The Next Generation Science Standards, Common Core State Standards, and English Learners:
Using the SSTELLA Framework to Prepare Secondary Science Teachers

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Introduction

This article focuses on a critical issue in STEM education: preparing novice secondary school teachers to provide effective science instruction to the rapidly growing population of students from language minority groups who traditionally have been underserved in STEM education and who are underrepresented in STEM degrees and careers (National Academy of Sciences [NAS], 2010; Oakes, Joseph, & Muir, 2004). This issue is both salient and timely. With the coincidence of the implementa-

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tion of the Common Core State Standards [CCSS] (Common Core State Standards Initiative, 2010) in English language arts and mathematics and the recently released Next Generation Science Standards (NGSS; Achieve, 2013), science teachers and teacher educators alike are faced with new challenges in regard to the integration of authentic scientific and literacy practices in science classrooms. Moreover, the convergence of the NGSS and the CCSS around the productive use of language in authentic contexts represents a major shift in the role of language in all areas of instruction (Lee, Quinn, & Valdés, 2013). We present an instructional framework (Secondary Science Teaching with English Language and Literacy Acquisition [SSTELLA]) that reflects the reciprocal and synergistic relationships among science, language, and literacy. We argue that this integrated model can be infused into secondary teacher preparation in ways that lead to improved teacher practice in terms of teaching English learners (ELs) and improved student achievement in science.

EL Access to Rigorous Science and English Language Development

ELs are the fastest growing sector of the school-age population, yet they also have the least access to the core academic curriculum (Genesee, Lindholm-Leary, Saunders, & Christian, 2005; Janzen, 2008; U.S. Census Bureau, 2010), and their achievement in science and literacy has lagged behind that of native English speakers for over 30 years (Lee & Luyxk, 2006; National Center for Education Statistics [NCES], 2011; Rodriguez, 2010). Further, gaps in achievement increase from elementary school to secondary school (NCES, 2011). Thus, it is not surprising that ELs are underrepresented in STEM degrees and careers and are less likely to perceive science subjects as relevant to their lives outside of school (Buxton, 2006). At the core of the problem is the assumption that ELs need to be proficient in English before being introduced to more rigorous instruction in the content areas (Met, 1994). This is problematic because it may take as long as seven years for these students to acquire a level of language proficiency comparable to native speakers (Collier, 1989; Cummins, 1981; Hakuta, Butler, & Witt, 2000). ELs fall behind academically if they do not learn the content of the curriculum as they acquire English. This problem is exacerbated by the elimination of specialized sheltered and bilingual instruction programs designed to provide ELs with access to content instruction in those states with the highest populations of ELs (Markos, 2012). Therefore, ELs are mainstreamed via a “sink or swim” approach, as they are placed in classrooms, including science classrooms (Business-Higher Education Forum [BHEF], 2006;

California Council on Science and Technology [CCST], 2007; Oakes et al., 2004), with teachers who have limited abilities to address their needs in content instruction (Lucas & Grinberg, 2008; Markos, 2012).

A significant body of research on second-language acquisition has demonstrated that contextualized, content-based instruction in students' second language can enhance the language proficiency of English learners with no detriment to their academic learning (Cummins, 1981; Met, 1994; Stoddart, Solís, Tolbert, & Bravo, 2010; Thomas & Collier, 2012). The subject matter content provides a meaningful context for the learning of language structure and functions, and the language processes provide the medium for analysis and communication of subject matter knowledge. Inquiry science, therefore, is an excellent context for learning language and literacy.

Integrating the teaching of science content with the development of English language and literacy through contextualized science inquiry has been consistently shown to increase ELs' achievement in both science and in the development of academic language and literacy (Bravo & Garcia, 2004; Echevarria, Vogt, & Short, 2012; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; Rivet & Krajcik, 2008; Rosebery & Warren, 2008; Stoddart, 2005; Stoddart, Pinal, Latzke, & Canaday, 2002). These advances in the knowledge base on teaching science and English language and literacy to ELs are consonant with the discourse about the development of NGSS, as well as the CCSS for English Language Arts (ELA). The ELA reading and writing standards for literacy in science and technical subjects require that students engage with technical (e.g., lab reports, scientific research articles) and non-technical (e.g., newspaper articles, letters to the editor) texts that are discipline specific by writing arguments, translating written information into visual forms (e.g., tables, graphs), and comparing/contrasting findings presented in various sources.

Similarly, the NGSS represents a major shift from the focus of scientific literacy as decontextualized content and process knowledge toward scientific literacy as the productive and integrated use of science language with science content while simulating what scientists do (e.g., plan investigations, develop models, argue from evidence). The NGSS, based upon the National Research Council (NRC; 2012) report, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, identifies core science ideas and cross-cutting themes that students could learn in more rigorous and relevant ways as they progress through their K-12 science education (NRC, 2012). Further, the Science Framework provides a description of eight scientific and engineering practices that promote not only investigative competence, such as asking questions, planning investigations, and analyzing data, but also representational thinking through the use of models and mathematical relationships. Four of these science and engineering practices are particularly language intensive: developing and using models; constructing explanations (science) and designing solutions (engineering); arguing from evidence; and obtaining, evaluating, and communicating information (Lee et al., 2013).

