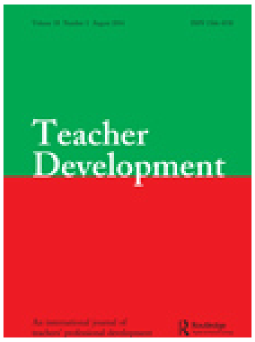

Teacher Development

An international journal of teachers' professional development

ISSN: 1366-4530 (Print) 1747-5120 (Online) Journal homepage: https://www.tandfonline.com/loi/rtde20

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**To cite this article:** David J. Carrejo & Judy Reinhartz (2014) Teachers fostering the co-development of science literacy and language literacy with English language learners, Teacher Development, 18:3, 334-348, DOI: 10.1080/13664530.2014.914564

**To link to this article:** https://doi.org/10.1080/13664530.2014.914564

*Teacher Development*, 2014
Vol. 18, No. 3, 334–348, http://dx.doi.org/10.1080/13664530.2014.914564



# Teachers fostering the co-development of science literacy and language literacy with English language learners

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(*Received 18 January 2012; final version received 5 March 2013*)

Thirty-five elementary teachers participated in a yearlong professional development (PD) program that was designed to foster a culture of on-going teacher learning to promote the co-development of science and language literacy for English language learners (ELL). An explanatory design methodology was used to determine the degree to which science and language literacy co-developed. The research question guiding this study was: In what ways did the yearlong PD science program support teachers at 10 elementary schools to become more knowledgeable about fostering science literacy and its role in co-developing language literacy (e.g. reading, writing, listening, and speaking) for ELL? The measurable and significant gains on the quantitative mandated state science and reading tests and the analysis of qualitative teaching episodes led to the conclusion that demonstrated the synergy between science learning and language learning – as one increased, so did the other.

**Keywords:** English language learners; science learning; language literacy; professional development; teacher learning

## Introduction

While several examples of science teacher professional development (PD) have been eloquently presented (Loucks-Horsley et al. 2003; Sparks and Loucks-Horsley 1990), many fall short in developing teacher expertise in fostering students' science literacy while enhancing their language literacy (Penuel, Gallagher, and Moorthy 2011). Since English language learning 'is a complex, non-linear process that is affected by many interrelated factors' (Thompson 2004, 3), McLester (2012) advocates PD models that are built on a culture of on-going teacher learning.

Teaching language in isolation from other disciplines in the curriculum de-contextualizes learning the academic language of science (Center for Research on Education, Diversity, and Excellence 2002; Slavin and Cheung 2004; Solomon and Rhodes 1995). Huntley (1998) and Baker and Saul (1994) assert the synergistic nature that science and language share and emphasize the need to integrate discipline-based instruction with language-based instruction. This integration is critical to the development and success of both science and language literacy (Douglas et al. 2005; Thier and Daviss 2002). By co-developing science literacy and language literacy in tandem, learning accelerates for both types of literacy (Collier 1995; Collier and Thomas 2006; Cummins and Miramontes 2006).

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There are many different definitions of science literacy. One comes from the National Research Council (1996) that defines science literacy as 'a person's ability to ask, find, or determine answers to questions derived from curiosity about everyday experiences … [and] to describe, explain, and predict natural phenomena' (22). Alberts (2009) offers another definition of science literacy, stating that students should have the skills of 'problem solving, communication, and general thinking required [of] effective workers and educated citizens in the 21st century' (80). Language literacy is typically defined within the context of how a person can derive and convey meaning using language skills (Moll 1994). A literate person has the ability to make and communicate meaning from and by the use of language (Halliday 1994). Some fundamental elements of language literacy include reading and analyzing text, communicating, and writing (Silliman and Wilkinson 1994) – all of which are necessary to learn science through inquiry.

Our current research attempts to identify the effectiveness of a yearlong PD science model that focused on the co-development of learning science along with acquiring language literacy. The more formal research question was: In what ways did a yearlong PD science model support teachers at 10 elementary school campuses to become more knowledgeable about fostering science literacy and its role in co-developing language literacy (e.g. reading, writing, listening, and speaking) for English language learners (ELL)? This study incorporates McLester's recommendation of building a culture of on-going teacher learning and extends and refines the work conducted in the areas of teaching science and language for ELL (Lee and Luykx 2006; Slavin and Cheung 2004; Stoddard et al. 2002; Thompson 2004).

## The study

### *Literacy: finding common ground between science and language*

Holbrook and Rannikmae (2009) posit that scientific literacy is dependent on the need to 'develop collective interaction skills, personal development and suitable communication approaches' (286) that include:

(1) *speaking* to describe and support ideas;
(2) *writing* to remember specific information;
(3) *reading* to expand learning and to find answers; and
(4) *listening* to enhance thinking.

