Coming to Terms with Language: Editorial for the EJSE Special Issue on Science and Language

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Introduction

Despite growing interest in second language acquisition in the specific context of science classrooms, educational research at the intersection of science and language is still fairly scarce. Relatively little theoretical and empirical consideration has been given by scholars to what it means to teach science to leaners who are still in the process of acquiring the language of instruction, how conceptual development in science interacts with second language acquisition, how teachers can effectively attend to the linguistic as well as epistemic needs of students, and how to pedagogically scaffold nonnative speakers' science learning while simultaneously improving their communicative skills in a second language. This special issue is an effort to address the paucity of research and theorizing in this area, and hence advance our present understanding of emergent bilingualism in the science classroom. Toward this end, this editorial examines theoretical and empirical work related to language and linguistics aspects of science. After providing readers with some background information, we present a descriptive overview of the set of papers that comprise this special issue. Our hope is to increase the utility of this publication by first familiarizing readers' with important issues related to language, science education, and learning.

Language and Its Use

Defining Language

What is "language" after all? As it turns out, answering this seemingly simple task is not such an easy task. This challenge becomes particularly evident when we consider its usage in everyday parlance. Consider for instance its meaning in the following hypothetical statements:

- My family and I speak only the English **language** at home.
- Many school teachers now agree that students need to learn the **language** of science.
- Most computer programmers in academia are familiar with the formal grammar of the C++ **language**.

Careful inspection of the above statements reveals clear variation in what is meant by term "language" (i.e., what is being referred by speakers). Although often assumed to be a transparent

and self-evident word, "language" is in fact a polysemous term, that is, a word with a multiplicity of meanings that can be used in a plurality of senses. "Language" can be used in reference to the official language of a nation-state (e.g., English), the specialized terminology or jargon of an expert community or discipline (e.g., science), and even the computational tool of a professional programmer (e.g., C++). The fact that science itself can be conceived as a language can be in itself a source of confusion, after all it stands to reason that scientific English is still English.

One quick and straightforward way of shedding some light on the above conundrum is to look up the meaning of "language" in a commonly used dictionary. According to Webster-Merriam, a language is:

> "a system of words or signs that people use to express thoughts and feelings to each other; any one of the systems of human language that are used and understood by a particular group of people; words of a particular kind…"

These dictionary definitions emphasize the semiotic nature of language (Pierce, 1955). From this perspective, natural language (i.e., human communicative activity) is mediated by *signs* (words), fixed units of meaning that are agreed upon by speakers of a given community. Each word acquires its representational meaning -- comes to stand for a given world entity or process -- by means of social convention. A group of speakers agree on a particularly way of verbally representing a particular object. Further, to learn an additional language is to acquire mastery over a new semiotic system, the ability to deploy a new referential system to make sense of the world (meaning). Put differently, language learners become fluent in a new system of labels. Human communication is conceived as pointing, naming and referring, with the underlying assumption that different languages have equivalent words/terms that refer to the same object. Figure 1 illustrates this perspective on language acquisition.

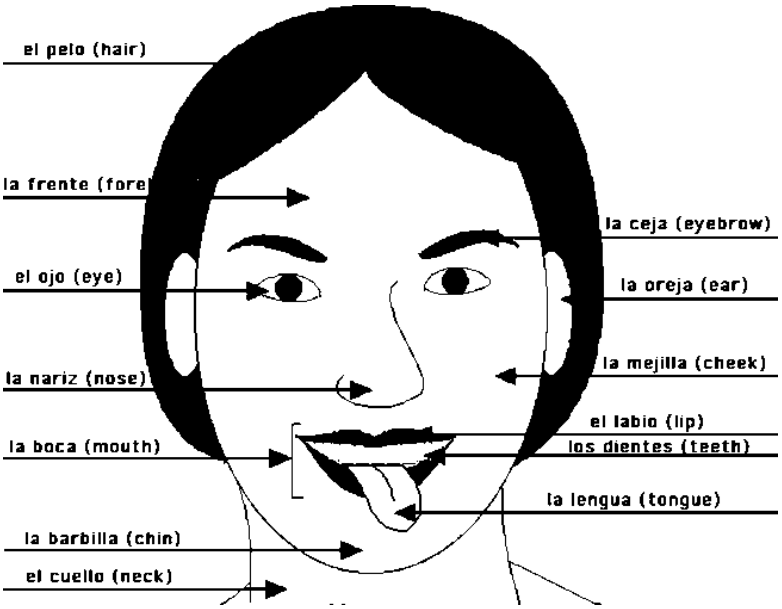

Figure 1. Language as labelling system (Spanish and English).