Therefore, a key issue remains. Few models of science teaching have been articulated in terms of how preservice secondary science teachers can learn to (a) promote authentic scientific discourse practices (Shaw, Lyon, Mosqueda, Stoddart, & Menon, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012), and (b) engage students in rigorous, contextualized learning experiences in linguistically diverse science classrooms (Rodriguez, 2010; Tolbert, 2013). Secondary science teachers generally consider themselves to be teachers of content rather than teachers of language, despite the fact that scientific argumentation, reasoning, and communication require a multitude of specialized written and oral literacy practices (Kelly, 2007; Lemke, 1990; Rodriguez, 2010). The prominent focus of NGSS on productive language use via the identification of language-intensive science and engineering practices has opened up new possibilities for all science teachers to consider the role of language in science and engineering instruction. This change represents a major shift in the way science teachers will be asked to teach in secondary classrooms, particularly in science classrooms with ELs.

Inadequate Science Teacher Preparation

In 2010, a combined report of the National Academy of the Sciences, National Academy of Engineering, and the Institute of Medicine proposed that improving the preparation of STEM teachers in high-need secondary schools with large numbers of minority students was the key to increasing their successful participation in STEM careers and degree programs and should be a national priority (NAS, 2010). However, despite the severity and persistence of the achievement gap between mainstream students and ELs, few teachers receive education in how to teach STEM subjects to students for whom English is not their first language (Ballantyne, Sanderman, & Levy, 2008; Darling-Hammond, 2006; Gándara, Maxwell-Jolly, & Driscoll, 2005). It is not surprising, therefore, that few novice or experienced teachers feel prepared to teach ELs (California Legislative Analyst's Office, 2007-2008; Gándara et al., 2005; NCES, 2001) and that ELs are the group least likely to have a qualified or experienced math or science teacher (BHEF, 2006; CCST, 2007). Each year, thousands of new teachers enter the profession feeling underprepared to teach this rapidly growing student population (Ballantyne et al., 2008).

The challenge for teacher educators is to prepare teachers to teach ELs by integrating rigorous science instruction with the development of English language and literacy. However, most teacher education programs do not provide such preparation. Courses on subject matter teaching typically give little attention to the importance of valuing and incorporating the linguistic needs and cultural experiences of the students who are being served (Godley, Sweetland, Wheeler, Minnici, & Carpenter, 2005; Trent, Kea, & Oh, 2008). Issues related to cultural and linguistic diversity, when taught, are presented in separate courses that often focus on social conditions and not on discipline-specific pedagogy (Trent et al., 2008). What is needed is the development of teacher education programs that provide explicit instruction, modeling, and coaching of integrated pedagogy, which show preservice teachers the how and why of integrating the development of academic language and literacy into the teaching of rigorous science content.

From Elementary to Secondary Science Teacher Preparation for ELs

Prior research on professional development with experienced and preservice teachers has demonstrated that teachers can be prepared to use an integrated pedagogy and that teachers' use of this approach improves the achievement of ELs in science, language, and literacy (Bravo & Garcia, 2004; Bunch, 2013; Ku, Bravo, & Garcia, 2004; Ku, Garcia, & Corkins, 2005; Lee et al., 2008; Shaw et al., 2013; Stoddart, 2005, 2013; Stoddart & Mosqueda, in press). For example, in our previous research project, *Effective Science Teaching for English Language Learners* (ESTELL), we restructured elementary science methods courses at three different university sites (Stoddart et al., 2010). The core intervention focused on engaging novice elementary teachers in personal learning experiences of science through integrated science content/science methods lessons. The preservice teachers then used an ESTELL lesson plan template to design and implement science lessons during their student teaching in classrooms with ELs and received coaching and support from an ESTELL-trained mentor teacher. We found that the ESTELL intervention (a) more effectively prepared elementary student teachers to use integrated science-language pedagogy with ELs as compared to a control group of student teachers in a "business as usual" teacher education program (Stoddart, Bravo, Solís, & Mosqueda, 2011; Stoddart, Bravo, Solís, Stevens, & Vega de Jesus, 2009); and (b) improved ELs' science learning, including science writing, in the classrooms of ESTELL first-year teachers at the same rate as for the non-ELs (Shaw et al., 2013; Stoddart, 2013; Stoddart & Mosqueda, in press). We built upon this research to develop a framework for preparing *secondary* science teachers to teach ELs.

Differences between Elementary and Secondary ELs

As the content gets more specialized and advanced in the transition from elementary to secondary school, there is even more of a need for the conceptualization and operationalization of English language support and opportunities for development for ELs to be embedded in the content areas themselves (Lee et al., 2013). The major transition for older school-age children who are ELs is the transition to varied academic genres as they move through the school system (Bunch, 2013; Lucas & Grinberg, 2008). While this literacy transition is part of the secondary school experience, it is a significantly greater challenge for secondary ELs to engage with varied texts that include the use of technical low-frequency, content-based vocabulary and writing for special purposes while still acquiring English language proficiency. Recognizing the different academic trajectories of these students is important in designing appropriate educational support and teacher training. In this regard, infusing literacy and language instruction across content-area subjects would address the need to explicitly teach academic language tasks authentic to each academic discipline (Bunch, 2013; Janzen, 2008). In addition, while elementary school teachers expect to teach language and literacy, secondary school teachers do not (Stoddart et al., 2002). Our current project, based on a framework described next, engages secondary preservice teachers in an in-depth analysis of the academic language and literacy demands of secondary science instruction and the specific strategies needed to scaffold and contextualize academic science language, literacy, and discourse.