Since these authors define science literacy in language-based terms, we used this definition to guide the development of the PD model in our study. In addition, the mandated fifth-grade science and reading standards were used to build the content curriculum for the model. Table 1 presents an overview of the standards that were included in the PD curriculum.

The PD model incorporated these sets of standards to demonstrate how hands-on science content learning provided a context for meaningful language usage (Castek et al. 2007).

Table 1. Science standards aligned with reading standards in the PD curriculum.

| Science standards | Language arts/reading standards |
|---|---|
| Construct simple graphs, tables, maps, and charts | Represent and organize information in different ways and for different purposes |
| Represent the natural world using models | Draw on their experiences to bring meaning to words in context |
| Draw inferences based on information | Analyze cause and effect relationships<br>Draw conclusions and generalizations based on evidence and experiences<br>Distinguish fact from opinion |
| Identify patterns and properties | Read and study words systematically |
| Collect information through observation and measurement | Recall information |

### *Literacy: approaches to teaching*

The instructional approaches advocated by Chamot and O'Malley (1996) were implemented during the PD program. These approaches are cognitive and social/affective in nature to support science and language literacy. The cognitive approaches include physical and mental manipulation of material to support science and language learning. They stimulate thinking and promote the use of descriptive, informal language to identify patterns, interpret and analyze information, and to explain properties and attributes of objects and natural phenomena. Teachers in the study had opportunities to experience the social/affective approaches first hand. Using social/affective approaches in a non-threatening, text-rich science classroom environment gave ELL many opportunities to speak, listen, discuss, and write. As teachers in our study learned to scaffold student learning by implementing the cognitive and social/affective approaches in their science classrooms, they recognized that a bridge formed between the formal, academic science language and informal, social language, thereby fostering both science and language literacy.

### *Participants of the study*

Thirty-five elementary public school dual-language teachers who taught science in English to ELL in their classrooms participated in the yearlong PD program. They were engaged in a continuous culture of learning that modeled the co-development of

Table 2. Participating campuses with respective ELL populations.

| School | Total student population 2010 | Total ELL 2010 | % of population 2010 | Total student population 2009 | Total ELL 2009 | % of population 2009 |
|---|---|---|---|---|---|---|
| Campus 1 | 764 | 308 | 40.31 | 750 | 335 | 44.67 |
| Campus 2 | 996 | 553 | 55.52 | 1012 | 529 | 52.27 |
| Campus 3 | 402 | 211 | 52.49 | 374 | 202 | 54.01 |
| Campus 4 | 662 | 221 | 33.38 | 626 | 206 | 32.91 |
| Campus 5 | 755 | 182 | 24.11 | 703 | 165 | 23.47 |
| Campus 6 | 505 | 264 | 52.28 | 511 | 257 | 50.29 |
| Campus 7 | 714 | 241 | 33.75 | 806 | 276 | 34.24 |
| Campus 8 | 920 | 216 | 23.48 | 957 | 195 | 20.38 |
| Campus 9 | 863 | 171 | 19.81 | 827 | 159 | 19.23 |
| Campus 10 | 771 | 326 | 42.28 | 756 | 329 | 43.52 |

science and language through campus-based collaboration. Of the total number of teacher participants from 10 schools in a district located in a Texas border region, more than 60% were Hispanic and bilingual with an average of 12 years of teaching experience. Average class size was 21 students. Table 2 presents the demographics for each school campus in the study.

According to district data, ELL students represented up to half of the total student population and over 80% were identified as economically disadvantaged. All teacher participants met monthly at a central location in the fall and in the spring met at their respective campuses to customize instruction for their specific student population.

### *The PD curriculum and the 5E pedagogy*

The science component of the PD curriculum focused on selected big ideas (cycles, density, energy, force and motion, organisms and environment) that embedded language arts and reading standards. The 5E pedagogy served as the delivery system for the PD curriculum and includes the following phases: engage, explore, explain, elaborate, and evaluate. The researchers' 5E pedagogy is a modified version of Bybee's 5Es (1997) in which the 'elaborate' phase provides opportunities for students to identify relationships between variables during experimental investigations to promote learner discussion and reflection. The scientific and, in some cases, mathematical constructs involved in this relationship become the heart of a science investigation.

In the 'evaluate' phase, a game format, using a science 'vocabulary loop', was used regularly to measure science language and literacy learning. Each student received a card that bears one phrase, 'I have [science term]' and another phrase, 'Who has [definition of a different science term].' The student who has the word or phrase on their card that matches the 'Who has' definition stands up next and reads their 'I have [matching word]' followed by their 'Who has' definition. The process is then repeated until all science vocabulary terms have been matched with their respective definition. The loop ends when the last definition matches the first term that is read. Table 3 provides a lesson from the PD on minerals using the 5Es along with a description of strategies for promoting science and language learning.