When approached as learning to label, language instruction takes the prototypical form of naming games: "*Pointing + Naming"* (Tomasello, 2001). Words are simply mapped onto the physical world as the adult/teacher shows a referent (object) to the child/learner. These naming games typically require an ostensive context involving concrete objects that are well-defined, tangible, and have simple shape (i.e., clear focus of attention). However, complications often arise when pointing to substances without definite shape (water, sugar) and when pointing to actions (e.g., the verb "to show"). Because pinpointing relations is more difficult, language learners tend to acquire concrete nouns before relational words, verbs, theoretical referents, and moving objects (Gentener & Boroditsky, 2001). Ability to perceive and refer to more elusive phenomena (e.g., gravity) requires conceptualization that goes beyond more obvious features such as shape, color, and texture. Put differently, speakers need to have a clear concept of what the referent is (the nature of the entity being referred to) in order to be able to name it. The prevalence of these abstract notions in science classroom discourse explicates the difficulty often faced by students (native as well as nonnative) when learning to speak the language of science.

In the specific context of science classrooms, this conception of language as a labeling system is particularly evident in the strong emphasis typically given to vocabulary. This is described by Montgomery (1996) as "the cult of jargon," a defining feature of scientific language. From the lexical perspective, learning science is to a large extent learning a new and more precise way of labelling the world which may differ from students' everyday labelling practices regardless of their native language. This is the reason why many science educators have advocated a content-first approach wherein content is first taught in the students' language, and then gradually jargonized (put in proper scientific terms) (Brown & Ryoo, 2008; Lemke, 1990). This typically involves simplification of scientific language to a level that is comprehensible to students. Nonetheless, as emphasized by Glass & Oliveira (2014), comprehensible input should not come at the cost of denying students access to the powerful scientific register (the specialized language of science). Students need to be provided with pedagogical scaffolding toward more complex linguistic forms in order to eventually acquire fluency in the specialized language of science.

Though intuitive and commonsensical, treating language as a labeling system is theoretically simplistic in the sense that it reduces language use to reference. In addition to referring to aspects of the world, speakers also use language to shape their social relationships with other members of our community (social functions), to prompt thinking and achieve shared understandings (cognitive functions), to promote emotional states (emotive function) and even to refer to language itself (metalinguistic function); often simultaneously (Silverstein, 1995; 2004). Furthermore, some labels may not exist in world languages wherein speakers have not encountered the need to lexicalize particular aspects of their human experience. Therefore, learning an additional language is more than simply developing mastery over a new labeling system. In pursuit of more sophisticated metaphorical conceptions of language that can better inform teaching practices aimed promoting linguistic acquisition, we turn to the scholarly literature.

Language Metaphors

Metaphors are a figure of speech that uses a known phenomenon as a way of identifying another unrelated phenomenon. Metaphors are used to clarify and show similarities by directly equating two ideas. Unlike the simile, metaphors do not use 'like' or 'as' in drawing the comparison.

Language as Conduit. Like other elusive notions, language is often conceived metaphorically, that is, nonliterally in terms of a more concrete processes or more familiar systems. Varied language metaphors pervade the scholarly literature on human communication. Central to Western thought is the conduit metaphor (Lakoff & Johnson, 1999; Reddy, 1979) -- the notion that language is fundamentally a conduit. This metaphor entails the following basic notions:

speaking	→	putting ideas into words
words	→	containers that carry words (packages)
ideas	→	entities that get packaged (contents)

These metaphorical underpinnings pervade our conceptions of language. They are particularly evident in commonly made statements such as "Good ideas need to be captured in words," "Sentences should not be overloaded with concepts," and "That thought should be placed somewhere else in the paragraph." Across all these examples, the conveyance of ideas is treated as a sort of shipment wherein thoughts are "boxed" into words and then shipped to an addressee, who in turn opens the box and receives its contents. Ideas travel through language (the conduit). Similar views permeate science wherein language is typically viewed as a "device able to contain and transfer knowledge without touching it" (Montgomery, 1996; p.2).

