The Education Trust–West

Science Education for English Language Learners

Annotated Bibliography
Compiled by Camrin Fredrick
for The Education Trust-West

The goal of this annotated bibliography is to identify, summarize, and evaluate resources that address how inquiry-based science aligned with the NGSS and CCSS can be used to further language development for English Language Learners (ELLs). The intended audience for this bibliography is K-12 classroom teachers, district instructional leaders, and administrators. Over 125 articles and papers were reviewed and 26 sources were selected for inclusion. Priority was given to recent articles in peer-reviewed publications that would be of practical interest to teachers and administrators in K-12 education. The papers are organized into three main categories with different audiences in mind.

The first category, *Making the case: why inquiry-based science is a good opportunity for language instruction*, includes two articles that speak to a broad audience about the benefits of integrating science and language instruction for English Learners (ELs) and all students.

The second category, *Best Practices for Classroom Instruction*, is geared for classroom teachers. The articles are organized by grade level (elementary, middle, and high school), and within each group there are sources that discuss instructional strategies as well as sources that provide concrete, classroom examples of the implementation of integrated science and language lessons and units.

The third category, *The Role of Curriculum, Instruction & Professional Development*, is intended for instructional leaders and administrators who are charged with making decisions about curricula to adopt, instructional strategies to prioritize, professional development opportunities for teachers, and policies related to instructional minutes and assessment. The articles included in this section are largely research-based and published in academic journals.

Following the annotated bibliography is a list of other resources of interest to educators who want to implement an integrated approach to science, language, and literacy instruction for ELs. The first group are all Internet-based sources and include: 1) websites for integrated models of curriculum and professional development programs available to districts; 2) free online tools for teachers for integrating science and literacy instruction; and 3) useful sites to reference for additional resources for learning about science instruction for ELLs. The second group of sources includes books and manuals for practitioners on effective science instruction for ELLs.

Following is an outline of the contents of this packet and a chart listing the annotated articles alphabetically.

I. The Literature:

A. Making the case: why inquiry-based science is a good opportunity for language instruction (2)

B. Best Practices for Classroom Instruction

1. Elementary school

a) Instructional strategies (1)
b) Classroom examples (3)

2. Middle school

a) Instructional strategies (2)
b) Classroom examples (2)

3. High school

a) Instructional strategies (4)
b) Classroom examples (2)

C. The Role of Curriculum, Instruction & Professional Development

1. Making the case for an integrated approach to science and literacy for ELLs: What the research says

a) Literature reviews (3)
b) Research studies (5)

2. Research-based instructional practices (3)

3. Professional Development (1)

II. Other Resources

A. Internet resources

1. Integrated science and literacy curricula & instructional models
2. Free tools for teachers
3. Sources for ongoing learning

B. Books and manuals

NOTE:
In the outline above, the number in parentheses indicates the number of sources on that topic.
In the reference below, an asterisk next to the author's name indicates an article that is available for free on the web.

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Table of articles

Below is an alphabetical list of articles included in the annotated bibliography. Checkmarks in the columns to the right indicate whether the articles address that topic.

PAGE NUMBER		ELEMENTARY SCHOOL	MIDDLE SCHOOL	HIGH SCHOOL	INSTRUCTIONAL PRACTICES	CURRICULUM	PROFESSIONAL DEVELOPMENT	POLICY RECOMMENDATIONS	CLASSROOM EXAMPLES	RESEARCH STUDY
19	Ardasheva, Y., Norton-Meier, L., & Hand, B. (2015). Negotiation, embeddedness, and non-threatening learning environments as themes of science and language convergence for English language learners. *Studies in Science Education*, *51*(2), 201–249.	X	X	X	X	X				X
17	August, D., Branum-Martin, L., Cárdenas-Hagan, E., Francis, D. J., Powell, J., Moore, S., & Haynes, E. F. (2014). Helping ELLs Meet the Common Core State Standards for Literacy in Science: The Impact of an Instructional Intervention Focused on Academic Language. *Journal of Research on Educational Effectiveness*, *7*(1), 54–82.		X			X	X			X
18	August, D., Artzi, L. & Mazrum, J. (2010). Improving Science and Vocabulary Learning of English Language Learners. In Center for Research on the Educational Achievement and Teaching of English Language Learners. *Improving educational outcomes for English learners in the middle grades: The CREATE briefs collection* (pp. 19-26). Washington, DC: Center for Applied Linguistics.	X			X	X	X		X	X
12	Bautista, N. & Castaneda, M. (2011). Teaching Science to ELLs, Part I: Key Strategies Every Science Teacher Should Know. *Science Teacher*, 78(3), 35-39.		X	X	X				X	
12	Bautista, N. & Castaneda, M. (2011). Teaching Science to ELLs, Part II: Classroom-based Assessment Strategies for Science Teachers. *Science Teacher*, 78(3), 35-39.		X	X	X				X	

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15	Bradbury, L. U. (2014). Linking Science and Language Arts: A Review of the Literature Which Compares Integrated Versus Non-integrated Approaches. *Journal of Science Teacher Education*, *25*, 465–488.	X				X	X			X
17	Bravo, M. A., & Cervetti, G. N. (2014). Attending to the Language and Literacy Needs of English Learners in Science. *Equity & Excellence in Education: University of Massachusetts School of Education Journal*, *47*(2), 230–245.	X			X	X				X
7	Brown, Z. A. & DiRanna, K. (2012). *Equal Access to Content Instruction: An Example from Science*. WestEd.	X	X	X	X			X		
13	DeLuca, E. (2010). Unlocking Academic Vocabulary. *Science Teacher*, *77*(3), 27–32.		X	X	X				X	
10	Echevarría, J. and Short, D.J. (2009). Using the SIOP Model to Improve Middle School Science Instruction. In Center for Research on the Educational Achievement and Teaching of English Language Learners. *Improving educational outcomes for English learners in the middle grades: The CREATE briefs collection* (pp. 9-12). Washington, DC: Center for Applied Linguistics.		X		X				X	
11	Goldfisher, D., Crawford, B., Capps, D. & Ross, R. (2015). Fossils, Inquiry, and the English Language Learner. *Science Scope*, 78–82.		X		X				X	
11	González-Howard, M., McNeill, K. L., & Ruttan, N. (2015). "What's our three-word claim?": Supporting English language learning students' engagement in scientific argumentation. *Science Scope*, *38*(9), 10–16.		X		X				X	
9	Huerta, M., & Spies, T. G. (2016). Science inquiry and writing for ELLs: A gateway for building understanding and academic language. *Science Activities*, *53*(1), 24-32.	X			X	X			X	

