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Connecting Literacy and Science to Increase Achievement for English Language Learners

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Abstract Giving students a purpose and a passion for sharing their thinking through authentic learning experiences and giving them tools for writing through which they can risk new vocabulary, new language, and new thought is critical for the linguistic and cognitive development of students. Furthermore, students develop a deep understanding of content they have heard and read when given time to process information through writing and speaking. This article describes one teacher's quest to identify and implement effective research-based instructional strategies that she could use to successfully support her kindergarten ELL students during science instruction.

Keywords Science · English language learners · Kindergarten · Early childhood education · Literacy

> To develop a complete mind, study the science of art; study the art of science, learn to see. Realize that everything connects to everything else.
> –Leonardo daVinci

"Miss Huerta, como se dice 'brillosa' en ingles?" ("Miss Huerta, how do you say 'shiny' in English?"), Juan asked as his pencil hovered next to his beautiful drawing of a shiny rock. He was ready to add a descriptive statement to his sketch, but he did not know the appropriate academic science vocabulary word required to complete his sentence. Juan's bilingual kindergarten class was studying rocks and because science is taught in English in his school district, Juan's challenge to connect vocabulary with content through writing was his teacher's challenge as well. How could she help her students internalize the language and content of science in a second language? This article describes one teacher's quest to find effective research-based instructional strategies that she could use to successfully support her kindergarten ELL students during science instruction.

The ethnic and racial composition of our nation's classrooms is changing as emphasized by Miller (2005), "The United States is now undergoing one of the most profound demographic transitions in our history. We are becoming a new people" (p. 6). During the past thirty years the proportion of white students enrolled in public schools declined from 78 to 58%, the proportion of Hispanic students increased by 20%, and the proportion of black students remained unchanged. This shift in classroom composition mirrors an increase in school-age students who speak English as a second language. The number of K-12 students who speak a language other than English at home doubled between 1975 and 2005 resulting in 10.6 million or 20% of all public school students being classified as language minority. The majority of these students report Spanish as their first language (*The Condition of Education*, 2007).

Concurrent with these changes in student population demographics, there have been substantial revisions to the core science curriculum. In 1985 the American Association for the Advancement of Science (AAAS) launched *Project 2061*, a long-term reform initiative designed to transform science education in America by 2061, the year that

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Halley's comet returns. In 1989 AAAS published *Science for All Americans,* a landmark report that defined science literacy and provided the groundwork for national science education standards by outlining what students should know and be able to do in science by high school graduation. This pioneering report defines a scientifically literate person as one who has a broad and functional understanding of science and the natural world, is aware of the interdependence of mathematics, technology and science, has a capacity for scientific thinking, and understands the coherence of science and society (*Science for All Americans*, 1989).

Benchmarks for Science Literacy (1993) provides a broad set of learning goals for students in grades K-12 that support the scientific literacy goals outlined in *Science for All Americans* (1989). The "benchmarks were designed to help curriculum designers and educators make decisions regarding what to include or exclude from a core curriculum scope and sequence" (*Benchmarks for Science Literacy*, 1993). Three years later, the National Research Council published the *National Science Education Standards* (NRC 1996) which "spell out a vision of science education that will make scientific literacy for all a reality in the 21st century" (p. ix). The *National Science Education Standards* (NRC 1996) introduction acknowledges the influence of *Science for All Americans* (1989) and *Benchmarks for Science Literacy* (1993) in the creation of standards regarding what students should know and be able to do in science. According to Wheeler (2006) the authors of these standards "sought to change the face of science education with the idea that science is something which students do, using both hands-on activities and structured learning experiences" (p. 169). Inquiry, a prominent feature of the *National Education Science Standards* (NRC 1996), is the instructional keystone that connects doing and learning science. Inquiry science is emphasized in state and local science standards because they are based on the *National Science Education Standards* (NRC 1996).

Coinciding with these efforts to create a more rigorous science curriculum designed to make scientific literacy in the 21st century a reality, there has been national legislation that mandates rigorous assessment of students' learning. The No Child Left Behind (NCLB) act requires that educators measure students' yearly progress, encourages high academic standards, and implements greater accountability throughout the Nation's school system (NLCB NLCB 2002). Of special interest to science educators is the requirement that schools must annually assess students' science knowledge and skills in elementary, middle school, and high school. As high-stakes testing moves into the realm of science, teachers of ELLs must develop English language fluency while simultaneously teaching science content (Durón-Flores and Maciel 2006). For these reasons, educational programs and research-based practices that are effective in promoting solid science content for ELLs *and* English literacy are crucial to identify and implement.