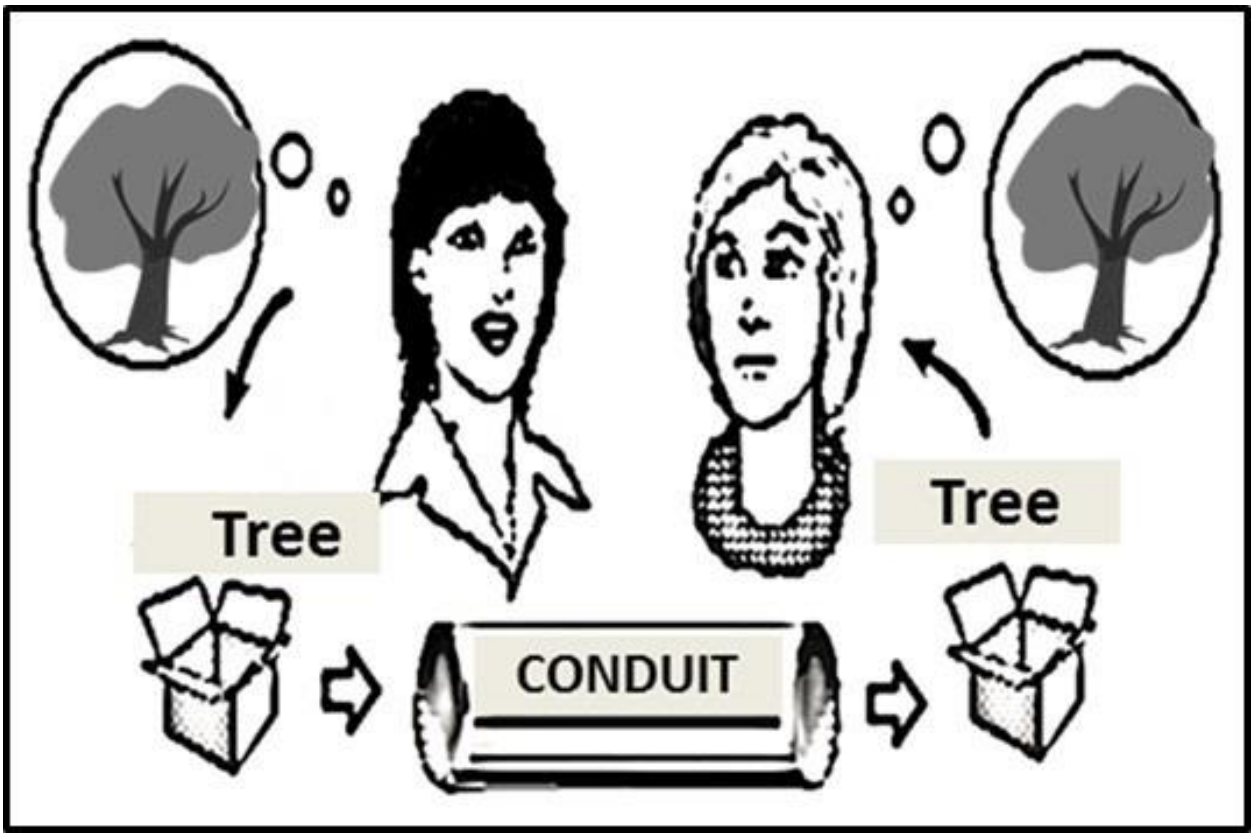

Figure 2. Language as a conduit for ideas.

Those who subscribe to this metaphorical view of language tend to treat classroom monolingual communication as transmission or flow of information (Figure 3a below). According the transmission model (Leach, Yates, & Scalon, 2008), a message is transmitted from a producer to a receiver through a series of encoding and decoding of linguistic signals similar to a broadcasting tower emitting a signal to a remote television. This engineering-based metaphor presumes the existence of a common code (the same language is spoken by both parties). When

extended to multilingual context wherein a bilingual speaker mediates face-to-face exchange among two monolingual speakers, we have an intermediary step of re-coding – the message in the first language (English) is decoded and re-encoded in the second language (Spanish) by the bilingual speaker (Figure 3b). These language metaphors emphasize the semiotic nature of natural language and human communication as an information-sending endeavor that is physically accomplished through signaling of a verbally encoded message.

