moving away from the traditional emphasis on language structure (phonology, morphology, lexicon, and syntax) to an emphasis on language use for communication and learning.

When students engage in "doing science and engineering," they rely heavily on oral discourse in small or large group settings. When students, especially ELLs, engage in "using language" to do specific tasks, oral discourse is critical. For example, students discuss their observations and engage in argument using evidence with others in small groups until they reach a shared "best" explanation or model. After small groups of students make oral presentations of their results and conclusions, they engage in discourse with other students who ask questions and discuss issues raised in the presentations. Because the oral discourse of such presentations and discussions is different from their everyday discourse, scientific explanations and arguments in oral forms precede scientific explanations and arguments in written forms. More typically, the development of both oral and written forms of scientific explanations and arguments proceed in parallel.

Oral discourse plays a special role in science teaching and learning:

- Science learning is based on experience
- Experience is essential for the development of oral language
- Oral language supports written language

- Oral discourse is critical to the construction of meaning
- If we can scaffold the use of language for science and engineering practices in oral discourse, this can support students' science learning as well as written discourse in science (and other content areas)

While oral discourse is important in content area learning for all learners, it is especially important for students who struggle with written discourse. Yet, oral discourse is not emphasized compared to written discourse in the CCSS ELA/literacy, "A Science Framework for K-12 Science Education" (NRC, 2011), and the NGSS. Given the centrality of literacy-based schooling, oral discourse is often regarded as not as important as written discourse broadly.

Below, two approaches to conceptualizing oral discourse in relation to written discourse as students engage in science and engineering practices are discussed: (1) receptive and productive language functions and (2) ways of using language with a focus on precision, explicitness, and complexity.

Language Functions

Language functions refer to what students do with language to accomplish content-specific tasks. Language functions can be used to describe the purposes for which language is used in the classroom. Their use offers a simple and practical way to ensure that content and language are integrated.

Language functions involve receptive and productive functions. Receptive language functions indicate language skills involved in interpreting and comprehending spoken or written language: "the interaction is with authentic written or oral documents where language input is meaningful and content laden. The learner brings background knowledge, experience, and appropriate interpretive strategies to the task, to promote understanding of language and content"

(Phillips, 2008, p. 96). Productive language functions involve producing language in spoken or written form: “The communication is set for a specified audience, has purpose, and generally abides by rules of genre or style. It is a planned or formalized speech act or written document, and the learner has an opportunity to draft, get feedback, and revise it before publication or broadcast” (Phillips, 2008, p. 96).

Receptive and productive language functions are carried out in both oral and written forms. In relation to the NGSS science and engineering practices, Figure 2 (see page 4) indicates receptive and productive language functions as students carry out analytical tasks in science. Furthermore, Figure 3 (see page 5) indicates that science and engineering practices and language functions take place in the context of the science classroom as teachers and students engage in “doing” science and engineering and “using” language during their interactions.

Ways of Using Language

Students need to be familiar with particular ways of using language to meet the language demands of science classroom discourse. Two points are noted at the outset. First, as oral and written language development occurs in tandem, ways of using language in oral form could be transferred to written language, making their writing more similar to what we understand as “academic language.” This point is particularly important, considering that students tend to write like they speak Yet, oral language meets particular communicative goals of science classroom discourse that are different from written language. Second, science classroom discourse should be inclusive and accept contributions for their meaning and value in the discourse, however flawed or informal the language of the speaker. Yet, science classroom discourse has particular registers and genres that are valued in the scientific community, and all students are encouraged and supported to participate in this community as the end goal of their learning.

Below, particular ways of using language in science classroom discourse are described. The conceptual framework of precision, explicitness, and complexity (see Figure 4 on page 12) originated from Lee and Lorena (2011-2015), while much of the description about science and engineering practices is drawn from Quinn, Lee, & Valdés (2012).

Precision. Science classroom discourse requires precision, accuracy, or exactness in thinking and language. Precision is expected as students engage in science and engineering practices. For example, precise observation demands both precise descriptive language and carefully constructed representation: “The level of detail of observation and explanation required by science and engineering is not common in everyday experience; it demands a comparable level of precision in language use" (Quinn, Lee, & Valdés, 2012, p. 4). As students are asked to explain their ideas or designs and critique those of others, they learn from experience of multiple examples about the level of precision and detail that scientific thinking requires. Likewise, their ability to use technical terminology develops because they need the precision that it offers. This demand for attention to precision and attention to detail goes beyond the meaning of technical vocabulary, to the evidence and logic of connecting cause and effect, and the validity of claims or warrants.

