Teaching Science Understanding in Second Language Settings

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*The key to understanding language in context is to start not with language, but with context.* (Hymes, 1972, xix)

This chapter is a call for a new context for science education in multilingual communities—one that will be fully inclusive for English language learners whose voices have not been included in mainstream science fields. This new context correlates with what is known about effective education for English language learners.

In this new context, science instruction moves away from traditional practices toward more contextual and holistic learning experiences. The science curriculum unfurls to include environmental impacts, intricate relationships, the complexity of individuals, culture and community, and an understanding of the power structures that control science thought and science resources. Science education programs incorporate the experiences and perspectives of women and minorities as well as a respect for life and the environment. This rich and complex context leads to more than just science careers; it develops scientifically literate citizens.

Contextualizing science means that the learning is situated in integrated, complex, real-world, and relevant subject matter. Science teachers work from the perspective that issues and problems can be used to contextualize the content, leading students to make sense and find meaning in their world. Teaching in this manner elicits student inquiries and desires. Rather than “schooling” the student, teachers provide a meaningful context whereby the student can “learn to learn” and ultimately apply the knowledge to effectively navigate a journey through life in a manner that is molded by culture and personal desire.

Contextualizing science also provides the motivation for ELL students to focus on meaning and content, and not language form alone. Meaningful purposeful learning facilitates “languaging” in a natural context. The focus is on meaningful language learned in context.
COMPONENTS OF QUALITY SCIENCE LEARNING IN MULTILINGUAL SETTINGS

How do teachers serving ELLs ensure that they are scientifically literate and empowered to be critical purveyors of societal change? Outlined below are components of a science education program that lead toward scientific literacy. Teachers in these programs are knowledgeable in how to make instruction comprehensible to students who are learning new content in a new language. The science curriculum is embedded in the community and interests of the learners. The daily activities are integrated with other content, founded in constructivist pedagogy, and rich in interactive dialogue with fellow students and the teacher in both the home language and in English. The teacher listens to the students to understand their world and to tap their prior knowledge to launch the learning experiences. The following is an example of a classroom where students are developing scientific literacy.

The Oil Spill Lesson

Ms. Loya teaches a fourth grade in a community where many students speak Spanish at home and are learning English in school. Some of her students volunteer to stay after school for weekly community clean up walks to pick up litter in the school neighborhood. On one of these afternoons the students saw a puddle of dirty oil in a gutter. They followed the oil trail to a dumpster behind an auto lubrication service shop. Someone had improperly disposed of dirty motor oil in the dumpster. The students informed the business owner. He assured them that it was not standard procedure, and someone had not followed the guidelines of his business. He showed the students the used motor oil is stored in a barrel until it is full. Then an oil company collects the barrel and recycles the motor oil.

Back at school the next week, the students who went on the walk shared the information with the rest of the class. A class discussion was generated about the problem of oil pollution on the land and in the water, and many questions emerged. “What does the oil company do with the dirty motor oil?” “Where does the oil come from?” “What is it used for?” “What causes oil spills in the ocean?” “How are oil spills cleaned up?” “What happens if you pour oil on the ground? On the water?” “What do fast food places do with their used cooking oil?”

The teacher wrote the questions on a large chart in English or Spanish, depending on the language the student used, in order to encourage a free flow of thoughts and questions. She encouraged the students to share any information they had about the questions. Celia’s sister worked at a fast food restaurant. She came back the next day, after talking to her sister, and told of the oil containers that some businesses used for disposal. Anthony told about watching a TV show about cleaning up an oil spill in the ocean. Nightly news reports focused on a recent oil spill near Spain, and several students told what they knew about that spill. Much of the class’s interest began to focus on oil spills in the ocean. A team of students began an Internet search for information on oil spills.

Ms. Loya encouraged the students to think about ways to clean oil from water and to explore further by discussing with their families and others about what they thought would be good ways to clean the oil from the water. Then she announced the “Oil Spill Clean-up Contest.” The students were given three days to research and plan ways to clean a mini oil spill which she demonstrated with a tablespoon full of gear lube oil in a small beaker of water. The guidelines were that they could bring any tools or equipment they needed for the contest, but, for consistency, the tools had to fit into a shoebox. They worked together in small teams.

Each team was given the beaker of water with the oil pollution. The work began. After everyone finished, the class evaluated each beaker’s cleanliness and assigned a
rating of one for very clean water to five for the dirtiest water. The students who combined several techniques had successful projects. This holds true for real oil spill cleanups. Two teams developed filters made of nets and sand. Both worked well, but the team who used a tissue to clean the edges after filtering the water had the cleanest water. This is similar to the way clean-up crews actually use paper towels after some spills to clean rocks and birds. One group brought hair clippings from a sister’s beauty shop, and had a successful project using the hair to absorb the oil.

Following the contest, students entered the information on a database listing the team members, a description of the method used, time to clean the water, and rating. The ELLs had an English-speaking partner to assist in entering the information in English. Using the print out of the database, they discussed the advantages and disadvantages of the methods used. For example, the team that sprinkled dry grass over the oil and scooped it out with a spoon concluded that this was cheap and effective but not very thorough.

The students also shared the results of the research they had been doing on oil spills. From the World Almanac and Book of Facts they found a table listing the world’s largest oil spills, the cause, and the tons of oil spilled. They were surprised about how many spills had occurred in the Gulf of Mexico and the Arabian Sea. They located these largest spills on a world map and devised a system of marking the size of the spills with dots—one pencil dot represented 10,000 tons of oil. The teacher demonstrated how to make the maps, and the English language learners were able to work independently on their maps converting the numbers to dots.