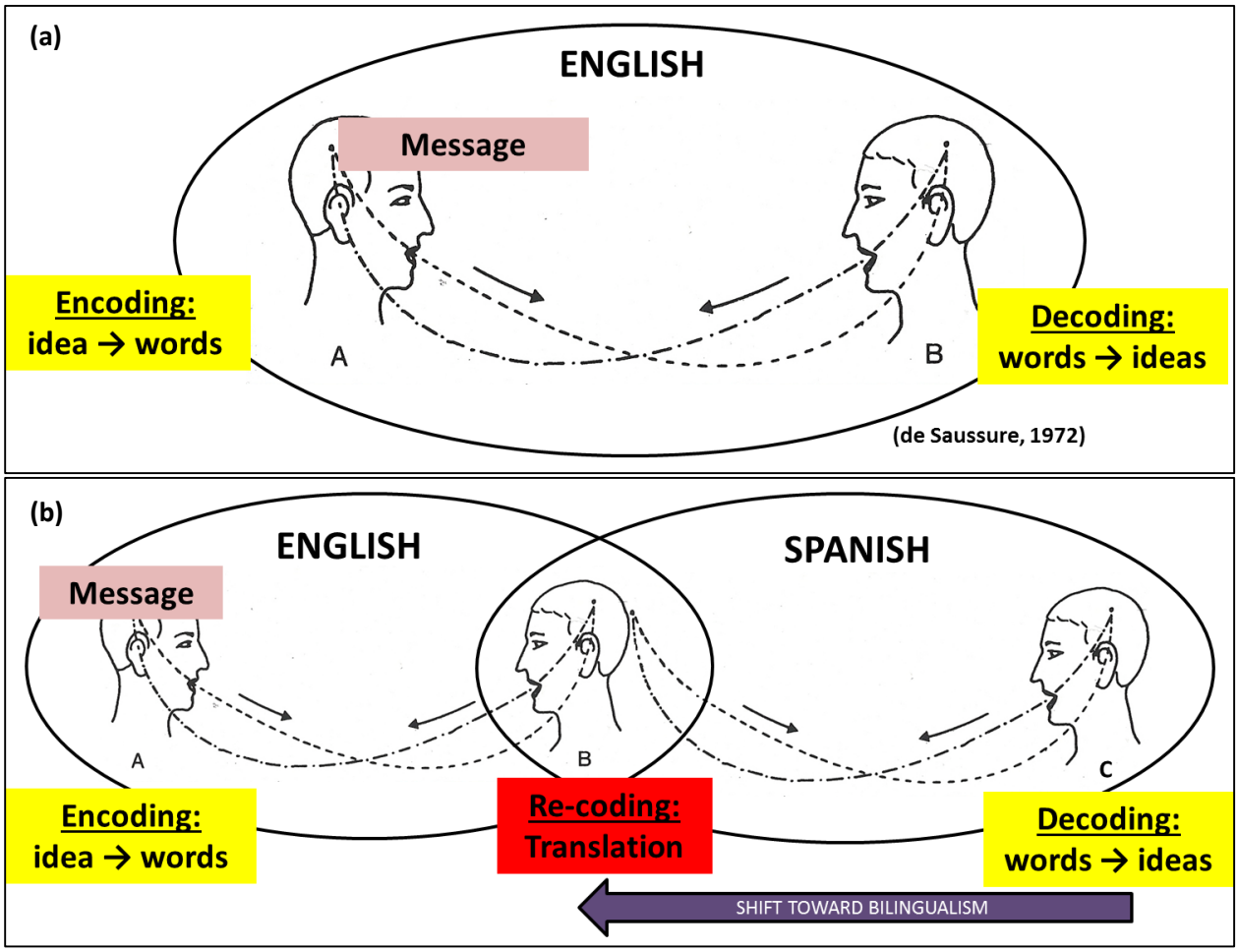

Figure 3. Language as transmission in (a) monolingual communication; and, (b) bilingual communication.

Transmission metaphors for language have been criticized for their lack of theoretical sophistication (Leach, Yates, & Scalon, 2008; Lewenstein, 1995; Logan, 1991) and tendency to reduce science communication to "one-way dissemination," that is, linear and unproblematic flow of a message from a sender to a passive receiver. However, in reality, the receiver is not really passive as s/he needs to actively decode the message being sent. As such, the transmission metaphors neglects the pre-existing knowledge of the receiver, which is formed through the combined impact of their education, their cultural and personal experiences, and the value-system or "frame" in which they live their life. Successful communication requires careful consideration

of the understandings and concerns of the receiver, to ensure that the message has a chance to be received and incorporated into improved understandings. Put differently, language-mediated communication is not simply a matter of unproblematic encoding and decoding. Unlike machines, message transmission by humans encompasses multiple and interrelated dimensions such as cultural, relational, emotional, cognitive, etc. Not taking these many dimensions into account would be ignoring important aspects of how we use language in verbal communication with other human beings.