Table 3. Mineral lesson included in the PD curriculum identifying teacher strategies to promote science and language learning.

| 5E phase | Strategies to promote science and language learning | Lesson sequence |
|---|---|---|
| Engage | Students will a) collect information through observations; b) organize information; c) draw inferences based on information presented; d) make generalizations supported by evidence; e) make connections to prior learning and bring meaning to words and pictures in context; f) ask and respond to higher order questions to offer a solution to a problem. | Lesson opens with a slide of a picture of a baby with some accompanying text. Students are asked to read the text: 'Every child born will need 3.7 million pounds of minerals, metals, and fuels in their lifetime.'<br>The teacher asks: What are minerals, metal, and fuels? Where do they come from? How are they alike? How are they different? Why do we need these materials? Why did the artist use a picture of a baby? What do you think the artist was trying to communicate in the picture? What is the artist's point of view?' |

(*Continued*)

Table 3. (*Continued*).

| 5E phase | Strategies to promote science and language learning | Lesson sequence |
|---|---|---|
| Explore | Students will a) interact with materials by using tools to guide their exploration; b) use their observation and data collection skills to write their hypotheses; c) communicate verbally with peers to draw pictures, write descriptions, and label specimens drawn in the science notebooks; d) begin to analyze information recorded and confirm hypotheses; and e) identify in writing common patterns, similarities, and differences. | Using trays of minerals, groups of students will: a) observe, identify properties and attributes, and categorize them; b) describe and record their ideas in their science notebooks (If disagreements emerge, they use the written data in their notebooks to support or refute claims.); c) respond to the question, 'Are there other attributes that were not mentioned, such as volume?'; and d) compare and contrast their ideas in their groups. |
| Explain | Based on student experiences during the 'explore', the teacher will a) introduce appropriate science vocabulary and content; b) guide the students through an oral discussion to build science understanding over time; c) encourage students to employ appropriate verbal, nonverbal, and listening skills to enhance interpersonal relationships; d) ask questions to promote connections between what is presented including hands-on experiences; and e) provide a learning environment that supports analyzing various types of information to determine the difference between facts and 'big ideas' (concepts) in science. | The teacher will: a) encourage students to consult classroom resources available and their textbooks if they have questions; b) ask, 'What is meant by common properties or characteristics of a mineral (e.g. color, streak, mass, volume, density)?'; c) assist students in making the connections between hands-on experiences; d) engage students in class discussions to encourage communication skills; and e) enhance their understanding of science vocabulary including the common properties of minerals through analysis of different types of written materials. |
| Elaborate | Students will a) build relationships between variables identified during an experiment; b) use scientific and mathematical models to make connections between their ideas and those that are scientifically intelligible, plausible, and applicable; c) become aware of connections involving cause and effect; d) complete a data table and plot data on a graph; and e) support their responses using various types of texts as well as evidence in their science notebooks. | Students will: a) test their ideas/hypotheses based on information gleaned from class discussions, hands-on experiences, and information written in their notebooks and textbooks; b) pose the question: 'What is the relationship between the mass and volume of the mineral (i.e. to determine the density of the mineral)?'; and c) gain insight into the characteristic of density of a mineral by conducting this experiment. |
| Evaluate | Students' level of fundamental language skills, science vocabulary, and interpretations of graphics are assessed through: a) written text in their science notebooks; b) speaking and listening to their peers in their work groups as well as whole class discussions; c) questions they ask; d) responses given to questions; and e) matching terms to definitions. | Students will participate in the vocabulary 'loop' (an oral exercise where students read aloud the information on their card and listen attentively to what is being read so that they can respond with the definition so there is a match). |

### *Methodology*

In prior research, the Carrejo, Cortez, and Reinhartz (2010) reported measureable and significant outcomes of ELL performance on mandated state science and mathematics tests at targeted school sites where principals and their teachers participated in a yearlong, comprehensive professional development program. Based on the success of this program, one school district organized a subsequent yearlong PD program for dual language teachers. The program identified schools with low performance on the annual mandated state science test for fifth graders and outlined a plan targeting these schools using the PD model proposed by the researchers. To measure changes in science and language literacy, an explanatory mixed-methods research design was chosen (Creswell et al. 2003).

The quantitative phase of the study included collecting and analyzing disaggregated scores from the mandated state science and reading tests for fifth graders at each of the 10 schools using a one-tailed test to compare two proportions. The data reported percentages of ELL students who met state science and reading standards for grade five from 2009 to 2010. In addition, qualitative observation data were collected and analyzed. The results from analyzing both quantitative and qualitative data shed light on how the PD program built science teachers' instructional capacity to support students in both science and language literacy.