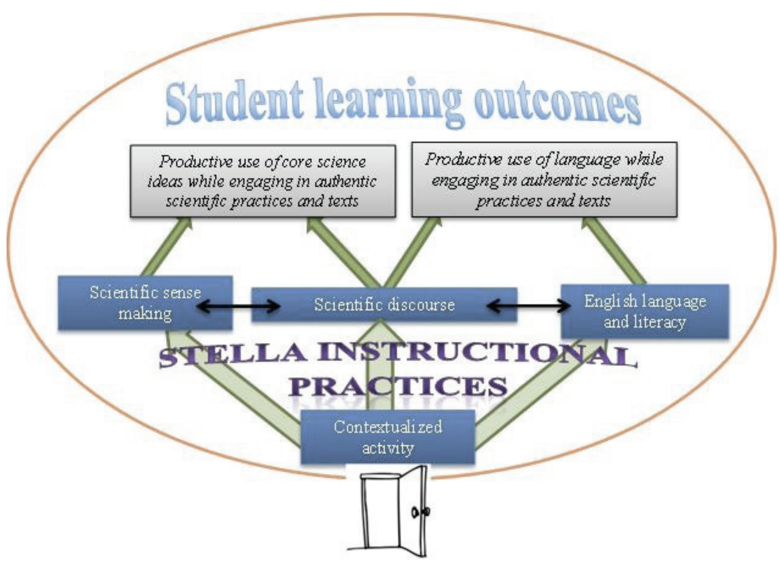
The SSTELLA Framework: Synergistic and Reciprocal Relationship between Language and Science for Secondary Teachers

The SSTELLA framework provides a much-needed response in science education to the many challenges that secondary school ELs face. SSTELLA is a framework for addressing inadequate teacher capacity for improving ELs' science achievement by advancing research-based instructional practices in the classroom. August and Hakuta (1997) reported that extending existing theories and methodologies of content area learning and second-language literacy are the highest research priorities for improving the schooling for language-minority children as they move across the curriculum. One reason cited is that attention to language instruction has often been foregrounded over content learning for ELs (August & Hakuta, 1997; Echevarria et al., 2011).

SSTELLA reflects principles from the Science Framework and is designed to prepare teachers to effectively integrate science, language, and literacy instruction for ELs by promoting the productive use of science language in authentic contexts, whereby "students are supported in using multiple resources and strategies for learning science and developing English" (Lee et al., 2013, p. 229). The SSTELLA framework is represented visually in Figure 1 to highlight the relationships among the four SSTELLA practices and anticipated student learning outcomes.

The framework views contextualized science activity (the "doorway") as the gateway through which ELs can come to understand relationships between school science learning and their lived experiences outside of schools. Teachers promote scientific sense-making, scientific discourse, and English language and literacy development through these contextualized learning experiences. Science content and language then intersect as students, for example, construct oral and written explanations and engage in argument from evidence (Cheuk, 2012; Lee et al., 2013), two

Figure 1
SSTELLA Framework



practices that echo CCSS for English Language Arts. Thus, the relationship between science learning and English language and literacy development can be viewed as reciprocal and synergistic. Through the *contextualized* and *authentic* use of language in scientific practices, students develop and practice complex language forms and functions. Simultaneously, through the use of language functions such as explanations and arguments in science investigations, students make sense of abstract core science ideas and enhance their conceptual understanding as well as understanding of the nature of science (Driver, Newton, & Osborne, 2000; Stoddart et al., 2002, 2010).

The four interrelated SSTELLA practices mediate two primary student learning outcomes. First, students use core science ideas (e.g., the cycle of matter and energy transfer in ecosystems) while engaging in authentic scientific practices and texts. They may be carrying out and reporting on an investigation related to ecosystems or using double-entry journals (Gomez et al., 2010) as a reading-to-learn strategy in an online article that provides a description of the uses of alternative energies. Second, students will productively use language while engaging in authentic scientific practices and texts: Instead of just paying attention to the science "content" while carrying out an investigation and reading an online article, the students also communicate a well-structured explanation for their investigation and identify, with supporting evidence, the tone and primary audience of the online article.

SSTELLA Instructional Practices

Scientific sense-making through scientific/engineering practices. Scientific sense-making refers to how students negotiate everyday and scientific ways of knowing, while developing increased awareness of the nature and practices of science via engagement in scientific/engineering practices. Scientific sense-making is enhanced when teachers make explicit to students what they are to learn (i.e., a "big idea"), make connections between the big idea and classroom activity and prior knowledge or experiences (August & Hakuta, 1997; Kelly, 2007; Rivet & Krajcik, 2008), and make students aware of how they will demonstrate mastery of the big idea (i.e., the learning objective; Wiggins & McTighe, 1998). Students can better relate to the big idea when it is couched within a puzzling question, ill-defined problem, and/or model-based inquiry (e.g., student development, refinement, and/or use of models; NRC, 2012; Passmore & Stewart, 2002; Windschitl et al., 2012). Expectations and classroom rigor for ELs are maintained through deliberate and sustained scaffolding (Walqui & van Lier, 2010), which may include modeling of instruction, graphic organizers, visual representations, realia, and use of technology.