The Need for Integrating Content Areas

Many early childhood classrooms emphasize instruction in reading and math. Recent research in high-stakes testing has found that ELLs perform poorly on content area exams such as science and math due to a lack of academic vocabulary and English literacy (Kieffer et al. 2009; Wolf and Leon 2009). Low test results seriously impede ELLs' motivation to stay in school in the long run, evident in the high drop-out rate of ELL students (Padrón et al. 2002). It is imperative, therefore, that as early childhood educators we not focus on just teaching reading and math skills. Rather, we need to thoughtfully integrate content areas in our lessons in order to provide our students with foundational experiences that simultaneously allow them to acquire skills, concepts, and vocabulary and, most critically, the motivation to learn. In fact, research notes that language and literacy are acquired best when they are embedded in meaningful activities (Lightbown and Spada 2006). For example, young ELLs can learn the mechanics of reading (i.e. phonics, syllables, etc.) and writing (i.e. putting phonemes together, spacing words, etc.) while simultaneously learning that reading has a purpose (i.e. to learn new information; to read for pleasure, etc.) and a structure (i.e. nonfiction text structure) by delving into the wonders of exploring science texts. They can also learn content vocabulary and concepts by reading literature that integrates science and math vocabulary, which, if presented correctly, can provide great motivation to develop literacy skills and vocabulary. Early childhood educators have the opportunity and responsibility to provide these kinds of rich and integrated learning experiences. Doing so will help establish critical foundations of knowledge and skills necessary for higher grades and high-stakes testing in all academic areas.

Language and Learning

Research has found that when people write about what they have learned they retain 70% of the content, but when they write about what they have learned and talk about it, they retain 90% of the content (Daniels et al. 2007). Language and its various mediums, including writing and speaking, are critical in helping students retain academic information. Yet, too often classroom practice neglects writing and speaking and focuses only on reading and listening. Traditional instructional practices inundate students with contextually reduced lectures and reading passages that have little or no meaning. Lucy Calkins, the great mentor of writing and reading strategies for children, stated that "talk, like reading and writing, is a major motor—I could even say the major motor—of intellectual development" (2000, p. 226). Calkins concludes that writing is a process of making meaning in our lives (1994), therefore a tool for constructing understanding as well as for giving us a purpose in learning and thinking.

It is critical, then, that writing and speaking become a focus in the teaching practice. It is not that educators should not teach with a "capital T" (Atwell 1998, p. 21)—we should—and it is not that educators should not have children read—this is an absolute. Rather, it is that educators couple the practices of listening and reading with opportunities for students to speak and to write. In working with ELL students in particular, we need to push toward intellectual development while also working on giving them the basic skills and purpose to develop a second language. Science as a content area provides rich possibilities for such an endeavor.

Inquiry-Based Science

Students should be given the opportunity to talk with their fellow classmates and with their teachers about their questions, ideas, and "a-ha" moments of understanding. Inquiry-based classroom instruction supports learners as they construct their own knowledge while teachers facilitate and guide investigations. Instructional strategies that support inquiry allow teachers to customize and scaffold learning experiences. Questioning techniques that promote higher-level thinking and provide speaking opportunities are important in this model. Effective inquiry instructors skillfully use assorted real-life tools and create authentic experiences that support students as they observe and interact with scientific content and processes. Additionally, students flourish when they are allowed to explore science in a risk-free learning-environment. With regard to ELLs, inquiry-based programs do three important things. First, they guard against the "pedagogy of poverty" that Haberman (1991) warns against. Second, they provide a rich basin of tactile experiences that provide a natural teaching-ground for building vocabulary and background knowledge for students. Finally, they are a gateway for using language to speak and write and therefore construct and solidify scientific understanding. When coupled with literacy skills, students are motivated to master language and use it as a tool to help them answer their questions about the world around them (Their 2002). In other words, science gives ELL students a purpose to learn English.