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8	Institute of Education Sciences. (2014). *Teaching Academic Content and Literacy to English Learners in Elementary and Middle School*. U.S. Department of Education.	X	X		X					
10	Jimenez-Silva, M., & Gómez, C. L. (2011). Developing Language Skills in Science Classrooms. *Science Activities*, *48*(1), 23–28.	X			X				X	
19	Lee, O., & Buxton, C. A. (2013). Integrating Science And English Proficiency For English Language Learners. *Theory Into Practice*, *52*(1), 36-42.	X	X	X	X	X	X	X		X
20	Lee, O., & Buxton, C. A. (2013). Teacher Professional Development to Improve Science and Literacy Achievement of English Language Learners. *Theory into Practice*, *52*(2), 110–117.	X	X	X	X		X	X		X
15	Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, 75, 491–530.	X	X	X	X	X	X	X		X
13	Lyon, E. (2016). The antibiotic resistance of MRSA: Teaching natural selection with literacy development for English learners. *Science Activities, 53*(1), 33–47.			X	X	X			X	
16	Maerten-Rivera, J., Ahn, S., Lanier, K., Diaz, J., & Okhee, L. (2016). Effect of a Multiyear Intervention on Science Achievement of All Students Including English Language Learners. *Elementary School Journal, 116*(4), 600-624.	X				X	X	X		X
9	Miller, E., Lauffer, H. B., & Messina, P. (2014). NGSS for English Language Learners: From theory to planning to practice. *Science and Children, 51*(5).	X			X				X	

PAGE NUMBER		ELEMENTARY SCHOOL	MIDDLE SCHOOL	HIGH SCHOOL	INSTRUCTIONAL PRACTICES	CURRICULUM	PROFESSIONAL DEVELOPMENT	POLICY RECOMMENDATIONS	CLASSROOM EXAMPLES	RESEARCH STUDY
13	Nargund-Joshi, V., & Bautista, N. (2016). Which Comes First -- Language or Content?. *Science Teacher*, *83*(4), 24-30.		X	X	X				X	
15	Pearson, P.D., Moje, E., & Greenleaf, C. (2010). Literacy and Science: Each in the Service of the Other. *Science*, *328*(5977), 459–463.	X	X	X	X	X		X		
7	Quinn, H., Lee, O., Valdés, G., (2012). Language demands and opportunities in relation to Next Generation Science Standards for English language learners: What teachers need to know. In Hakuta, K. & Santos, M. (Eds.), *Commissioned Papers on Language and Literacy Issues in the Common Core State Standards and Next Generation Science Standards* (pp. 32–43). Stanford, CA: Stanford University.	X	X	X	X					
12	Sandefur, S.J., Watson, S.W. & Johnston, L.B. (2007). Literacy Development, Science Curriculum, and the Adolescent English Language Learner: Modifying Instruction for the English-Only Classroom. *Multicultural Education*, (Spring), 41–50.		X	X	X				X	
10	Silva, C., Weinburgh, M. & Smith, K.H. (2013). Not Just Good Science Teaching: Supporting Academic Language Development. *Voices from the Middle*, 20(4), 34-42.		X		X				X	
18	Zwiep, S. G., & Straits, W. J. (2013). Inquiry Science: The Gateway to English Language Proficiency. *Journal of Science Teacher Education*, *24*(8), 1315–1331.	X			X	X	X			X
20	Zwiep, S. G., Straits, W. J., Stone, K. R., Beltran, D. D., & Furtado, L. (2011). The Integration of English Language Development and Science Instruction in Elementary Classrooms. *Journal of Science Teacher Education*, *22*(8), 769–785.	X			X	X				X

I. The Literature

A. Making the case: why inquiry-based science is a good opportunity for language instruction

*Brown, Z. A. & DiRanna, K. (2012). *Equal Access to Content Instruction: An Example from Science*. WestEd. Retrieved from: https://www.wested.org/wp-content/files_mf/1372286186EqualAccessforEnglishLearners10.pdf

This article provides a useful overview for a broad audience on the topic of access to inquiry-based science instruction as a matter of equity for English Language Learners. It provides an explanation of what academic language is and its importance as a topic of explicit instruction for ELs along with content area subject matter. The authors make the argument that the study of science is rooted in a particular type of language and thinking that make it a rich opportunity for academic language development. As well, the shift towards more use of non-fiction texts encouraged by the CCSS and the introduction of the NGSS provide further rationale for an integrated approach to science and language instruction for ELs. Research showing positive results of an integrated approach on both science and language learning are highlighted. The article concludes with policy recommendations that: 1) science be restored as a core content area; 2) science be assessed as an accountability measure; 3) new instructional materials that address academic language and science should be developed; and 4) school districts should ensure all students get access to science and that time is provided to do inquiry-based science to develop science understanding and competency in academic language.

*Quinn, H., Lee, O., Valdés, G., (2012). Language demands and opportunities in relation to Next Generation Science Standards for English language learners: What teachers need to know. In Hakuta, K. & Santos, M. (Eds.), *Commissioned Papers on Language and Literacy Issues in the Common Core State Standards and Next Generation Science Standards* (pp. 32–43). Stanford, CA: Stanford University. Retrieved from: http://mes.sccoe.org/resources/ALI%202012/11_KenjiUL%20Stanford%20Final%205-9-12%20w%20cover.pdf#page=44

This article makes the argument that four of the eight key science and engineering practices recommended by the National Research Council's framework for using the NGSS, in particular, create a language rich environment that affords the opportunity for effective language development by ELLs and all students. The four practices discussed are all involved in "sense making" during a scientific inquiry, and they are: developing and using models; constructing explanations and developing designs; engaging in argument from evidence; and obtaining, evaluating and communicating information. The article details the specific types of language development opportunities integral to each of the four scientific practices. Key challenges for ELLs, namely presented by the specific nature of scientific language, are discussed, including: science vocabulary, science discourse, multiple modes of representation, and science texts. The article highlights instructional best practices in the areas of:

1. Literacy strategies for all students (e.g. activating prior knowledge, teaching vocabulary in context, modeling and supporting the use of a variety of academic language functions, requiring and providing multiple models of scientific genres of writing, using graphic organizers, reading thematic literature, providing journal writing prompts);
2. language support strategies with ELLs (e.g. engage students in hands-on, inquiry-based science activities; total physical response; use of realia, modeling, and demonstrations; effective use of journals);
3. discourse strategies (The article stresses the importance of creating an inclusive classroom culture of civil discourse based on argument from evidence in which content not accuracy of expression is the focus, practice and repetition is encouraged, and teachers clearly enunciate, give more wait time, provide multiple examples, repeat and rephrase, and use multiple modes of representation.);
4. home language support (e.g. teacher use of home language for explanations, identifying cognates and false cognates, allowing students to combine home language and English to communicate, and allowing students to write in home language); and
5. home culture connections (e.g. making space for different communication patterns and using cultural artifacts and community resources in instruction).

The articles provides an excellent overview of how best to approach effective instruction of ELLs in the science classroom, however, it does not provide details about how to implement specific strategies in the classroom.