Scientific discourse through scientific/engineering practices. Developing a coherent understanding of science requires that students learn how science knowledge is constructed, presented, and shared through specialized scientific *oral* and *written* language forms, i.e., the discourse of science (Graham & Perin, 2007; Kelly, 2007; Pearson, Moje, & Greenleaf, 2010; Snow, 2010; Veel, 1997). This can occur through students' use of scientific/engineering practices, whereby students are exposed to and encouraged to engage with disciplinary specific uses of language (e.g., scientific discourse), such as communicating scientific explanations and arguments, and engineering solutions. These forms of oral discourse promote conceptual understanding, investigative competence, and an understanding of the epistemology and social nature of science (Driver et al., 2000). Scientific discourse is, in itself, a social and collaborative practice that can help students make sense of both science concepts and develop language (Kelly, 2007; Lemke, 1990).

English language and literacy development. Scientific genres are characterized by dense clauses, technical and general academic vocabulary, and the use of the passive voice (Pearson et al., 2010; Snow, 2010). To become independent consumers and producers of science knowledge, students need to be able to both comprehend and use scientific discourses, with attention not only to technical science vocabulary but also to general academic words and English language structures commonly used in science (August, Carlo, Dressler, & Snow, 2005; Snow, 2010). In secondary schools, however, all students, particularly ELs, face both (a) an increase in complexity of language genres and registers associated with disciplinary reading, writing, speaking, and listening (Scarcella, 2003); and (b) a decrease in authentic content learning opportunities (Bruna & Gomez, 2008). English learners can engage in authentic literacy practices that promote both content learning (e.g., core science ideas) and language and literacy development (Krajcik & Sutherland, 2010; Pearson et al., 2010). Targeted comprehension, composition, and vocabulary development strategies can support ELs in understanding and communicating complex science concepts (Rodriguez, 2010). Some of these strategies include reciprocal teaching (Palinscar & Brown, 1984), annotation and summarization (Gomez et al., 2010), and interactive science notebooks and writing heuristics as well as non-traditional writing activities (e.g., blog entries, letters; Hand, Prain, Lawrence, & Yore, 1999; McDermott, 2010; Wallace, Hand, & Prain, 2004; Weiss-Magasic, 2012) and a focus on process-oriented writing skills (Graham & Perin, 2007; Olson et al., 2010). Vocabulary development can be supported through the use of word walls, facilitating word consciousness/analysis, and providing repeated exposure to and multiple opportunities to use new words (August et al., 2005).

Contextualized Science Activity. Finally, a key aspect of supporting ELs in learning academic content is the incorporation of their cultural and linguistic background into classroom learning experiences; these experiences should be not only rigorous but also meaningful and relevant. Teachers and schools often have positioned underserved ELs as deficient and in need of remediation prior to engaging in rigorous coursework, which essentially sets students up for failure before they even step foot into a secondary science classroom (Oakes et al., 2004). Teachers must understand that ELs are quite capable of grappling with authentic and contextualized real-world problems that enhance both language development and conceptual understandings, and they should provide opportunities for them to do so (Lee & Luykx, 2006; Lee et al., 2013; Moll, Amanti, Neff, & Gonzalez, 1992; Rosebery & Warren, 2008). By engaging students in science investigations and engineering design problems in authentic, real-world problems, teachers can leverage students' funds of knowledge from their homes and communities, the local physical (e.g., school building, community center) or ecological environment (e.g., local stream, watershed issues), and/or socio-scientific issues (e.g., stem cell research, sustainability science) as a way to engage ELs in meaningful and rigorous science learning experiences (Rivet & Krajcik, 2008; Rosebery & Warren, 2008). To summarize, the four interrelated instructional practices just described highlight the reciprocal and synergistic relationship between science learning and English language and literacy development. The challenge for teacher educators is to infuse these practices into teacher education programs in ways that support secondary science preservice teachers in learning how to effectively teach science to all students, including ELs.

Infusing SSTELLA into Secondary Teacher Preparation

In this section, we describe how SSTELLA can be infused productively into secondary science teacher preparation. An extensive body of literature has demonstrated that the development of expertise in novice teachers, in both elementary and secondary teacher preparation, is facilitated by engaging them in observation, analysis, and experience with explicit models of the instructional approaches that they are being prepared to utilize (Abell & Cennamo, 2004; Roth et al., 2011) as well as by providing them with opportunities to practice instructional approaches, with intensive feedback, coaching, and support, with the student population whom they are being prepared to teach (Loucks-Horsley, Hewson, Love, & Styles, 1998; Speck & Knipe, 2001). This requires restructuring of the pedagogical model of the teacher education coursework by developing curriculum that engages student teachers with explicit models of instructional practice and establishing coherence among the various components of the teacher education program: coursework, practicum, and supervision (Stoddart, 2013). The first step is to develop explicit instructional exemplars of integrated practice in secondary school classrooms that explain the how and the why to student teachers and to articulate these models into teacher education curriculum materials and practice.