Language as Action. The above criticism led to the emergence of the toolmaker metaphor (Reddy, 1979), a new paradigmatic perspective wherein language is viewed pragmatically as an instrument purposefully used by speakers to perform social acts (discourse moves). Also known as speech act theory or social pragmatics, this perspective on language emphasizes that the main purpose of language is "doing things" rather than just "saying things" (referring to states of affair in the world). In his seminal book *How To Do Things With Words,* Austin (1962) uses the notion of a "speech act" in reference to what we accomplish (explicitly or implicitly) in saying or by saying something. For instance, by uttering the words "what is a chemical reaction?," a science teacher implicitly performs the speech act of asking a question. A more explicit performance of the same speech act would be "here is my question, what is a chemical reaction?" wherein the teacher now explicitly labels the speech act being performed. Speakers use language to perform a wider variety of social acts (social work), including: asking for help, requesting confirmation or clarification, giving directives, posing questions, declaring opinions, agreeing, disagreeing, thanking, apologizing, challenging others' ideas, building on others' ideas, acknowledging, etc.

From a socio-pragmatic standpoint, linguistic fluency is mainly a matter of being able to use language purposefully and in culturally appropriate ways (according to the social norms of a social group). Acquiring an additional language is mastering a new set of tools, that is, becoming proficient in actively doing things with a new set of words. Further, such a perspective on language is highly consistent with constructivist notions such as "making meaning" wherein content is learned through active language use (i.e., by using language to do things such as arguing, debating, and writing).

Science as a hybrid language

To make the concept of "language" more complicated, Lemke (1998, 2004) suggests that the language of science is a hybrid that includes mathematical expressions, visual representations, and manual-technical operations in addition to natural language. Extending the concept of the "language" that is needed in science classrooms to include three more ways of communicating and of making meaning of experiences also extends the complexity of helping emerging bilinguals negotiate science.

Lemke (2004, 2013) introduces the idea that mathematical expressions and symbols are important as components for meaning-making in science. He further explains the historical need for scientists to move toward more precision in communication. From this point of view, students must be able to move from the typology (large categories) that can be expressed in natural language to the topology (degrees) that can be expressed mathematically and back again. They must be able to 'read' the symbols just as they would read the words in a natural language sentence. The symbols include operational (+,-,%, $\sqrt{}$, $\sum$,), rational (<, >, =, $\neq$), nominal ($\Diamond$, $\circ$, $\measuredangle$, $\llcorner$, r), numerical (1, 2, X, π), and signal ($\forall, \therefore, \because, \Rightarrow$) and are used to create 'sentences'. However, mathematical thinking is

more than just knowing the symbols. It also includes being able to express ideas as numbers, graphs, and charts as both output and input.

Visual representations, such as pictures and drawings, play an important role *for* learning (receptive) and *of* leaning (productive) (Ford, 2008; Waldrip, Prain, & Carolan, 2010). Textbooks are filled with visuals and students are expected to translate and transform knowledge as they move between and among representation. In addition, ELLs must learn which visual representations are appropriate for specific kinds of communication. For example, is the visual a bird's eye view (from above) or worm's eye view (from below) be best; a photograph or drawing; actual or representational? Just as with natural language and mathematical expression, students must be taught how to 'read' the visuals and when/how to use them.

Manual-technical operations also function as mechanisms for making meaning and for expressing meaning. Of the four components of the hybrid language of science, this is least theorized and researched. The important ideas included bodily movement and interaction with tools within the context of scientific meaning-making. Manual-technical helps move science discussions away from surface-level, fun, hands-on activities to more in-depth, situated practices (Weinburgh & Stewart, 2015) that involve ELLs. Authentic involvement with the tools develops new scientific knowledge as it grants access to the community of science. Additionally, becoming scientifically literate includes the physical as well as the dialogic. The physical process may take many forms from donning particular safety gear to the manipulation of highly specific tools.