Balancing Vocabulary Building and Higher-Level Thinking

In inquiry lessons, teachers aim to ask children "open-ended questions" rather than "closed questions" (Carin et al. 2005, p. 128). Open-ended questioning stimulates further discussion among children and they promote higher-level thinking which is important for building understanding. "What would happen if…" "How do you know that…?" This does not mean that teachers do not scaffold their way to open-ended questions. Students still benefit from closed-questioning techniques such as "What do you see?" "What is this called?" These initial steps promote observation and experience that in turn build background knowledge and serve as tools to help students build scientific vocabulary. Once the vocabulary has been introduced, students begin to internalize the words and concepts and then become "fluent" in using them (Durón-Flores and Maciel 2006, p. 328). Teachers can then successfully frame open-ended questions using comprehensible vocabulary for the ELL student so that students receive comprehensible input during class time.

Working word walls are effective vocabulary building tools used in successful ELL classrooms. Working word walls provide an opportunity for ELL teachers to balance a use of closed and open-ended questions while building English vocabulary with students (Durón-Flores and Maciel 2006). This kind of word wall is not pre-fabricated. It is not put up on the wall by the teacher before the students arrive and then never referred to. A working word wall is a living word wall. Students and teachers work together to collect, analyze, classify, and label real-life objects.

A Kindergarten Inquiry

After my encounter with Juan's struggle to find the accessible English word for "shiny" in my bilingual Kindergarten class, I decided to ask my students to collect rocks from the playground. We had already spent time observing and classifying rocks that I had brought to the classroom. This time we repeated the process using rocks the children had collected and brought to the classroom. Additionally, though I allowed them to describe their rocks in Spanish, I made sure to use the English vocabulary words as I spoke with them to ensure that they were hearing them. I then created a graphic organizer with the children like the one below, making sure to model how to sound out the words in English, and pointing out new sounds like "sh" and "th" which do not exist in Spanish:

Rocks	
Shiny	Dull
Rough	Smooth
Round	Pointy

The children chose a rock sample from their personal rock collection to place in a clear plastic bag. We then taped their samples under the appropriate category/label. As we did so, some students who had more quickly grasped the vocabulary began to debate about which category a dull, smooth rock should go under. The next day during recess, rock collections began to spontaneously form around me as students sorted rocks and began trying out the vocabulary words from the previous day! We were on a roll. In another science lesson, we dissected a plant and drew a huge diagram of a plant on chart paper. We labeled the plant. Then, we placed real plant parts in clear bags and taped them next to the labels. Our diagram stayed up proudly on the wall for weeks (without excessive rotting). A song about plant parts accompanied the diagram, as did experimental lessons on the function of the different plant parts. Soon, I had a chorus of ELL learners bringing me flowers from home or from the playground and using English to explain what the plant parts were called and what role they played in a plant system.

In a sense, working word walls can become inquiry lessons in themselves. Students create the vocabulary and concept together with tactile objects; they see the printed word associated with the concept that they have helped create; and they hear the teacher say the word and repeat it as they speak to each other during cooperative group investigations. Therefore, the word walls/charts become tools for internalizing vocabulary and concepts. More importantly, they become tools for writing in their science journals as students continue to construct and refine their understanding of science and English.

Science Notebooks

Students should be given the opportunity to write about what they are hearing and reading. Michael Klentschy explains that a science notebook is a "central place where language, data, and experience work together to form meaning for the student" (Klentschy 2005, p. 24). Klentschy echoes the words of Lucy Calkins. She advocates that writing is a process of making meaning in our lives, therefore a tool for constructing understanding as well as for giving us a purpose in learning and thinking. Furthermore, writing creates meaning and deep understanding of a subject whether that subject is a scientific or social question that we are seeking to understand (Calkins 1994). Finally, it supports what researchers and practitioners are discovering about how writing develops a deep understanding of science content as students refine their thoughts on paper (Kotelman et al. 2006). For ELLs, writing, like speaking, is a linguistic gateway for developing English writing skills while refining scientific understanding.

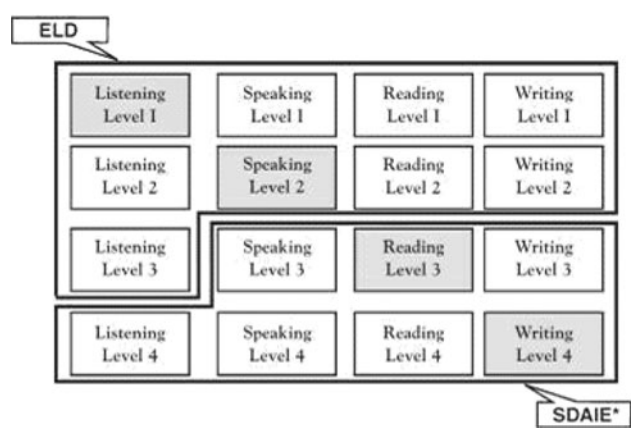
Balancing Writing Skills and Higher-Level Thinking