Elementary and secondary teachers, however, also come with different subject matter backgrounds and expectations of what they will be teaching. The preservice secondary teachers in our current SSTELLA project all have majors in the science subject they are preparing to teach: Biology, Chemistry, Physics, or Earth/Environmental Sciences. In contrast, prospective elementary school teachers typically have less science content preparation. Our previous National Science Foundation (NSF) elementary school science teacher preparation project (ESTELL) included a strong emphasis on personal learning of content through extensive content learning experiences through ESTELL pedagogy. In SSTELLA, the emphasis is on using integrated instructional approaches to explicitly scaffold language learning for specific concept learning goals related to NGSS.

Explicit Exemplar of the SSTELLA Integrated Framework

The vignette below was generated by SSTELLA project members (the authors and Joanne Couling, a chemistry teacher, SSTELLA graduate, and student researcher) to demonstrate how a secondary science teacher could integrate the SSTELLA practices into a thermochemistry lesson. The vignette is followed by commentary on how the lesson exemplifies specific elements of SSTELLA instructional practices. We also describe how the vignette, which models SSTELLA practices, can take form in multiple teacher education components: video cases, instructor modeled units, and preservice teacher-developed and -implemented lessons.

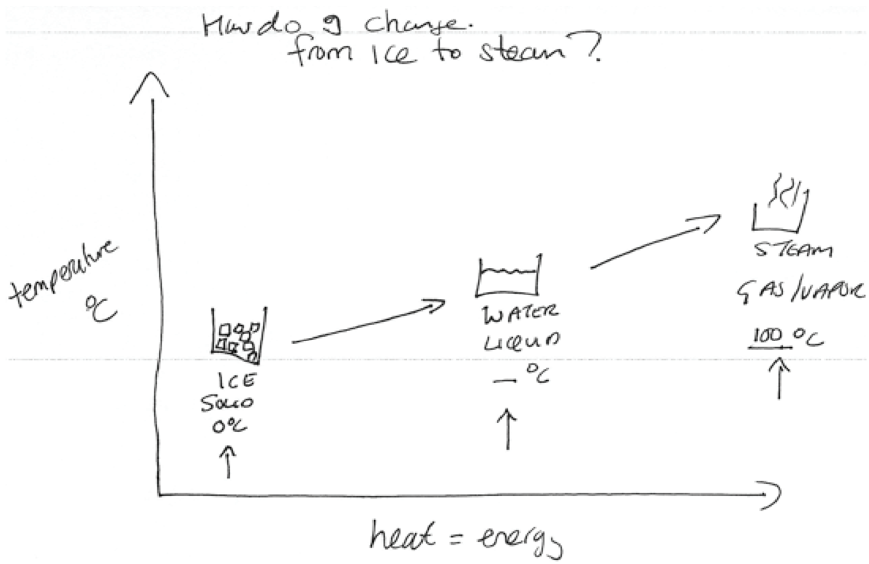
Ms. C is teaching a thermochemistry lesson for tenth and eleventh-grade students, including current and re-designated ELs with varied levels of English language proficiency. The lesson is a midpoint lesson in the Energy topic and builds on physical properties of matter to create a heating/cooling curve model for water that students will later use for energy calculations to apply the mathematical equation $q=mc\Delta T$. In partial preparation for that lesson, students, during this lesson, will "develop and use a model based on evidence to illustrate the relationships between components of a system" (see HS-PS3-2, HS-PS3-5, Science and Engineering Practices, NGSS).

Ms. C begins by introducing the big idea, "How is energy transferred and conserved?" Her lesson today is part of a series of lessons that will help students develop an understanding that the macroscopic scale of energy can be accounted for as "motions of particles or energy associated with the configuration of particles," based on the NGSS *Disciplinary Core Idea* that "energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system and that the total change of energy in any system is always equal to the total energy transferred into or out of the system" (PS3.A). To orient her students toward this learning goal, Ms. C communicates the big idea at the start of the lesson by telling students that they will be looking at the relationship between energy and phase changes for water. Ms. C initiates small group discussions in which students think-pair-share (Gunther, Estes, & Schwab, 1999) about water in different phases in everyday life. Students suggest swimming, water parks, ice-skating, driving on icy roads, gaseous water molecules in the air, and using steam in the home. Ms. C builds on the latter suggestion as a bridge to the remainder of the lesson.

Ms. C uses a document camera to provide visuals that support ELs' understanding of the driving question. She displays the phrase, "Use of steam in the home" and a photo of steam coming up from a teapot. She asks for student suggestions, and they offer "cooking vegetables" and "ironing." One student states, "My mom once used steam to clean a stain on the carpet." Ms. C records these suggestions, then shows students a container of ice cubes: "Let's say I need some steam to clean my carpet, but all I have is this ice. *How could I turn this into steam?*" Students offer: "heat it" and "put it in a pot of boiling water." Ms. C probes further: "How long would it take?" and "What factors might I need to consider?" She makes sure that Juan, an EL, participates (e.g., "Juan, what could you add to what Cindy has just said?") and encourages students to build on each other's ideas using an optional sentence frame as a contextual language support for ELs, if needed (e.g., I think that . . . because . . .). The shared perspectives lead students to generate, collectively, a hypothesized visual model (Figure 2) of the phase changes of water when energy is applied.