This Special Issue

Language is conceived in varied ways by authors in this special issue. In their study of the integration of secondary science and foreign language in a navy boarding school in Brazil, Finardi, Silveira, and Alencar conceive of English as a "vehicular language" through which science content can be delivered to speakers of other languages. In close alignment with the conduit metaphor, such a conception of language as a vehicle presumes metaphoric traveling and delivery of ideas by a carrier (words). Content delivery is ensured by building vocabulary in the target language. A similar metaphoric conception is held by Lew who views high-school teacher training in ESOL as provision of "effective delivery models" (i.e., language pedagogies). ESOL training not only enables effective delivery of science content but also has an impact on teachers' professional identities. Both programs describe in-service teacher professional development.

Underlying other articles is a "labelling system" metaphor wherein the language of science is treated mainly as a resource for precisely naming parts of the world. This perspective is particularly evident in the article by Smith-Walters, Bass, and Mangione who argue that pre-service science teachers need to be equipped with vocabulary-building strategies in order to become prepared to overcome the lexical challenges of teaching science to English language learners, namely excessive terminology. Interestingly, Jimenez-Silva, Merritt, Rillero, and Kelly make a distinction between operational vocabulary (needed to introduce classroom activities) and conceptual vocabulary (emergent from science learning experiences). Their article provides a multi-layered, systemic account of a collaborative effort to integrate or "infuse" language acquisition into a pre-service science teacher preparation program in the US. For these authors, science content acquisition in a second language is largely a matter of promoting vocabulary

attainment through pedagogical strategies such as collaborative talk in small groups and problem-based learning.

In sharp contrast, the remaining articles have theoretical underpinnings rooted in the metaphorical notion of language-as-action, and as such treat the language of science as a resource for doing things (as opposed to labelling the world). Drawing on current US policies (NGSS and CCSS) and scholarly work in education, Cheuk proposes that second language acquisition can be supported through scaffolded engagement in interdisciplinary argumentation from/with evidence. Arguing, Cheuk posits, provides language learners with opportunities to engage in more authentic dialogue in the target language and to perform a wider variety of acts other than the E (Evaluation) of IRE sequences. Two articles from Brazilian scholars address Content and Language Integrated Learning (CLIL) which is grounded in the idea that the relationship between language (text) and content (focus of the text) are interwoven to the point of being inseparable. For Lombardi, Mendes, and Salgado, communicative action involves harmonious and purposeful deployment of fragments of language or "translanguaging." Their study of integration of science content and foreign language instruction in a Brazilian classroom reveals expansion of elementary students' communicative repertoires (i.e., increased ability to combine and hybridize multiple languages) rather than mastery over a second linguistic entity that is stable and completely distinct from students' first language. Similarly, Concario uses the notions of *languaging* and *to language* (as action verbs), also emphasizing language as doing, in this case speaker performance of communicative acts such as reporting content learned. His study of low performing, fifth- and sixth-grade students in Brazilian public schools reveals varied levels of ability to verbalize their experiences learning content (i.e., *to language* content). Likewise, Casenove and Kirk conceive of language learning in terms of students' acquisition of the ability to perform particular acts in writing, namely composing Introduction and Discussion sections with appropriate use of hedges when reporting scientific experiments. Their examination of a corpus of scientific reports written by English learners at a Japanese University focus specifically students' emergent ability to express uncertainty when communicative the tentative nature of science in a second language. Lastly, Griffith, Faggella-Luby, Silva, and Weinburgh treat second language acquisition in terms of retelling action (the ability to orally perform acts of recounting informational science tradebooks). Their study is focused on assessing the levels of reading comprehension and conceptual understanding of immigrant and refugee students in the US who participated in a summer program. These articles are consistent with work of language scholars such as Cohen (2005) who argues that learning a second language is more than mastering vocabulary and grammar. The language learner also needs to acquire the social pragmatics of the second language (i.e., learn how to perform social acts such as asking a question, making a claim, responding, and rebutting in contextually appropriate ways). Becoming a competent social actor takes priority over mastery of vocabulary and grammar.

Together, the above articles illuminate the multifaceted nature of teaching and learning at the intersection of science and language. They highlight the need for more careful consideration to be given to our assumptions about language acquisition and conceptual development, as well as increased recognition that language is paramount to the enculturation of students into scientific thought. As Oliver Wendell Holmes poetically argues, "language is [after all] the blood of the soul into which thoughts run and out of which they grow."

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