## Results

### *Quantitative data*

A one-tailed test for comparing two proportions was used to determine if the success rate in 2010 was better when compared to the rate in 2009. A *z*-score was calculated using the number of English language learners at each campus in each testing year and the percentage of those at each campus who met the standard. Table 4 provides quantitative information for fifth-grade ELL science performance at 10 school campuses, indicating the percent change along with a *z*-score and *p*-value for each campus.

Given a calculated *z*-score, and comparing each calculated *p*-value with an alpha level of .05, that is $P(Z < = z)$ compared to alpha, quantitative results indicate that fifth-grade ELL performance in science at all campuses showed significant gains from 2009 to 2010.

To measure language literacy gains, the authors collected and analyzed scores from the mandated state fifth-grade reading test because of its alignment with the goals of the PD model and the study. Table 5 shows the percent change between 2009 and 2010 for each campus along with their respective *z*-score and *p*-value.

Given a calculated *z*-score, and comparing each calculated *p*-value with an alpha level of .05, that is $P(Z < = z)$ compared to alpha, quantitative results indicate that fifth-grade ELL performance in reading at all 10 campuses showed significant gains from 2009 to 2010, and the reading success rate in 2010 was better than in 2009. In addition to collecting quantitative data, our explanatory research design included collecting and analyzing qualitative data to identify the possible reason(s) for student success from 2009 to 2010 on the science and reading mandated state tests.

Table 4. Percentage of fifth-grade ELL students who met the standard in science at participating school campuses.

| School | Science 2009 | Science 2010 | % pt change | *z*-score | *p*-value |
|---|---|---|---|---|---|
| Campus 1 | 64% | 93% | 29% | –8.852 | .00003 |
| Campus 2 | 68% | 88% | 20% | –7.968 | .00003 |
| Campus 3 | 63% | 92% | 29% | –7.091 | .00003 |
| Campus 4 | 55% | 80% | 25% | –5.531 | .00003 |
| Campus 5 | 88% | 99% | 11% | –4.234 | .00003 |
| Campus 6 | 85% | 91% | 6% | –2.110 | .01743 |
| Campus 7 | 78% | 90% | 12% | –3.675 | .00012 |
| Campus 8 | 87% | 99% | 12% | –4.861 | .00003 |
| Campus 9 | 76% | 99% | 23% | –6.406 | .00003 |
| Campus 10 | 63% | 94% | 31% | –9.644 | .00003 |

Table 5. Percentage of fifth-grade ELL students who met the standard in reading at participating school campuses.

| School | Reading 2009 | Reading 2010 | % pt change | *z*-score | *p*-value |
|---|---|---|---|---|---|
| Campus 1 | 0.7 | 0.92 | 22% | –7.039 | .00003 |
| Campus 2 | 0.44 | 0.69 | 25% | –8.298 | .00003 |
| Campus 3 | .05 | 0.6 | 55% | –11.874 | .00003 |
| Campus 4 | 0.71 | 0.81 | 10% | –2.424 | .00768 |
| Campus 5 | .05 | 0.99 | 94% | –17.554 | .00003 |
| Campus 6 | 0.78 | 0.91 | 13% | –4.109 | .00003 |
| Campus 7 | 0.88 | 0.93 | 5% | –1.919 | .02749 |
| Campus 8 | 0.79 | 0.93 | 14% | –4.129 | .00003 |
| Campus 9 | 0.89 | 0.99 | 10% | –3.878 | .00005 |
| Campus 10 | 0.67 | 0.99 | 32% | –10.883 | .00003 |

### *Qualitative data*

Qualitative data were collected in participants' classrooms during the spring term through a series of in-person and/or videotaped observations of classroom instruction. A constructivist grounded theory methodology (Charmaz 2008) was used to gather and analyze classroom and videotape observation data. The method is both constructivist and grounded because both analysis and researcher–participant interaction were firmly rooted in the study's classroom environment (Charmaz 2000; Mann 1993).

In this study, teaching episodes were used to examine the interactions between students and students as well as students and their teachers and were mindful of how they were embedded within a larger context of time, place, and situation. It would be quite tempting for the authors to rely on a protocol based on preconceived notions about ELL learning, implementing preconceived 'approaches', and testing a scientific hypothesis, but a constructivist grounded theory method afforded a more reflective and inductive process for analysis; therefore, no prior assumptions or hypotheses were formulated.

*Categories*

For the qualitative phase, three types of incident-to-incident coding were used in analyzing observation data:

(1) initial coding identified actions and interactions between students and teachers;
(2) focused coding used selected initial codes to revisit data – a constant-comparison approach that defined initial categories and described patterns of interaction; and
(3) theoretical coding relied on theoretical sensitivity to stimulate reflection of the data and determine attributes of initial categories, thereby constructing theoretical categories.