Ms. C refines the problem: "We really want to know the *relationship* between energy and temperature in these phase changes. Is the relationship linear?" She writes the question with the doc-u-cam and invites another EL in her class to write the question in Spanish: "*¿Cuál es la relación entre la energía y la temperatura, es la relación lineal?*"

Figure 2
Drawing of how energy is transferred and conserved.

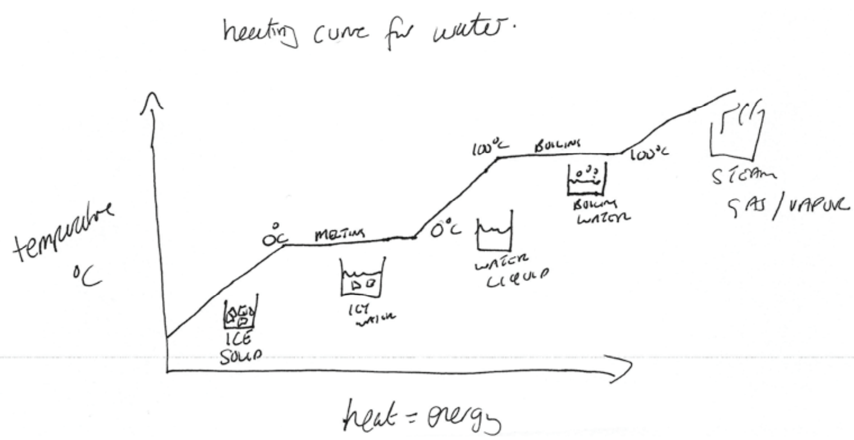


Students record both versions in their science notebook. Cause-and-effect relationships are an important NGSS *Cross-Cutting Concept* (HS. PS.35). Exploring phase changes with students helps them to develop an understanding of the physical properties of water. Students often consider heat and temperature to be analogous; this lesson helps to distinguish heat as a form of energy and temperature as a method of measuring the effects of changing energy. Discovery of the linear/non-linear relationship links to and builds on intermolecular forces and, thus, also builds on the big idea of that topic. The lesson continues with students' working with water, ice, a heating device, and a thermometer in heterogeneous and purposefully grouped teams (by EL proficiency level and class grade) to test the model. Some students observe their ice at a temperature lower than 0˚ C. While walking around the class, Ms. C encourages students in one group to think about what this means for the visual model they have created. The students recognize the need to relocate the position of the first beaker in the diagram. Additional observations lead students to notice that their thermometer stays at 0˚ C while the ice melts.

At the end of the activity, Ms. C again displays an optional sentence frame to help support ELs to construct arguments from the evidence: "I claim that the diagram should really look like. . . . because . . . " She reminds students that they are not required to use the sentence frame but that they must use evidence from their investigation to support any changes to the diagram that the class constructed at the beginning of the lesson. She also reminds students that scientists construct knowledge by making claims that they support with evidence. To further support ELs' new vocabulary development, Ms. C also refers students to the class-generated science word wall and the "student friendly" definitions of *claims* and *evidence* previously recorded in their science notebooks. Moving around the classroom, she asks students to share what they have written and provides feedback on their writing.

Finally, Ms. C uses a cooperative structure, e.g., Numbered-Heads-Together (Kagan & Kagan, 2009), to ensure equitable participation and individual accountability as student groups share their explanations to the whole class, which leads to a discussion about how to amend the initial heating/cooling curve diagram. As Ms. C draws the revised model to match the model the students have developed (Figure 3), she reminds students that models are useful for explanation and for developing understanding and that they can be revised. She then returns to the question of the energy and temperature relationship during phase changes and invites students to share experiences outside the classroom where they can apply their model to their own everyday experiences. Ms. C is careful to incorporate into the discussion the suggestions that students made in the beginning (e.g., water parks, ice-skating). In a follow-up lesson, students will use Reciprocal Reading (Palinscar & Brown, 1984), a collaborative reading-to-learn strategy that has been demonstrated to help students develop more active comprehension of complex text.

Figure 3
Drawing of heating curve for water.



Using this strategy, students work in groups to read scientific studies of related topics (e.g., how water is used to absorb heat from nuclear reactors). Additionally, each year, Ms. C takes her students to a local (within 45 miles) hot springs site, where she helps students apply their knowledge about thermochemistry to a real-world, local context.

Scientific sense-making through scientific/engineering practices. In the above vignette, Ms. C helps students make sense of a natural phenomenon through explicit communication and reflection of a "big idea," driven by an ill-defined problem: "How could I turn this [ice] into steam?" Ill-defined problems involve more than open-ended questions; beyond their having more than one right answer, they are constrained in terms of information presented and the assumptions that need to be made (Fortus, 2008). In this case, students do not have information about what tools to use or principles to draw on while explaining; there is no prescribed path from problem to solution. Often, ill-defined problems connect with some real-world problem or controversial issue that also could have framed the lesson. The collaborative generation of a partial model (first heating/cooling diagram), followed by the testing and refining of the model, presses student engagement in scientific practices, using complex English language functions. At the end of the lesson, Ms. C provides opportunities for students to reflect on how their conceptions have changed, with attention to the big idea, as well as how their work is representative of the work of "doing science" in authentic contexts.