B. Best practice instructional strategies for integrating science and language instruction

<u>Resources by Grade Level</u>:

1. Elementary

a. Instructional strategies

*Institute of Education Sciences. (2014). *Teaching Academic Content and Literacy to English Learners in Elementary and Middle School*. U.S. Department of Education. Retrieved from: http://ies.ed.gov/ncee/wwc/pdf/practice_guides/english_learners_pg_040114.pdf#page=38

This is a DOE published guide presenting evidence-based recommendations for teaching academic content and language development to ELs in grades K-8. It discusses four key strategies that can be using to foster language development across the content areas. The strategies include: 1) intensive instruction in key academic vocabulary across several days using a variety of activities; 2) integrating oral and written language instruction into content-area teaching; 3) providing regular, structured opportunities to develop written language skills; and 4) small-group instructional intervention to students struggling with literacy and ELD. The guide summarizes the research-based evidence for each recommended strategies as well as provides a detailed explanation with examples of how to implement it in the classroom. While this guide does not explicitly focus on science instruction, the strategies recommended are those discussed in several other articles about how best to support ELs' language development in the science

classroom. Many of the instructional examples provided are on science topics. Teachers will find the detailed and concrete tools depicted and explained very useful in figuring out how to translate these practices to their classrooms.

b. Classroom examples

Huerta, M., & Spies, T. G. (2016). Science inquiry and writing for ELLs: A gateway for building understanding and academic language. *Science Activities*, *53*(1), 24-32.

This article provides a detailed picture of how to implement an integrated science inquiry and writing lesson on plants for Kindergarten ELLs that is aligned with national standards. The author discusses the usefulness of this approach in building students' conceptual science understanding and academic language simultaneously. The article includes the detailed lesson plan used, which was designed based on the 5-E science inquiry model (i.e., Engage, Explore, Explain, Elaborate, Evaluate), along with sentence stem/scaffolds used for each stage of the inquiry process. The lesson involves student use of science notebooks, and the article includes photos of students' entries in their journals. The teacher-author describes how she planned the lesson, previous instruction to build students' background knowledge, what she said and did for each part of the lesson, how students responded, and suggestions for extension activities. Also included and discussed is a teacher-created formative assessment framework for evaluating students' science notebooks that involves recording a student's science knowledge, academic language, and English language proficiency skills and identifying the teacher's next move with the student. This article is a very useful read for a classroom teacher wanting a step-by-step breakdown of how to plan, implement, and evaluate an integrated science inquiry and writing lesson for ELLs.

*Miller, E., Lauffer, H. B., & Messina, P. (2014). NGSS for English Language Learners: From theory to planning to practice. *Science and Children*, *51*(5). Retrieved from http://nstahosted.org/pdfs/ngss/resources/201401_NGSS-MillerLaufferMessina.pdf

The teacher-author describes her experience teaching evidence-based scientific argumentation to her 2nd/3rd grade class with a high percentage of ELLs. Students conducted investigations to explore the relationship between the organisms above ground and the below-ground system. The author explains the difficulties she initially encountered getting students to challenge each other's claims and evidence, rather than just agreeing with each other. To address the problem, she utilized the NGSS to develop specific content and language goals and developed better language supports to support students in the practice of scientific argumentation. The author provides a detailed description of the scaffolds she used to effectively support whole-class and partner dialogue to each a more rigorous level of scientific argumentation. She describes an extension activity and includes a link to a rubric.

This same teacher-author, Emily Miller, drew from her classroom teaching experience with 2nd and 3rd grade ELLs to write the vignette for the NGSS case study of how to use research-based

practices to engage ELLs with the NGSS. To read more, see: http://ngss.nsta.org/case-study-4.aspx

Jimenez-Silva, M., & Gómez, C. L. (2011). Developing Language Skills in Science Classrooms. *Science Activities*, *48*(1), 23–28.

The author describes the use of the "mode continuum" (Gibbons 2002) to integrate science and writing instruction, with a specific focus on its effectiveness for ELLs. The article explains how the process moves students from talking to writing about a science inquiry. The mode continuum involves four key phases: 1) students doing experiments in small groups using their current vocabulary and prior knowledge of the topic; 2) the teacher introducing key scientific vocabulary to small groups; 3) the teacher facilitating student report outs on their learning to the whole class; and 4) students reflecting on their learning through journal writing. An example of a lesson on gravity implemented with a 4th/5th grade class is described in detail. The article includes excerpts of teacher and student talk, a student journal, and a question framework for assessing writing.

2. Middle School

a. Instructional strategies

Silva, C., Weinburgh, M. & Smith, K.H. (2013). Not Just Good Science Teaching: Supporting Academic Language Development. *Voices from the Middle*, 20(4), 34-42.

The authors are science, math, and language educators who have collaborated to develop an integrated science and literacy curriculum that addresses the academic language needs of ELLs within a middle school inquiry-based science classroom. The unit structure is explained with detailed descriptions of the strategies used and accompanying student work samples. Some of the strategies discussed include: use of an academic vs. everyday language word wall to make discourse expectations explicit, teaching vocabulary explicitly after the science experience, introducing features of science texts such as the use of 3rd person and lexical density, teaching mathematical expression and visual representation as part of the hybrid language of science through "book walks," and student production of digital storytelling and written texts to reflect on and demonstrate their learning. The authors recommend teacher collaboration, such as theirs, between language and content areas in order to develop authentic ways to explicitly teach the academic language features that best serve each discipline.
https://secure.ncte.org/login/?lr=3&RootUrl=http%3a%2f%2fwww.ncte.org&ft=1&ReturnURL=%2flibrary%2fNCTEFiles%2fResources%2fJournals%2fVM%2f0204-may2013%2fVM0204Not.pdf (free for NCTE members) https://secure.ncte.org/store/2013-may-voices-from-the-middle-v20-4 (for purchase)

*Echevarría, J. and Short, D.J. (2009). Using the SIOP Model to Improve Middle School Science Instruction. In Center for Research on the Educational Achievement and Teaching of English

Language Learners. *Improving educational outcomes for English learners in the middle grades: The CREATE briefs collection* (pp. 9-12). Washington, DC: Center for Applied Linguistics. http://www.cal.org/create/pdfs/create-briefs-collection.pdf

This brief provides an overview of the SIOP model with examples of how to implement it in a middle school science class. The authors highlight: 1) how to formulate language objectives; 2) instructional strategies for teaching vocabulary; 3) a classroom activity for fostering student-student talk; and 4) a creative structure for review and assessment of vocabulary at the end of a lesson.

b. Classroom examples

*Goldfisher, D., Crawford, B., Capps, D. & Ross, R. (2015). Fossils, Inquiry, and the English Language Learner. *Science Scope*, 78–82. Retrieved from: https://www.nsta.org/exhibitsadv/2016MediaKit/Sample_PDF/Scope_Summer2015_complete.pdf

The teacher-author describes a lesson she taught to her linguistically diverse, beginning level ELL 7th graders that incorporates ELL language acquisition strategies. The lesson was part of a two-week long inquiry-based fossil investigation aligned to NGSS. The author describes six different ELL instructional strategies she used including: 1) paired and cooperative grouping; 2) referencing background and prior knowledge; 3) supportive visual references; 4) demonstrating techniques; 5) explicit academic vocabulary instruction; and 6) hands-on investigation. The author identifies previous units she taught to build her students' background knowledge, provides suggestions for how to adapt this lesson to the observations of other natural objects, and discusses how she assessed students. The article includes a detailed description of teacher and student moves within the lesson that provides a concrete picture of how to implement this or a similarly structured lesson. An extensive list of resources is provided for educators who want to implement this lesson.