Science notebooks are more than a place to just record data and facts (Klentschy 2008). In fact, Klentschy (2008) specifically delineates seven components of a science notebook that should be used during an investigation to ensure higher-level thinking processes:

1. Question, Problem, Purpose (What? How? Why?)
2. Prediction (If…then; I think…because)
3. Developing a plan (data organizing or process writing)
4. Observations, Data, Charts, Graphs, Drawings and Illustrations
5. Claims and Evidence
6. Drawing conclusions (This includes a "making meaning conference" where they share and listen to others ideas) and
7. Reflection—Next Steps/New Questions

All seven components might not necessarily be found in entries for every lesson, but the focus of the components is clearly to push students towards higher-level thinking processes: to answer open-ended questions through writing and come up with their own questions.

With respect to ELLs, especially young ones acquiring language, teachers must be attuned to the English level and writing capability of their students when considering the seven components of a science notebook. The following matrix of the stages of language acquisition serves as a reference for placing an ELL within his or her range of linguistic capability in the second language:



Note: **SDAI* Specially Designed Academic Instruction in English (Mora 2000).

For example, a teacher should focus on listening strategies with Level 1 students, on speaking strategies with Level 2 students, on reading strategies with Level 3 students, and on writing strategies for Level 4 students. A teacher's awareness of the student's linguistic level in English allows him or her to scaffold the student to the next level. This does not mean, however, that a Level 1 student cannot or should not be exposed to strategies that intersect horizontal domains. An ELL at the listening level can still be asked to write down his or her predictions in Spanish and then prompted to write his or her observations, perhaps a drawing with English labels, in the science notebook. After all, drawings can hold much content, especially for young writers. "When children compose pictures, they employ visual-design features to express understanding…they use color, size, shape, and position of objects to express or distinguish important concepts…" (Varelas et al. 2006). This idea arguably transfers to older students who are still at the beginning stages of literacy in either their first or second language. Educators should also consider that it is possible for a second language learner to be a fluent reader and writer of a second language without being a fluent speaker, especially if the student has developed academic language in English in another country and has then arrived to a U.S. school setting. The matrix is a framework from which to work, and the key is for the teacher to be attuned to the different linguistic modalities and find the strengths and weaknesses of his or her students.

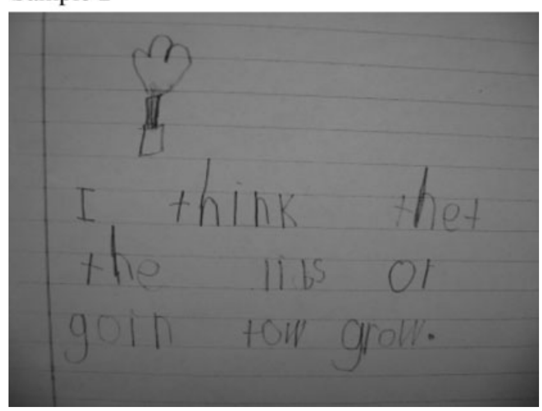
The following examples from my ELLs' science notebooks illustrate how basic literacy skills and higher-level thinking skills can develop simultaneously through writing in a science notebook. In the analysis that follows, I will refer to Klentschy's seven components of science notebooks (2008) as well as to Mora's levels of language acquisition (2000) in an attempt to show how higher-level thinking and language development can intersect at all levels in a science notebook.

Samples 1 and 2

In my bilingual Kindergarten class, we wanted to know what role stems played in a plant system. So, we wrote down our questions and a purpose for a science experiment as a whole group (Component 1—questions). We then planned our experiment together (Component 3—developing a plan). Two celery sticks with leaves were placed in two separate cups with food coloring (for fun, we put one in red water and one in blue water). The students were then asked predict what would happen to celery sticks that were left in red water and blue water (Component 2—predictions).