Scientific discourse through scientific/engineering practices. Rather than giving closed evaluations to student responses (Cazden, 1988), Ms. C facilitates productive student talk by eliciting student conceptions and hypotheses throughout the lesson (e.g., how to turn ice into steam) and activating collaborative talk among all students, including the ELs (via, e.g., mixed groups, clear ground rules, wait time), which increases student access to science discourse and concepts. Students develop scientific discourse through discussions with peers and the teacher that promote arguing from evidence (e.g., justifying why they agree/disagree with a peer, supporting claims with evidence from the investigation).

English language and literacy development. Individually and through small groups, Ms. C presses students to explain and discuss/critique their models as well as to produce an authentic scientific text. She scaffolds students' language and literacy development through strategies such as using sentence frames, having students write in science notebooks, drawing upon students' proficiency levels (e.g., L1), and giving targeted feedback (Hanauer, 2006; Lemke, 1990). Sentence frames also are a type of talk that facilitates student elaboration on each other's responses (Maata, Dobb, & Ostlund, 2005). Ms. C provides multiple opportunities for students to use general academic and content-specific vocabulary, e.g., through discussions and written products that emphasize common words, such as "intermolecular forces," "energy," "claim," "evidence," "cause," and "effect." She draws attention to the everyday uses of scientific words such as "heat," "energy," and "temperature" and how the everyday uses of words are often distinct from scientific definitions. The focus on relationships also helps students to better understand the connections between words.

Contextualized science activity. Ms. C contextualizes the science activity by making connections to students' observations of steam in their homes, which she used to extend the lesson by drawing on a specific experience (using steam to clean the carpet). She closes the lesson by once again inviting students to share ways in which they could apply what they have learned, i.e., leverage their experiences as a means to learn complex science content (Moll et al., 1992; Rosebery & Warren, 2008). She also provides opportunities throughout the lesson for students to use their own sense-making and language processes as resources for science learning in school (Lemke, 1990; Rosebery & Warren, 2008). Finally, she helps students to apply their knowledge to a local context during a future trip to a popular hot springs site.

Relevant Program Components for SSTELLA Framework

We see the SSTELLA framework, instantiated in the vignette above, as being most productively infused into two main components of teacher education: (a) a secondary science methods course that models the use of integrated pedagogy, and (b) a field practicum with coaching and support by trained teacher supervisors and cooperating teachers.

SSTELLA Science Methods Course

The SSTELLA science methods course addresses the core content of science methods instruction, i.e., theory and research on secondary science teaching, as well as appropriate state science standards and NGSS. In addition, the course addresses language and literacy integration for ELs, as well as appropriate CCSS for English Language Arts. SSTELLA practices are presented through multiple vehicles: video cases, instructor modeled science-language-literacy integrated units, and preservice teacher-developed and -implemented science-language-literacy-integrated lessons.

Observation and analysis of video cases. The use of video cases is effective in developing novice and experienced teachers' ability to identify, analyze, and use new teaching strategies through focusing their attention on specific classroom events, in this case, the SSTELLA practices (Abell & Cennamo 2004; Roth et al., 2011; Sherin, 2004). Video cases from the classrooms of experienced secondary science-ELL teachers include the detailed footage needed to provide visual exemplars of the four SSTELLA instructional practices. The video cases contain both successful and failed episodes so that novice teachers can discern more-effective from less-effective strategies and transform their own conceptions and practices to approximate those of expert teachers (Ash, 2007; Sherin, 2004). The presented vignette could be an example of episodes shared with preservice teachers and used to promote productive discourse for both individual and collaborative reflection (Sherin, 2004; Zhang, Lundeberg, Koehler, & Eberhardt, 2011).

Application in integrated science units. Informed by units previously developed in the ESTELL project, science methods instructors implement SSTELLA-infused secondary science instructional units that integrate NGSS and CCSS (the previously described vignette might represent one modeled lesson). Throughout the lesson, instructors engage in "meta-talk" to discuss SSTELLA practices and ways to enhance learning for linguistically diverse students. For instance, after the lesson, the instructor might prompt students to reflect on how literacy was integrated throughout, as part of the focal science activities, and consider ways to support language development that would especially benefit ELs.

Development of integrated science lessons. Preservice teachers draw on the modeled video cases and instructional units to develop their own SSTELLA-infused science and engineering activities to be taught in the course and in their student teaching (to be videotaped). The vignette presented earlier exemplifies the type of lesson we would hope to see, even in these novice teachers. The science methods instructor and other students analyze and provide feedback on the lessons using the project-developed SSTELLA Classroom Observation Rubric (SCOR).