*González-Howard, M., McNeill, K. L., & Ruttan, N. (2015). "What's our three-word claim?": Supporting English language learning students' engagement in scientific argumentation. *Science Scope*, *38*(9), 10–16. Retrieved from: https://www.nsta.org/exhibitsadv/2016MediaKit/Sample_PDF/Scope_Summer2015_complete.pdf

This article describes instructional strategies used by a 6th-8th grade Sheltered Instruction science teacher to engage her students in scientific argumentation during a lesson on antibiotics and bacteria. The lesson is part of the *Amplify Science* curriculum created by Lawrence Hall of Science. The article includes a chart identifying a comprehensive set of instructional strategies categorized by purpose (e.g. comprehension, production) and type (e.g. talking, writing. The article provides a detailed description with classroom examples of three particular strategies used, including: 1) discussing the meaning of a keyword or phrase related to argumentation (in this case, "relevant"); 2) doing a think-aloud to model appropriate language to use during a task

(in this case, a card sorting activity); and 3) simplifying a complex claim by identifying concepts using a three-word summary strategy.

3. High school

a. Instructional strategies

*Bautista, N. & Castaneda, M. (2011). Teaching Science to ELLs, Part I: Key Strategies Every Science Teacher Should Know. *Science Teacher*, 78(3), 35-39. Retrieved from: http://static.nsta.org/files/tst1103_35.pdf

This article is geared for secondary science teachers who want an introduction to how to approach teaching science to ELLs in a heterogeneous classroom. Key strategies for planning and implementing science instruction are briefly described and illustrated with concrete examples from the classroom. Planning strategies include: 1) identify students' language proficiency levels; 2) identify explicit language objectives aligned with content objectives; and 3) create a link between students' background knowledge and science instruction. Key strategies for science instruction include: 1) provide comprehensible input and opportunities for students to practice producing language in writing and orally; 2) structure collaborative learning in partners or small groups (with lower proficiency ELs paired with speakers of their native language and higher proficiency ELs paired with proficient English speakers); and 3) use performance-based assessments to give ELs multiple opportunities to demonstrate their science learning rather than traditional assessments which often inadvertently assess students' language proficiency.

*Bautista, N. & Castaneda, M. (2011). Teaching Science to ELLs, Part II: Classroom-based Assessment Strategies for Science Teachers. *Science Teacher*, 78(3), 35-39. Retrieved from: http://static.nsta.org/files/tst1103_40.pdf

The article describes four classroom-based assessment strategies for science teachers. They include: 1) identifying ELLs' language proficiency levels and tailoring assessments accordingly; 2) making the language of the assessment tasks and content accessible without lessening rigor; 3) providing diverse and multiple ways for ELLs to demonstrate content knowledge through the use of performance-based assessments, including visual representations such as drawings, charts, and concept maps, or oral presentations; and 4) documenting student growth through the use of portfolio assessments that are evaluated for their demonstration of content knowledge, not language skills.

Sandefur, S.J., Watson, S.W. & Johnston, L.B. (2007). Literacy Development, Science Curriculum, and the Adolescent English Language Learner: Modifying Instruction for the English-Only Classroom. *Multicultural Education*, (Spring), 41–50.

The target audience for this article is secondary science teachers who are looking for an introduction to effective literacy strategies for ELLs in the mainstream science classroom. The authors provide a concise "top 10" list of literacy strategies with brief descriptions and examples

of how to implement them. While not comprehensive of current research, the article does a good job of summarizing strategies effective at supporting reading comprehension for ELLs and struggling readers. The recommendations are in alignment with the Sheltered Instruction approach to learning and include: 1) tradebooks rather than textbooks; 2) simplifying text (not content) with graphic organizers, outlines, etc; 3) building background knowledge prior to reading through hands-on activities; 4) guiding students as they read; 5) teacher think-alouds; 6) supporting students' talk about text; 7) meaningful writing about text; 8) time to read in class; 9) teaching how to identify text structures; and 10) using the language of effective reading comprehension strategies.

DeLuca, E. (2010). Unlocking Academic Vocabulary. *Science Teacher*, *77*(3), 27–32.

This article is geared for science teachers who want to learn specific strategies for teaching academic vocabulary to ELLs. The author provides detailed explanations with examples of how to implement six ESOL text comprehension strategies in the science classroom, including: metalinguistic awareness development, classification activities, semantic webs, visualization, learning logs, and key-points reviews.
http://www.nsta.org/store/product_detail.aspx?id=10.2505/4/tst10_077_03_27 (Free for members; $0.99 for nonmembers)

b. Classroom examples

*Nargund-Joshi, V., & Bautista, N. (2016). Which Comes First -- Language or Content?. *Science Teacher*, *83*(4), 24-30. Retrieved from: http://www.nsta.org/store/product_detail.aspx?id=10.2505%2f4%2ftst16_083_04_24

This article provides succinct explanations of both the 5E (Engage, Explore, Explain, Elaborate, and Evaluate) Learning Cycle for inquiry-based science instruction and the SIOP (Sheltered Instruction Observation Protocol) framework for language instruction, and it identifies where they overlap and differ in their approach. The authors present a three-session lesson on land pollution that integrates the two approaches. The article lists the content and language objectives for the lesson and identifies connections to the NGSS. This article is a useful introduction to the 5E model and SIOP framework for teachers who are unfamiliar with one or both of them and would like a concrete example of how the two approaches can be integrated for a mainstream science classroom with ELLs.

Lyon, E. (2016). The antibiotic resistance of MRSA: Teaching natural selection with literacy development for English learners. *Science Activities, 53*(1), 33–47.

This article provides a detailed example of what an integrated approach to language, literacy, and science using inquiry-based science instruction can look like in a mainstream high school biology class with ELs. It describes a detailed plan for a two-week unit on natural selection that

is organized around the question of "what causes superbugs?" Students construct an explanatory model, using the theory of natural selection, to account for the emergence of MRSA. Students read scientific texts and write their own explanations. The article includes: instructional visuals, graphic organizers, student work, as well as the readings used for students and an assessment rubric for the final written assignment.