Explicitness. In science, we often seek to report, explain, and inform our audience about objects and actions not immediately present, and explicitness makes such language more informative (Schleppegrell, 2004). For example, models are an important step in the development of an explanation as to how something happens or an idea for a design solution. The practice of developing and using models provides a way to express a thought or an understanding in an oral form (Quinn, Lee, & Valdés, 2012). Using models to explain and describe systems provides students an impetus to name aspects or parts of their own model and to speak about how it explains observations. In doing so, students refine their understanding of needed scientific terminology. With a model in hand the student can say “this piece here . . . .” and then has a reason to want to know that this piece is called a cog or a flagellum, and thus to learn appropriate language in context as they express their ideas and grow in their understanding of the system under study. This move toward explicit detail occurs even when students do not yet have the written language to be explicit if simply asked for an explanation or design proposal orally.

Complexity. In science, we often communicate about relationships and logical connections (Lemke, 1990). Complexity of language moves beyond grammatical correctness, science correctness, or vocabulary to the relationship between specific ways of using language and specific reasons for using language. While engaging in science and engineering practices, students demonstrate complexity in their thinking and language. For example, students use models more than a record of observations, but to support the development of explanations of phenomena. They construct explanations that show a causal relationship and use the language of causality (e.g., because, as a result). They use the language to talk about argument, such as claims, reasoning, evidence, data, and observations.

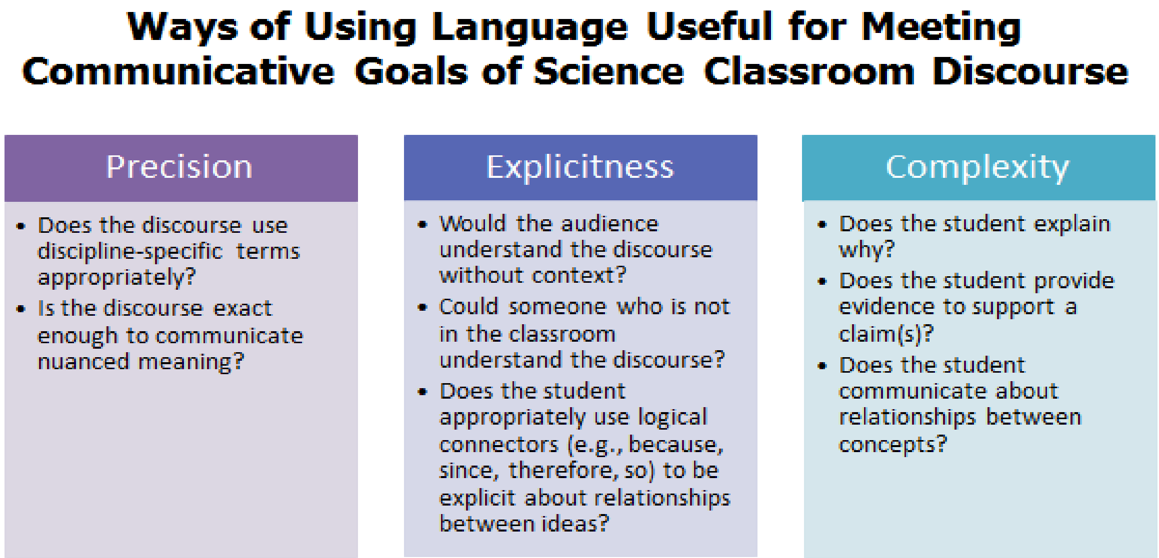

Figure 4: *Ways of using language*

Closing

Given the richness of science and engineering practices, the NGSS could lead to science classrooms that are also rich language learning environments. As oral discourse is important for both science and language learning, effective approaches to support oral discourse in relation to the NGSS are needed. This paper illustrates two approaches to conceptualize oral discourse in relation to written discourse in the context of the NGSS: language functions and ways of using language. An important role of the science teacher is to encourage and support language use and development in the service of making sense of science for all students, including ELLs.

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