The results from focused coding revealed three initial categories of reading, speaking, and experimenting that are outlined in Table 6. Attributes of each initial category are also provided.

Table 6. Initial categories and their attributes.

| Initial category | Attributes with applicable initial codes |
|---|---|
| Speaking | *'Prompting'* – Teachers stressed a need to elicit knowledge from students through simple oral prompts (for example, 'What do you know about ___?', 'Can you describe, what ___ is?', Can you tell me, 'What does ___ mean?'). |
| | *'Presenting'* – Teachers tested students by having them orally read/recite what had just been presented (with or without visual aids) and participate in activities such as charades to describe science vocabulary, the words shown in PowerPoint slides (e.g., sun, magnets, and prey). |
| Reading | *'Textbook reading'* – Teachers stressed a need to elicit knowledge based on what students had read from the text. |
| | *'In-class reading'* – Teachers stressed a need for students to fill gaps in their knowledge (if recall is unsuccessful) by giving them material to read in class. |
| | *'Vocabulary loop'* – Teachers stressed that students stand, project their voice, and read what was on their card. Other students were to listen as this information was read. |
| Experimenting | *'Physical'* – Students examined or 'played with' concrete objects that were a part of activities. |
| | *'Notebook'* – Students were required to write, make sketches and scientific illustrations, and label them in their science notebooks as part of activities. |
| | *'Prompting'* – Teachers stressed a need to elicit knowledge from students through simple oral prompts (for example, 'What does a ______ do?', 'How it is alike? How is it different?', 'What do you know about ___?', 'Can you tell me what ___ is?', 'What does ___ mean?'). |
| | *'Student talk'* – Students attempted to connect ideas by questioning the teacher or a fellow student ('Does my conclusion make sense?'; 'Is this the same as that?'; 'What do you mean ___ relates to ___?'). |

Table 7. Theoretical categories and their attributes.

| *Theoretical category* | *Attributes* |
|---|---|
| Engaging as verbalizing | For teachers, the 'engage' phase of the 5E was the time to have students speak to each other (and to the teacher) about their initial ideas, observations, and their prior ideas. Discussion became a critical part of the 'engage' phase, the beginning of the lesson. |
| Experimenting as communicating | Teachers believed that building vocabulary during science investigations necessarily involved writing along with speaking. Discussion, based on science observations and notebook entries, became an integral part of the 'explore' phase. |

Focused codes evolved during the analysis based on the initial codes and, through constant-comparison methods, two theoretical categories were constructed. These categories along with their attributes are presented in Table 7.

Two theoretical categories of 'engaging as verbalizing' and 'experimenting as communicating' evolved into specific meanings over the course of the analysis. They were based on the researchers' interactions with the participants that made possible a plausible theory or interpretation of events to address the research question.

### *Representative episodes*

Two representative classroom episodes are presented along with an interpretation and a brief discussion of each episode. These episodes highlight the two theoretical categories of 'engaging as verbalizing' and 'experimenting as communicating'. The teaching episode data present a broader context for analyzing the implications of the quantitative data (Cobb et al. 2001).

*Episode one.* Gloria was a fifth-grade teacher serving the children of migrant workers with limited English skills. Gloria's lesson focused on habitats with particular emphasis on adaptation. The goal of the lesson was to have students understand the different characteristics of animals based on their needs and their environment. Her classroom was conducive to student group work, and she indicated during a pre-observation interview that she liked to decorate her classroom with 'many interesting things' so that students would be engaged in the topic she was presenting.

In Gloria's teaching episode, the structure she used to facilitate classroom discussion was particularly interesting. Her teaching paradigm included a firm belief that students learned science language best by working together. Gloria told the students to speak to group members, and, eventually, the class about what they believed is important to know about adaptation. She also asked them to provide some examples. After the discussion and writing key information on the board, she required students to take notes in their science notebooks. She used the earthworm as a case study and distributed a set of sticky notes to each group and asked each student to write one interesting characteristic about the earthworm on the note. She asked them to write in their notebooks five 'things' that they knew about earthworms and each student was required to share this information orally with the class. She then provided a set of instructions.

Gloria: Now, I want each person to stand up and I want you to ask one question about earthworms that you would like answered.

Student 1: How do they walk?
Student 2: How do they see?
Student 3: How do they hear?
Student 4: How do they eat?
Student 5: Do they have bones?
Student 6: Can they fly?
Student 7: How do they dig a hole?