The unit was developed in conjunction with the Secondary Science Teaching with English Language and Literacy Acquisition (or SSTELLA) Project. The SSTELLA Project utilizes four key research-based instructional practices that are aligned with NGSS and CCSS for ELA that are effective for ELLs and all students, which include: 1) contextualize science activity - connect to background knowledge, make culturally relevant, connect to real-world issues; 2) promote scientific sense-making through scientific/engineering practices - negotiating ways of knowing through scientific modeling; 3) promote scientific discourse - students participate in argumentation and evidence-based explanation orally and in writing; and 4) promote English language and disciplinary-literacy development - through strategies such as close reads, reciprocal teaching, jigsaw, etc.

C. The Role of Curriculum, Instruction & Professional Development

1. Making the case for an integrated approach to science and literacy for ELLs: What the research says

a) Literature reviews (3)

*Bradbury, L. U. (2014). Linking Science and Language Arts: A Review of the Literature Which Compares Integrated Versus Non-integrated Approaches. *Journal of Science Teacher Education, 25*, 465–488. Retrieved from: http://ci.appstate.edu/sites/ci.appstate.edu/files/Linking%20Science%20and%20Language%20Arts.pdf

This article examines the approaches utilized and impact on student learning and affect of 13 comparative studies of integrated science and literacy instructional interventions at the elementary level over the last 20 years. The author concludes that overall, the research results showed positive outcomes across grade levels for student achievement in both science and reading, as well as positive student attitudes toward both science and reading when students participated in instruction that integrated the two subject areas. The importance of appropriate professional development for teachers and teacher educators on how to implement integrated instruction is highlighted. This is a very useful summary of recent research that makes a strong case for an integrated approach to science and literacy instruction.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, 75, 491–530.

This article is useful to read for district instructional leaders in science. It is a widely cited and comprehensive overview of the research on science education for ELLs as of 2004. It examines the research available on the effectiveness of different curricular models, instructional interventions, and assessment practices, as well as the literature on attitudes and beliefs among science teacher about ELLs and the effectiveness of professional development interventions. Lee argues for inquiry-based science and better preparation and professional development for science teachers to effectively teach ELLs.

*Pearson, P.D., Moje, E., & Greenleaf, C. (2010). Literacy and Science: Each in the Service of the Other. *Science, 328*(5977), 459–463. Retrieved from: https://www.researchgate.net/profile/P_Pearson/publication/43299103_Literacy_and_science_Each_in_service_of_the_other/links/5416638b0cf2fa878ad4018d.pdf

The authors discuss how reading and writing can be used as tools to support inquiry-based science and how reading and writing benefit when embedded in an inquiry-based science setting. They then identify challenges preventing large-scale adoption of integrated science literacy instruction. Of particular value to district instructional leaders will be the authors' detailed

descriptions of the various integrated science and literacy curricula available and the research supporting their efficacy. Curricula reviewed include: Concept-Oriented Reading Instruction (CORI) by Guthrie, Guided Inquiry supporting Multiple Literacies (GIsML) by Palincsar and Magnusson, In-depth Expanded Applications of Science (Science IDEAS) by Romance and Vitale, Seeds of Science—Roots of Reading by Cervetti and Pearson, Reading Apprenticeship by Greenleaf, and Textual Tools by Moje. The authors conclude with policy recommendations for teacher preparation, professional development, curriculum development, and assessment.

Pearson, P.D. (2014). *Science and Literacy: Better Together: Each in the Service of the Other* [PowerPoint slides]. Retrieved from: http://www.scienceandliteracy.org/research/pdavidpearson

This is a useful resource for district administrators who may need to develop a presentation to make the case for an integrated approach to literacy and science instruction.

Vitale, M. R. and Romance, N.R. (2010). *Curricular Policy for Advancing School Reform by Integrating Reading Comprehension within Time-Expanded Science Instruction in Grades K-5* [PowerPoint slides]. Retrieved from: http://scienceideas.org/RefDocs/176%20NARST%202010%20Policy%20Powerpoint%20v008%2003-19-2010%20.pdf

This is another useful resource for elementary district administrators to draw from who are preparing a presentation to make the case for an integrated approach to language arts and science instruction.

b) Research studies (5)

Maerten-Rivera, J., Ahn, S., Lanier, K., Diaz, J., & Okhee, L. (2016). Effect of a Multiyear Intervention on Science Achievement of All Students Including English Language Learners. *Elementary School Journal*, *116*(4), 600-624.

The authors discuss the results of a large scale instructional intervention in an urban district that aimed to increase the science achievement levels of all 5th grade students, and ELLs in particular, as measured by a state high-stakes science assessment. The intervention was part of the *Promoting Science among English Language Learners* (P-SELL) study, which uses an inquiry-based, standards-aligned, ELL focused, year-long, 5th grade science curriculum. The study also involved professional development on the implementation of the curriculum for teachers that consisted of 5 days of teacher workshops each of the first 2 years and a 1-day workshop in the third year of the study. Teachers were provided with curriculum guides, class sets of student books, and supplies.

Results of the study showed a positive effect on student science achievement in the 2nd and 3rd years of the intervention, which the authors argue, demonstrate the delayed effect of professional development on student outcomes, which has been substantiated by other studies. The authors conclude that the positive results of this study demonstrate: 1) the effectiveness of a hands-on, inquiry-based science curriculum with embedded English-language development for ELLs - and

all students; 2) the effectiveness with ELLs of rigorous, standards-based curriculum tied to accountability measures; 3) the importance of high-quality instructional materials and supplies; and 4) the importance of professional development that addresses both science content and language development strategies and that involves all teachers, especially those who do not typically volunteer for professional development opportunities.

*A brief discussion of the highlights of this study are available at: http://steinhardt.nyu.edu/site/ataglance/2016/03/science-curriculum-tailored-to-english-language-learners-boosts-student-achievement.html

August, D., Branum-Martin, L., Cárdenas-Hagan, E., Francis, D. J., Powell, J., Moore, S., & Haynes, E. F. (2014). Helping ELLs Meet the Common Core State Standards for Literacy in Science: The Impact of an Instructional Intervention Focused on Academic Language. *Journal of Research on Educational Effectiveness*, *7*(1), 54–82.

This article discusses an experimental research study on the effectiveness of a curricular and professional development intervention (Quality English and Science Teaching 2 - QuEST2) on the academic language development and science achievement among 6th grade ELLs and their English proficient classmates in a high-poverty district with a high-percentage of Latino students and ELLs. The article is geared for an academic audience well-versed in research; however, the explanation of the intervention and discussion of the results is useful for instructional leaders who are deciding what interventions their district should make to increase academic language and science achievement among all students, and ELs specifically.