Sample 1

Sample 2

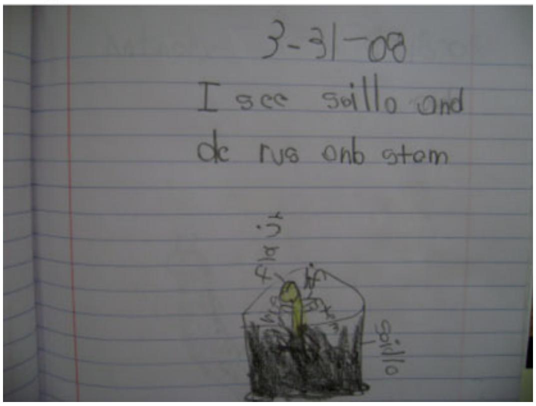


The student in Sample 1 was beginning to transition to the speaking level (Level 2), so he wrote his prediction in Spanish: "I think that it will be another color. One will be purple and the other will be pink." The student in Sample 2 was at the reading and writing level (Levels 3 and 4), so he wrote down his prediction in English: "I think that the leaves are going to grow." The first student who wrote in Spanish was more approximate in his prediction with respect to the experiment and the food coloring. The second student who wrote in English was not as approximate with respect to the experiment and food coloring, but he had an intuition, or perhaps background knowledge, that stems help leaves grow. Both demonstrated thoughtful predictions. Both were working on their literacy skills as well. The first student would later read his prediction in Spanish and explain it as best he could in English; the second would later read his prediction in English and explain it to me in English as well with elaboration in Spanish.

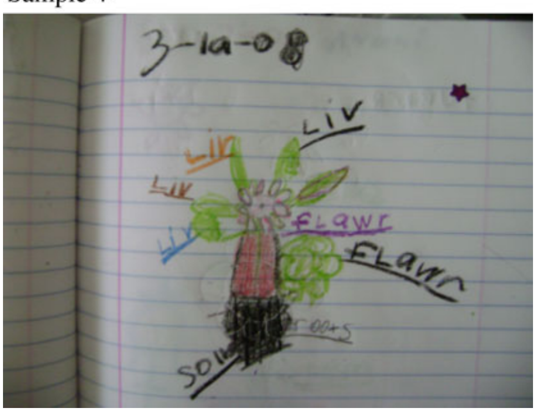
Samples 3 and 4

With especially young learners writing down observations (Component 4—observations) and communicating what they have learned (Component 5—claims and evidence) very often intersect. I would imagine that an older student's diagram of his or her observation of scientific phenomena could do the same thing.

Sample 3



Sample 4



In Sample 3, the student was transitioning into reading and writing in English (Levels 3 and 4). The student was jotting down observations about the beans we had planted as a class. Notice the detail in the drawing and the labels that read "flower," "leaf," and "soil". The caption above reads, "I see soil and the root and stem." The writing exemplifies a classic ELL writer. It contains a mixture of sight words from our English word wall and words that are phonetically sounded out using knowledge of the primary language phonetic system. I later conferred with the student and asked him what he had learned (Component 5—claims and evidence). He told me that he learned that the bean seed opened in half to let the plant grow. Even though he did not write down his response at this time, I validated his answer since he was demonstrating his learning through his oral explanation.

In Sample 4, the student also labeled observations of a complete plant system in English. The diagram shows keen attention to the number of leaves on the plant versus the number of flowers. This student's plant had more leaves than flowers, as she would later explain to me in Spanish. She would also go on to ask me why it was that her group's plant had more leaves than the other group's plant. She was, therefore, forming a new question (Component 7—reflections and new questions). It should be noted that this student had a strong command of listening and reading skills in English (Levels 1 and 3) but not so much of speaking and writing (Levels 2 and 4), though she was transitioning into writing.

As a final reflection of the analysis of the science notebook entries that my bilingual Kindergarten ELLs produced, it is important to keep the following in mind: "Even if they can't read or write English well (yet), they can all think" (Rojas 2006). Vygotsky would most certainly agree with this statement since he believed that thought preceded language (1978). He also believed that acquiring spoken and written language was directly linked to developing higher-level thinking. This is why it is critical that we continue to find ways to promote literacy in our ELL students. My emergent writers were in different places in their language and conceptual development of English and science, but they were all working towards deeper understanding. They were motivated to give English a chance because they were given background experience and tools such as word walls and linguistic registers like labels and comprehensible input to work with.

Conclusion

Giving students a purpose and a passion for sharing their thinking through authentic learning experiences and giving them tools for writing through which they can risk new vocabulary, new language, and new thought is critical for the linguistic and cognitive development of students. Furthermore, students develop a deep understanding of content they have heard and read when given time to process through writing and speaking, through crafting words on paper and in their minds.

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