Students then listened to the teacher, who read the book *I Wonder What it is Like to Be an Earthworm.* As she read the book, Gloria required students to write key terms and their meanings in their notebooks. After reading the terms and definitions from the book, Gloria asked a student, at random, to 'read aloud the term and its definition' from her notebook. She then took an informal oral survey and asked the rest of the class, 'Do you agree?' During this activity, there was some disagreement about some definitions, but Gloria addressed these and obtained class consensus on the list of vocabulary in their notebooks.

After getting the students engaged in the lesson, Gloria sent students to their desks, arranged in groups, to observe live earthworms. Group members were required to write what they observed and share them with group members. Students read their information and each group created a final list of observations. Following the activity, each group presented their list to the class. At the end of class, Gloria mentioned to her students that they would play a vocabulary 'loop'.

*Brief analysis of episode one.* Gloria allowed students to speak and have discussions with her and their peers to enhance oral language skills. To foster science and language literacy, Gloria had the students write in their notebooks and read from them. During the 'engage', the students spoke to each other. Gloria followed the engage with an 'explore' that involved hands-on experiences of observing and touching the earthworm. Her engage and explore reflected the desired approach of using real objects and observation skills to stimulate academic content and language literacy.

In the PD program, we stressed that the purpose of the engage and the explore phases was to introduce the students to a big science idea and a way to build language based on their experiences. In summary, Gloria implemented what she learned in the PD program about the engage and explore in the 5E pedagogy delivery system. The data collected via classroom observations formed the basis of the first theoretical category, 'engaging as verbalizing'.

*Episode two*. Yvonne was a fifth-grade teacher in a school where the majority of her students were bilingual, 58% were coded as economically disadvantaged, and the majority were classified as ELL. Yvonne's science lesson was on the solar system. First, she wanted to help her students understand the relative size of the planets with the ultimate goal of understanding the model of the solar system. Yvonne expressed concern about students learning formal, academic science vocabulary, which was a part of the district curriculum. She recognized quickly that she needed to address measurement and estimation because she believed students would be interested in finding out 'how big the planets are'.

Yvonne began with the question, 'How big is the sun?' She elicited many answers, but she directed the class to listen to other students' responses. She also had the students write an answer to this question in their science notebooks emphasizing that their answer needed to include 'detail'. Students naturally began *comparing* the size of the sun to other objects they were very familiar with – their classroom, school, playground, neighborhood size, and so forth. Since her main goal was for students to construct a model of the solar system, she took the opportunity to question students regarding their perspective.

Yvonne: Why does the sun look so small?
Student 1: Because it's so far away.
Student 2: It's like when we are driving to our house … it gets bigger when you get closer. But we can't get close to the sun.

In Yvonne's case, the 'defining' moment of her engage was not immediately to provide a list of science vocabulary or a list of facts. She built on students' prior experiences and informal language before having her students construct a model of the solar system during the explore.

Yvonne, in the explore phase, asked the question, 'If this [holding up a penny] is the size of the Earth, then what is the size of Jupiter?' Initially, students were puzzled, but Yvonne allowed them to talk to each other and to write down their ideas in their science notebooks so that they could test their own ideas.

Student 3: It's about 100 times bigger than that.
Student 4: No, it's not.
Yvonne: OK. You have some string and everything you need on your table. Show me what you think.

After allowing students to present their ideas and recall some prior knowledge, Yvonne's 'explain' turned to introducing some factual information that the students were required to write in their notebooks.

Yvonne: OK. What scientists know is that Jupiter is the largest planet and 11 times bigger than earth. Do you know what that means?
Student 1: Do they mean like the whole thing?
Yvonne: What do you think?
Student 5: We were thinking straight across [implying the diameter of a circle].
Yvonne: Yes. That's what I mean, too. Good. We will look at mass and weight soon.
Student 6: Wow. How heavy is Jupiter?

The explore phase was taken outside where students measured the diameter of a penny and determined Jupiter's diameter so they could draw Jupiter on the playground surface. They made sketches in their notebooks. Back in the classroom, Yvonne asked students to compare what they saw outside with their own predictions written in their notebooks. She guided the discourse so that students could speak and be heard.

From Yvonne's perspective, 'Now I can engage them in other things.' Students proceeded to draw the other planets. If they appeared too large to be drawn at their tables, they questioned Yvonne as to whether or not they could return to the playground to draw them. Yvonne correctly believed (based on age-level appropriateness and cognitive development) that she would need to give them more information so they could build the complete model of the solar system, including relative distance of each planet to the others and their size.