The intervention involved: 1) a 5E model inquiry-based science curriculum that explicitly addressed academic language needs and included teacher and student guides; and 2) five days of professional development to help teachers use the curriculum as well as biweekly observation and coaching by a mentor teacher. Researchers found that the intervention produced modest gains in both vocabulary and science for student achievement overall, with modest gains for ELLs in academic language but not science achievement. They conclude that their research findings show that real teachers in high-poverty schools teaching science to heterogeneous groups with significant EL populations can successfully integrate science and literacy instruction with no detriment to student content learning and, at a minimum, modest gains in academic language development for all students. They recommend more intensive and sustained professional development for teachers on how to implement strategies for academic language development as well as on science content.

Bravo, M. A., & Cervetti, G. N. (2014). Attending to the Language and Literacy Needs of English Learners in Science. *Equity & Excellence in Education: University of Massachusetts School of Education Journal*, *47*(2), 230–245.

This article presents results of a research study of an integrated science, language, and literacy curriculum called *Seeds of Science, Roots of Reading* that showed a positive impact in science understanding and science vocabulary among 4th and 5th grade ELs in comparison to ELs

exposed to a "hands on" science curriculum. The researchers' premise was that while inquiry-based science does provide an opportunity for rich language instruction, it requires teachers skilled in how to take advantage of that opportunity for effective language development to occur among ELs. The researchers argue that the results of this study support the idea that providing a curriculum to teachers can be an effective means for professional development, especially when in-person professional development is cost prohibitive. The curriculum consisted of a 40-lesson unit on space science. The model involved hands-on inquiry, reading in support of inquiry, discussing the investigations and texts, and writing about the investigations and concepts under study. The curriculum was designed to be culturally and linguistically responsive to ELs including use of students' everyday discourse to learn scientific discourse practices and allowing use of home languages. The curriculum also utilized scaffolded language supports and emphasized science vocabulary. The researchers conclude that the emphasis on oral communication and sense-making in classrooms using the curriculum explained the increased achievement in science concepts and vocabulary of ELs. There was more talk between teachers and students, as well as among students in comparison to the control groups.

Zwiep, S. G., & Straits, W. J. (2013). Inquiry Science: The Gateway to English Language Proficiency. *Journal of Science Teacher Education, 24*(8), 1315–1331.

This article reports the results of a 4 year study of the impact of a blended inquiry science and ELD program in grades K-5 in a large urban district in CA. EL students in the program showed small but significant gains in speaking and listening skills as measured by CELDT scores and small increases in CST ELA scores compared to control students participating in a state-adopted ELD program. Students also showed higher CST science scores in their 3rd and 4th years of the program. The researchers argue that these results point to the benefits of a blended approach to ELD instruction in which inquiry-based science is used as a context for English language development and that restricting EL students exposure and access to science content in order to provide designated ELD or ELA instructional minutes is unnecessary and likely limits students' future potential to enter STEM fields.

The curriculum model was designed to prioritize student thinking. The 5E inquiry format was used to teach science content, and language forms and functions were taught within the lessons, including front loaded and embedded vocabulary instruction. A more detailed discussion of the blended curriculum model, including a lesson template, is discussed by the same authors in a previously published article (Zwiep, S. G. et al, 2011). Of note is that intensive professional development was a key component of this intervention. Each summer, teachers participated in two weeks of professional development on both science content and pedagogy as well as a functional linguistic approach to ELD. During the year, teachers engaged in site-based lesson study teams.

*August, D., Artzi, L. & Mazrum, J. (2010). Improving Science and Vocabulary Learning of English Language Learners. In Center for Research on the Educational Achievement and Teaching of English Language Learners. *Improving educational outcomes for English learners in the middle grades: The CREATE briefs collection* (pp. 19-26). Washington, DC: Center for Applied Linguistics. Retrieved from: http://www.cal.org/create/pdfs/create-briefs-collection.pdf

In this brief, the authors begin by reviewing research on effective science instruction for ELLs to show that, along with inquiry-based science curriculum, ELs need explicit instruction in language and literacy. They highlight the potential of approaches that build on students' first-language science knowledge as well as their linguistic and cultural backgrounds. The researchers then describe two interventions that were effective in developing the academic vocabulary of ELs. One intervention was in a 3rd/4th grade ELD program and involved supplementing FOSS curriculum with language lessons. The other intervention was in heterogeneous 6th grade science classes and utilized the QuEST model, which includes 5E model curriculum and professional development for teachers. The researchers concluded that their results demonstrate the effectiveness of inquiry science coupled with scaffolding and a focus on language development. The brief includes detailed descriptions of the classroom instruction involved in the interventions along with examples of the instructional visuals used.

2. Research-based instructional practices

*Lee, O., & Buxton, C. A. (2013). Integrating Science And English Proficiency For English Language Learners. *Theory Into Practice, 52*(1), 36-42. Retrieved from: http://s3.amazonaws.com/academia.edu.documents/32636510/Integrating_Science_and_English_Proficiency_for_English_Language_Learners.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1471490592&Signature=3MAxSQN1fKQeFjlhYfRwCRpX4gg%3D&response-content-disposition=inline%3B%20filename%3DIntegrating_science_and_English_proficie.pdf

This article details five areas of effective instructional strategies for teaching science to ELLs: (a) literacy strategies for all students, (b) language support strategies with ELLs, (c) discourse strategies with ELLs, (d) home language support, and (e) home culture connections. Additionally, it offers recommendations for school and district leaders with regard to resources, curriculum, instructional time, and professional development to support effective, integrated language and science instruction for ELLs.

*Ardasheva, Y., Norton-Meier, L., & Hand, B. (2015). Negotiation, embeddedness, and non-threatening learning environments as themes of science and language convergence for English language learners. *Studies in Science Education, 51*(2), 201–249. Retrieved from: https://www.researchgate.net/profile/Brian_Hand2/publication/281653277_Negotiation_embeddedness_and_non-threatening_learning_environments_as_themes_of_science_and_language_convergence_for_English_language_learners/links/55f832f708ae07629dd163fc.pdf

The authors provide an extensive review of current academic literature relevant to science education for ELLs (building on Lee 2005) and use their findings to support their recommendation for the use of the *Science Writing Heuristic* approach to integrated science and literacy instruction for ELLs. They explain the *SWH* model as an immersive, argument-based inquiry approach that involves students in authentic science inquiry. The authors argue that this approach is well-aligned with key themes that emerged from the literature, including: 1) negotiation: students are engaged in constructing meaning through authentic inquiry and argumentation; 2) embeddedness: language instruction is embedded as students use, learn and

live the language of science; and 3) non-threatening learning environment: a student centered learning environment, collaborative learning among students, teacher as facilitator, respect for use of students' home language and culture to build science understanding, and the opportunity to practice academic language are all encouraged. This article is a useful read for district administrators who want to keep current on the research on best practices for science education for ELLs and who are considering possible instructional models for implementation.