SSTELLA Teaching Practicum with Coaching and Support

All SSTELLA students receive coaching and support from the SSTELLA-trained cooperating teacher in whose classroom they are placed and are supervised by a SSTELLA-trained university supervisor who visits them in their classrooms, observes their teaching performance, gives them feedback, and provides a final evaluation. All of the cooperating teachers and teacher supervisors participate in professional development activities whereby they experience and debrief the SSTELLA framework via a sequence of activities that parallel those included in the SSTELLA science methods course. In particular, this includes (a) an introduction to the theory behind language-science integration, (b) participation in SSTELLA lesson activities, (c) study of the SSTELLA framework through analysis of video cases (once again, the vignette reflects the type of practices highlighted), and (d) curriculum analysis (deconstruction and reconstruction) and lesson plan development using the SSTELLA framework. Additionally, cooperating teachers and university supervisors receive training in how to use the SSTELLA rubric for assessing student teachers' performance and providing coaching and feedback.

Next Steps: Researching the Impact of the SSTELLA Framework

Although the SSTELLA framework is grounded in empirical research, we still must determine the impact that it could have on preservice science teachers and their future students. We are currently using the SSTELLA framework in a quasi-experimental longitudinal study[1] at four university teacher preparation programs across the western and southwestern United States. The design calls for us to track two secondary science cohorts at each program (~180 teachers), one during the 2013-2014 academic year and one during the 2014-2015 academic year. The first cohort serves as our baseline control, i.e., teachers who receive no curricular intervention, whereas the second cohort will receive specialized instruction and mentoring focused on the SSTELLA instructional practices. Our theory of change states that *Science Method* instructors' increased implementation (and modeling) of SSTELLA practices will lead to positive changes in preservice secondary teachers' knowledge of SSTELLA practices and beliefs about teaching science to ELs. This, in turn, will lead to increased implementation of SSTELLA practices as student and novice teachers, which will ultimately improve student learning. Thus, we will know whether our framework is effective if we see (a) a significant increase in STELLA-trained teachers' knowledge, beliefs, and practices of teaching secondary science to ELs, as compared to a baseline control group; (b) a relationship between *Science Methods* instructors' fidelity of implementation (FOI) of SSTELLA practices and treatment teachers' knowledge, beliefs, and practices of teaching science to ELs; and (c) a relationship between treatment teachers' FOI of SSTELLA practices and their students' science achievement in the second year of teaching.

We are collecting quantitative and qualitative data from three primary sources. First, we are using a survey that consists of Likert items and open-ended items to track changes in teacher beliefs before their science methods course, at the end of their teacher preparation program, and during their first and second years of teaching. Second, we will follow up with an interview immediately after the administration of each survey to elicit a more nuanced understanding of teacher beliefs that can then be compared to the survey results. Finally, we will observe and videotape teachers four times (twice during student teaching and twice during their first two years of teaching), using SCOR to gather quantitative and qualitative data on how their teaching practices change over time. All three instruments are aligned to the four SSTELLA practices.

In addition to observing the preservice teachers, we are observing the teachers' method instructor at each program site, using SCOR to analyze relationships between what the method instructors do and what the preservice teachers then implement in their classrooms. Finally, for a smaller subset of second-year teachers (both control and treatment), we will administer and analyze student achievement data before and after an instructional unit related to students' productive use of *core science ideas* and *language* while engaging in authentic scientific practices and texts. Thus, we will attempt to measure the impact of implementing the SSTELLA framework through an analysis and comparison of students' science achievement. Our mixed method research design allows for statistical analysis of program impact, as well as a more in-depth qualitative analysis of this impact and changes over time. We anticipate using these findings to refine how preservice secondary science teachers are prepared to teach ELs. For instance, we may find that teachers, and perhaps even method instructions, demonstrate lower levels of implementing contextualized instruction than other practices. We could then adjust our curriculum to address contextualization more intensely.

Concluding Remarks

In this article, we propose a framework, SSTELLA, for developing a preservice teacher education program designed to prepare secondary teachers to integrate the teaching of academic language and literacy with rigorous science content instruction for the rapidly growing population of English learners. Novice teachers benefit from explicit models of integrated instructional practices that use exemplar instructional units and video cases that link the models used in teaching science methods with those in teaching practicum activities. Coherence would be achieved, as preservice teachers receive coaching and feedback while developing integrated teaching practices by expert mentors who themselves have been coached. We see the SSTELLA framework, which builds on the

NGSS and CCSS, as central to this integrated model of preservice secondary teacher preparation.

Although this article has focused on the preparation of teachers to work with ELs, the new standards recognize the critical role that language, literacy, and discourse play in the learning of science for all students. One cannot learn science without also learning the scientific register: the specialized, cognitively demanding language functions, and structures needed to understand, conceptualize, symbolize, discuss, read, and write about topics in academic subjects. Similarly, one cannot *do* science without using scientific tools for sense-making and thinking that are mediated through language. Thus, secondary science teachers also need to understand how ELs and English proficient students benefit from the integration of science with academic language and literacy development.

Finally, although we developed our argument in the context of science, it may extend to other subject areas, such as mathematics and social studies. Students can benefit from learning experiences that enable them to use language functions situated in each of their content areas. The critical points are that language processes promote understanding of content across all subject matter domains, and that language use should be contextualized in authentic and concrete activity. We suggest that, across the United States, where language minority students represent a significant percentage of the school-age population (U.S. Census Bureau, 2010), methods of English language development should be integrated into all elementary and secondary subject matter methods classes and staff development programs. Integrated instruction will assist language minority students in mastering the English language and simultaneously improve their achievement in academic subjects.

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