*Brief analysis of episode two.* For Yvonne, the engage was a time to interest students in the size of objects/planets in space while developing their oral and written communication skills. While still informal at this point, she would soon be able to build more formal academic language centered on units of measure and the names of the planets in the solar system model. As Yvonne and her students progressed through the lesson, the engage, explore, and explain phases became more inter-related, and Yvonne's support for her students' curiosity and communicating their ideas, at least in her eyes, became more focused. She scaffolded and built on student ideas to promote science and language literacy. From these ideas, Yvonne felt more comfortable about 'where to go next'. However, it may take time. Yvonne ended the lesson using a vocabulary 'loop' based on the names of the planets, some factual planet information, and measurement terminology; students repeated the 'loop' several times and each time the loop was completed more quickly. Each student read what was on his/her card (the 'Who has…' section), listened to what was being read, and responded with the correct answer on his/her card (the 'I have….' section) to complete the loop.

Reflecting on Yvonne's episode, she used the model of the solar system as a foundation for learning formal academic science language through informal discussions. This example highlights how the theoretical categories of 'engaging as verbalizing' and 'experimenting as communicating' evolved and shed light on what we believe made PD program participants successful in achieving improved ELL science and reading learning outcomes.

## Discussion

The yearlong PD program included ways for teachers to strengthen their science knowledge and pedagogical skills while developing a mind-set for co-developing science literacy and language literacy through contextualized instruction. Our PD science program offered an array of hands-on approaches embedded in the 5E delivery system that informed both instructional practice and our research focusing on teaching English language learners.

Teaching ELL in the science classroom is challenging for many teachers. For one, there is a perceived urgency to increase language proficiency first and then consider teaching the other disciplines in the curriculum. This long-held assumption may no longer be tenable because for students to be successful on the mandated state science test, they need to know certain literacy elements, namely reading comprehension, vocabulary development, and representing information in different ways. Our research provides additional evidence that there is a continuum of learning that science and language share, and teachers do not have to choose one over the other.

Science served as the instructional engine to promote English language skills. The most convincing data came in the form of higher scores on the fifth-grade mandated state science and reading tests and data collected during classroom observations. The PD model, based on a culture of on-going teacher learning, provided participants opportunities to re-examine and reflect upon their own teaching against the backdrop of experiences afforded by the curriculum and 5E pedagogy.

Reflecting upon their teaching practices in their science classrooms, the participants found that all levels of English language learners benefitted from the use of concrete materials and visuals during the engage and explore while more advanced ELL benefitted from graphic organizers. Writing supported both science and English language learning by encouraging students to record information from their observations of physical characteristics of objects during the explore or the elaborate. Teachers observed their students asking and responding to more science-specific questions, which helped them gain additional insight into understanding their world. These actions required students to use language – reading, writing, speaking, and listening.

In summary, we are not advocating one best PD model or program to support English language learners in the science classroom. What we are presenting is a different perspective for educators to consider – co-developing language and science literacy in the classroom through contextualized instruction. Without this perspective, we feel the science and language literacy achievement gap for ELL will continue to widen.

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## References

Alberts, B. 2009. "Restoring Science to Science Education." *Issues in Science and Technology* 25 (4): 77–80.

Baker, L., and W. Saul. 1994. "Considering Science and Language Arts Connections: A Study of Teacher Cognition." *Journal of Research in Science Teaching* 31: 1023–1037.

Bybee, R. W. 1997. *Achieving Scientific Literacy*. Portsmouth, NH: Heinemann.

Carrejo, D. J., T. Cortez, and J. Reinhartz. 2010. "Developing Leadership Roles Within a Community of Practice for Promoting Academic Performance of ELL Students." *Academic Leadership: The Online Journal* 8 (4). Accessed April 22, 2014. http://contentcat.fhsu.edu/cdm/landingpage/collection/p15732coll4

Castek, J., D. J. Leu, J. Coiro, M. Gort, L. A. Henry, and C. Lima. 2007. "Developing New Literacies Among Multilingual Learners in the Elementary Grades." In *Technology-Mediated Learning Environments for Young English Learners: Connections in and out of School*, edited by L. Parker, 111–153. Mahwah, NJ: Lawrence Erlbaum Associates.

Center for Research on Education, Diversity, and Excellence. 2002. *Research Evidence: Five Standards for Effective Pedagogy and Student Outcomes*. Technical report, University of California, Santa Cruz.

Chamot, A. U., and J. M. O'Malley. 1996. "The Cognitive Academic Language Learning Approach: A Model for Linguistically Diverse Classrooms." *The Elementary School Journal* 96 (3): 259–273.

Charmaz, K. 2000. “Grounded Theory: Objectivist and Constructivist Methods.” In *Handbook of Qualitative Research*, edited by N. Denzin and Y. Lincoln. 2nd ed., 509–535. Thousand Oaks, CA: Sage Publications.

Charmaz, K. 2008. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. Los Angeles, CA: Sage Publications.