*Zwiep, S. G., Straits, W. J., Stone, K. R., Beltran, D. D., & Furtado, L. (2011). The Integration of English Language Development and Science Instruction in Elementary Classrooms. *Journal of Science Teacher Education*, *22*(8), 769–785. Retrieved from: www.csulb.edu/~wstraits/aste2010.doc

Readers interested in learning more about the instructional model reported on in Zwiep, S.G. et al (2013) will find this article very useful in understanding the pedagogy driving instruction and curriculum design process used to arrive at the final lesson template. A blank lesson template and sample lesson are included. The article also includes a detailed discussion of the findings from observations of and interviews with teachers and principals which revealed: 1) Enhanced status for science among teachers and students; 2) increased student use of English oral language in and beyond the classroom; and 3) positive change in teachers' perceptions of students' capacities leading to a general increase in rigor and expectations.

3. Professional Development

*Lee, O., & Buxton, C. A. (2013). Teacher Professional Development to Improve Science and Literacy Achievement of English Language Learners. *Theory into Practice*, *52*(2), 110–117. Retrieved from: http://s3.amazonaws.com/academia.edu.documents/32636580/Teacher_Professional_Development_to_Improve_Science_and_Literacy_Achievement_of_English_Language_Learners.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1471491391&Signature=8AqfudfUay1Dhwpu9waOi6%2Ffzz0%3D&response-content-disposition=inline%3B%20filename%3DProfessional_development_to_support_the.pdf

This article discusses effective professional development of K–12 science teachers to support their teaching of science and English language and literacy to ELLs. It begins with an excellent summary of best practices of effective science teachers of ELLs. Building from this knowledge base, and findings from the literature on the core features of effective professional development for teachers in general, the authors propose the following as key components of effective professional development for science teachers of ELs: a) content focus: include opportunities for science teachers to learn subject matter science content, language and literacy unique to science, and the integration of science with language and literacy; b) active learning: opportunities for teachers to engage in model science inquiry activities and science content-language integration activities based on theories of second language acquisition; c) coherence: this is most likely to be achieved if teachers are trained on curriculum that has been approved by the district, or materials that are aligned to the required curriculum, rather than training in general strategies for ELLs; d) sufficient duration; and e) collective participation: ideally this would involve teachers from the same school, department, or grade level, as well as collaboration among science and ESOL teachers.


The Education Trust–West

INTERNET RESOURCES:

A. Curricular resources for integrated science, language & literacy approaches

Below is a list of websites that represent several of the main integrated science and literacy curricula and instructional approaches that are currently available to districts and teachers. These resources were selected based on the frequency with which they were referenced in the academic literature cited above and on research-based approaches currently utilized in California Bay Area schools. The list is intended as a resource to inform educators of what is available, not as an endorsement of any particular curriculum, organization, or product. Along with each site listed is a short summary of the instructional approach and resources available on the website, as well as highlights of any resources that appear to be particularly useful for teachers and instructional leaders.

UC Berkeley & Lawrence Hall of Science (Barber, Bravo, Cervetti, & Pearson)
Seeds of Science, Roots of Reading Curriculum
http://scienceandliteracy.org/

The *Seeds of Science, Roots of Reading* Curriculum is a 2nd-5th grade, integrated science and literacy curriculum designed for heterogeneous classrooms with English Language Learners in mind. The curriculum is organized into units, each comprised of 40 lessons, around big concepts (e.g. Gravity & Magnetism, Variation & Adaptation) and uses the "Do-it, Talk-it, Read-it, Write-it" approach. For each concept, students engage in hands-on investigations, structured peer discussions, reading of trade books, and formal and informal writing tasks. The website includes samples of the various curricular components, research studies demonstrating the effectiveness of the curriculum, resources for professional development, and resources for teachers. The curriculum for purchase includes all of the materials for investigations and a variety of student texts.

- A 3-page written explanation of the inquiry process used in the curriculum and how it evolves from 2nd to 5th grade is available at: http://scienceandliteracy.org/sites/scienceandliteracy.org/files/biblio/barber_inquirycycle_pdf_54088.pdf
- A PowerPoint Presentation that details the integrated approach of the curriculum is available at: http://scienceandliteracy.org/sites/scienceandliteracy.org/files/biblio/ascd_2010_academiclang_pdf_16436.pdf

Lawrence Hall of Science
Amplify Science
http://www.amplify.com/curriculum/amplifyscience

Amplify Science is a new K-8, inquiry based science curriculum aligned to the NGSS that engages students to apply scientific practices to solve real-world problems. It emphasizes argumentation as a key practice. According to the publisher, students conduct

investigations, read scientific texts, critique models and build their own visual models of their understanding of scientific phenomena, and use digital simulations to collect evidence and craft oral scientific arguments based on observational data. It uses an interactive digital platform to allow teachers to access and customize lesson plans. The curriculum is available as both a full-year course or broken up as individual units. Each full-year course comprises Life Science, Earth and Space Science, Physical Science and Engineering Design. As of August 2016, only the middle school level curriculum is available for purchase.

Institute for Inquiry at the Exploratorium
Educator's Guide to Inquiry-based Science and Language Development
http://www.exploratorium.edu/education/ifi/inquiry-and-eld/educators-guide

This guide was created to give educators a picture of what English language development in the context of inquiry based science can look like in elementary school classrooms with a high percentage of ELLs. It includes a conceptual overview that explains the Institute of Inquiry's curricular model, which involves facilitating signature experiences for students and integrating in contextualized mini-lessons as needed to scaffold student learning. The three types of "signature experiences" outlined are: inquiry-based science investigations, science talks, and science writing. All three types of experiences can take place in one lesson and/or happen at different times across multiple lessons of a unit. The "contextualized mini-lessons" are offered in response to teachable moments - presumably anticipated by and planned for by the teacher. This model allows for a lot of teacher freedom and could be successful for a knowledgeable and well-prepared teacher.

The guide also includes: an explanation of the project's approach to professional development; reports from an independent study of the model's impact on student science and language learning, and attitude and confidence; and, of most use to teachers, several annotated classroom videos of the curriculum in action. Classroom videos of two teachers, both of whom have combined 2nd/3rd grade classrooms with over 75% ELLs of varying levels of proficiency, are available. One teaches an investigation on magnets and the other on snails. See: http://www.exploratorium.edu/education/ifi/inquiry-and-eld/educators-guide/classroom-video-gallery

Florida Atlantic University & East Carolina University (Romance & Vitale)
***Science IDEAS* curriculum**
http://scienceideas.org/index.html

Science IDEAS is an integrated K-5 science, reading comprehension and writing curriculum. It addresses reading comprehension and writing within daily, 45-120 minute instructional blocks focusing on in-depth science instruction (in lieu of traditional basal reading/language arts instruction). The curriculum is organized

around key science concepts and uses a multi-day lesson structure that includes inquiry-oriented hands-on science, reading comprehension, writing/journaling, and concept mapping activities.

The website includes extensive information explaining the instructional model, research studies demonstrating its effectiveness, requirements for implementation, and information on scaling it. Much of the curriculum is available electronically in the "Information Binders" section of the site under Teacher Resources (see http://scienceideas.org/TeacherResources/index.html).

University of Maryland (Guthrie)
***Concept-Oriented Reading Instruction* (CORI)**
http://www.corilearning.com/

Concept-Oriented Reading Instruction (CORI) is an integrated reading and science instructional program designed to foster reading engagement and comprehension through the teaching of reading strategies, teaching of scientific concepts and inquiry skills, and its explicit support of the development of student intrinsic motivation to read. It aims to have students participate in engaged reading for 60-minutes per day. It currently has upper-elementary and middle school curriculum projects. The website includes classroom vignettes, videos of a 3rd and 4th grade classroom, teacher training modules for grades 3-5 and grade 7-8 for purchase, and an extensive list of research publications.

University of Michigan (Magnusson & Palincsar)
***Guided inquiry Supporting Multiple Literacies* (GiSML)**
http://www.umich.edu/~gisml/

The GiSML project represents an instructional approach to K-5 science teaching in which students engage in first-hand and second-hand investigations of science concepts using an inquiry approach to hands-on science and the study of scientific texts. The website's instructional resources include instructional plans, sample texts, activities, and assessments on a variety of topics for grades K-3 (motion, sound) and grades 3-5 (soils, light, motion, sinking & floating, and electricity).

WestEd (Greenleaf & Schoenbach)
Reading Apprenticeship
http://readingapprenticeship.org/

Reading Apprenticeship is a framework for instruction at the middle school, high school, and college levels that aims to develop students' literacy competencies, subject area knowledge, and dispositions as learners. It involves teachers in intensive, inquiry-based professional development to master the framework's target instructional routines for effectively addressing the personal, social, cognitive, and knowledge-building

dimensions of student learning in their classrooms. Practices central to the Reading Apprenticeship approach include "Metacognitive Conversation" and "Extensive Reading."

The website includes information about the approach, research studies demonstrating its positive impact, as well as several related publications.

- 2-page overview of the Reading Apprenticeship: http://readingapprenticeship.org/wp-content/uploads/2014/01/Reading-Apprenticeship-2-pager.pdf
- An excerpt from their Reading Apprenticeship Academic Literacy (REAL) curriculum unit on science: http://readingapprenticeship.org/wp-content/uploads/2014/02/U3-Lesson-13.pdf

E.L. Achieve (Dutro)
Constructing Meaning
http://www.elachieve.org/what-we-do/about-constructing-meaning.html

Constructing Meaning is an approach to explicit language instruction for content area teachers that is designed to meet the needs of ELLs at varying language levels. The approach includes intensive professional development for teachers on how to use the method and tools to plan and implement integrated content and language instruction. It employs a functional language approach organized around the tasks and text structures of content-area coursework and emphasizes oral and written language skills. See the one-page overview: http://www.elachieve.org/images/pdf/elachieve_about_cm.pdf

B. Free online tools for science teachers:

The Argumentation Toolkit:
http://www.argumentationtoolkit.org/

This is a free online toolkit designed for middle school science teachers to support their students in scientific argumentation. It includes an online professional development module and useful strategy guides and classroom videos. It was developed as part of a collaboration between Lawrence Hall of Science and Boston College.

Lawrence Hall of Science: Learning Design Group
http://learningdesigngroup.org/resources-strategy-guides

This site includes a number of NGSS aligned "Strategy Guides" for middle school teachers that emphasize scientific disciplinary literacy. Each guide includes detailed explanations of how to implement the strategy, along with all of the materials needed to

implement it (i.e. readings, worksheets, visuals, etc). Some examples of the guides offered include: *Analyzing Visual Representations: How Earthquakes Cause Tsunamis; Combining Simulations and Text to Support Scientific Explanations: Gravity and Orbits; Engaging in Argumentation with a Science Seminar: Regional Climate in the Atacama Desert; and Engaging with Text Through Active Reading: Wind Currents*.

WordSift
https://wordsift.org/

WordSift is a free online tool designed in collaboration with middle school teachers to use to address vocabulary and academic language in content area instruction. It was developed by Kenji Hakuta at Stanford University and is intended to support English Language Learners.

C. Resources for ongoing learning about ELLs and science instruction:

Colorín Colorado
http://www.colorincolorado.org/teaching-ells/content-instruction-ells/science-instruction-ells

Colorín Colorado is a national multimedia project that offers research-based information, activities, and advice for educators and families of ELLs. The website's page on science instruction for ELLs offers strategies, resources, and guidance for helping ELLs succeed in science.

Cheche Konnen Center
https://external-wiki.terc.edu/display/CKC/Cheche+Konnen+Center+Home

The Cheche Konnen Center, led by Roseberry and Warren, aims to provide bilingual students access to authentic and rigorous inquiry-based science practice. An extensive list of publications is available.

Understanding Language Initiative at Stanford University (Hakuta & Santos)
http://ell.stanford.edu/content/science

Understanding Language: Language, Literacy, and Learning in the Content Areas is a collective of experts in the field of language and content area teaching and learning, currently led by Hakuta and Santos, with the aim of developing research and resources to increase awareness of how essential it is for all students, but especially English Language Learners, to learn the language of each academic discipline so they can rigorously and authentically engage with its content, as is intended by the CCSS and NGSS.

NGSS Standards:
http://www.nextgenscience.org
http://ngss.nsta.org
*National Research Council. (2013). *Appendix D: All Standards, All Students: CASE STUDY 4: English Language Learners and the Next Generation Science Standards in Next Generation Science Standards*. Retrieved from http://www.nextgenscience.org/sites/default/files/%284%29%20Case%20Study%20ELL%206-14-13.pdf

English Language Development Standards:
https://www.wida.us/standards/eld.aspx (national)
http://www.cde.ca.gov/sp/el/er/documents/eldstndspublication14.pdf (California)

B) Additional books & manuals (listed from newest to oldest date of publication)

Lyon, E.G., Tolbert, S.; Solis, J., Stoddart, P. & Bunch, G.C. (2016). *Secondary Science Teaching for English Learners: Developing Supportive and Responsive Learning Contexts for Sense-Making and Language Development.* Lanham, MD: Rowman & Littlefield Publishers.

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

Carr, J., Sexton, U., & Lagunoff, R. (2007). *Making science accessible to English learners: A guidebook for teachers*. San Francisco: WestEd.

*Fathman, A.K.,& Crowther, D.T. (Eds.). (2006). *Science for English language learners: K-12 classroom strategies*. Arlington, VA: National Science Teachers Association. http://static.nsta.org/files/PB194Xweb.pdf