Cobb, P., M. Stephan, K. McClain, and K. Gravemeijer. 2001. “Participating in Classroom Mathematical Practices.” *The Journal of the Learning Sciences* 10 (1&2): 113–163.

Collier, V. P. 1995. *Promoting Academic Success for ESL Students: Understanding Second Language Acquisition for School*. Woodside, NY: New Jersey Teachers of English to Speakers of Other Languages-Bilingual Educators.

Collier, V. P., and W. P. Thomas. 2006. “Predicting Second Language Academic Success in English Using the Prism Model.” In *The International Handbook of English Language Teaching*. Vol. 1, edited by J. Cummins and C. Davidson, 333–348. Norwell, MA: Springer Publications.

Creswell, J. W., V. L. Plano Clark, M. Gutmann, and W. Hanson. 2003. “Advanced Mixed Methods Research Design.” In *Handbook of Mixed Methods in Social and Behavioral Research*, edited by A. Tashakkori and C. Tegglie, 209–240. Thousand Oaks, CA: Sage.

Cummins, N. L., and O. B. Miramontes. 2006. “Addressing Linguistic Diversity From the Outset.” *Journal of Teacher Education* 57 (3): 240–246.

Douglas, R., M. P. Klentschy, K. Worth, J. McKee, and D. Ogle. 2005. *Linking Science and Literacy in the K–8 Classroom*. Arlington, VA: National Science Teachers Association.

Halliday, M. A. K. 1994. “The Place of Dialogue in Children’s Construction of Meaning.” In *Theoretical Models and Processes of Reading*, edited by R. B. Ruddell, M. R. Ruddell and H. Singer. 4th ed., 70–82. Newark, DE: International Reading Association.

Holbrook, J., and M. Rannikmae. 2009. “The Meaning of Scientific Literacy.” *International Journal of Environmental & Science Education* 4 (3): 275–288.

Huntley, M. A. 1998. “Language and Implementation of a Framework for Defining Integrated Mathematics and Science Education.” *School Science and Mathematics* 98: 320–327.

Lee, O., and A. Luykx. 2006. *Science Education and Student Diversity: Synthesis and Research Agenda*. New York: Cambridge University Press.

Loucks-Horsley, S., N. Love, K. E. Stiles, S. E. Mundry, and P. W. Hewson. 2003. *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, CA: Corwin Press.

Mann, M. P. 1993. “Grounded Theory and Classroom Research.” *Excellence in College Teaching* 4: 131–143.

McLester, S. 2012. “Sustainable Professional Development.” *District Administration*. Accessed March 2013. http://www.districtadministration.com/article/sustainable-professional-development

Moll, L. C. 1994. “Literacy Research in Community and Classrooms: A Sociocultural Approach.” In *Theoretical Models and Processes of Reading*, edited by, R. B. Ruddell, M. R. Ruddell and H. Singer. 4th ed., 179–207. Newark, DE: International Reading Association.

National Research Council. 1996. *National Science Education Standards*. Washington, DC: National Academies Press.

Penuel, W. R., L. P. Gallagher, and S. Moorthy. 2011. “Preparing Teachers to Design Sequences of Instruction in Earth Systems Science: A Comparison of Three Professional Development Programs.” *American Educational Research Journal* 48: 996–1025.

Silliman, E. R., and L. C. Wilkinson. 1994. “Discourse Scaffolds for Classroom Intervention.” In *Language Learning Disabilities in School-Age Children and Adolescents*, edited by G. P. Wallach and K. G. Butler, 27–54. Boston, MA: Allyn & Bacon.

Slavin, R. E., and A. Cheung. 2004. “How Do English Language Learners Learn to Read?” *Educational Leadership* 61 (6): 52–57.

Solomon, J., and N. Rhodes. 1995. *Conceptualizing Academic Language*. Santa Cruz, CA: National Center for Research on Cultural Diversity and Second Language Learning.

Sparks, D., and S. Loucks-Horsley. 1990. “Models of Staff Development.” In *Handbook of Research on Teacher Education*, edited by W. R. Houston, M. Haberman and J. Sikula, 234–250. New York: Macmillan Publishing Company.

Stoddard, T., A. Pinal, M. Latzke, and D. Canaday. 2002. "Integrating Inquiry Science and Language Development for English Language Learners." *Journal of Research in Science Teaching* 39 (8): 664–687.

Thier, M., and B. Daviss. 2002. *The New Science Literacy: Using Language Skills to Help Students Learn Science*. Portsmouth, NH: Heinemann.

Thompson, L. W. 2004. "Literacy Development for English Language Learners: Classroom Challenges in the NCLB Age." Accessed December 2011. http://www.shastacoe.org/uploaded/.../English_Language_Learners.pdf