To demonstrate what they had learned about oil spills and what they still wanted to learn, the students worked in teams to devise their own assessments. All were presented in English, and the English-speaking team members assisted the English language learners so they could share in the presentations. Some chose to create books for third-graders informing them of the most important concepts of oil spills. One team made a Power Point presentation. One team made a comic book about oil spills, and several students chose to make illustrated posters. As a final written evaluation, each team submitted a short essay describing their plans for further investigations in areas they found interesting. In the oil-spill activity, students had learned science terms such as “absorb,” “dissolve,” and “soluble.” They used these science terms in their essays. The ELLs wrote as much of the essay as they could in English and were allowed to elaborate in their home language. The plans for further investigation included learning more about the world’s largest user of oil, the United States, and the long-term environmental damage of oil spills and other oil pollution sources.

Comprehensible Instruction for Learning New Content in a New Language

Equity, meaningful/purposeful learning, and active hands-on learning—these common threads of the new science learning are also threads of effective instruction for second language learners. Therefore, science and language learning are natural partners. Some of these common threads include thinking maps and graphic organizers and the utilization of strategies such as visuals, hands-on projects, manipulatives, and thematic integrated instruction. These are good for ALL students, but for ELLs they serve a second function in that they provide students with the language they need to talk about the content, to write about their ideas in the content activities and develop more vocabulary and understanding of grammar.

Ms. Loya ensured that all of the students were engaged because she provided this integrated activity based on the students’ interests. The projects were hands-on experiments, such as the oil clean-up, and visual representations, such as the map charting and the student-generated data base. Students were developing vocabulary and grammar by talking about their experiments and their research and writing about their ideas.
Several strategies provide meaningful and purposeful learning by scaffolding second language acquisition through content instruction. These include providing text in manageable chunks, paraphrasing, stressing vocabulary development activities in context, and using other activities that involve resource tools such as almanacs and bilingual dictionaries. Ms. Loya wanted her students to "publish" what they learned from their oil spill investigations via an oral and written report in English. She wanted to ensure that all of her students had meaningful learning experiences, and she understood that student's L1 is always the foundation to structures and understanding in L2. Therefore, she recommended that they have Spanish and English expertise on their teams. This provided ELLs the opportunities to use their L1 as a resource while acquiring content, new scientific terms, and new language structures. This sense of acceptance and security allowed them to participate fully in the meaningful learning.

Effective teachers in second language classrooms understand second language acquisition and its stages in listening, speaking reading and writing. They are able to monitor their own language use and are careful with the use of idioms and complex structures that require more proficiency in a language. Although the focus is to shelter instruction by use of many of these strategies, it is never meant to water down curriculum. The focus is on the mode of delivery and making sure that all students have meaningful access and participation in the full curriculum. The demands are many for both teachers and ELLs in school.

Also, teachers who understand this relevant inquiry in science curriculum focus on depth of understanding of concepts rather than skimming the surface of content and recalling it as discrete facts. This "less is more" approach benefits English dominant, mainstream students as well as the students learning English. The oil-spill lesson took several days, allowing the multifaceted concepts to develop in depth. By allowing the time to develop a deeper understanding about science, ELL's also need the time to process language necessary for them to talk, read, and write about their science learning. They develop scientific literacy.

**Constructivist, Interactive Science Learning**

In a constructivist science curriculum like Ms. Loya's, the students are interacting with the natural or designed world in a meaningful and challenging social context to construct new understandings. The concepts develop less through language text or lecture and more through interacting with real and designed earth materials. Language development took place along with conceptual understanding. Much research is available to show that students learn science better through constructivist, interactive science instruction such as that described above (Bredderman, 1983; Kyle, Bonnstetter, McCloskey, & Fults, 1988; Shamansky, Hedges & Woodworth, 1990; and Yager, 1993). A study by Klentschy, Garrison, & Amaral (1999) shows significant improvement in writing, as well as science, when students are involved in a constructivist, interactive science curriculum.

Our brains are programmed to explore our natural world. We, and especially the youngest of our species, are natural scientists, ready to explore, ask questions, investigate, observe, and wonder about the world around us. Kovalik (1997) defines content that comes from the natural world around us as meaningful content. Students can access this content because it is age-appropriate. It is complex enough that the brain struggles to seek patterns and create meaning. It is related to the learner's prior experiences and is useful to the learner. There is little need for external rewards because the learning experience is full of discovery and excitement. This approach to learning science aligns with new information about how the brain works. Caine and Caine (1994) encourage educators to provide multiple complex and concrete experiences to optimize the human brain's
capacity to make connections. “Every complex event embeds information in the brain and links what is being learned to the rest of the learner’s current experiences, past knowledge, and future behavior” (p. 5).

Teaching science should be based on children’s natural tendency to explore their world. As teachers or family members, we guide them into more formal science skills. We help them learn to organize their questions and information gathering so they gain a deeper and more thorough understanding of a concept. For example, condensation on the outside of a cold glass appears to be water leaking out through the glass. Providing more investigations with empty cold glasses, mirrors, and teakettles leads the student to construct better explanations. We help them organize their information into charts, tables, and graphs. As their development levels grow, we begin to lead them to understand how to design and interpret investigations. We help them analyze the information and communicate what they have learned about the exploration. We provide the opportunities for them to question where these understandings fit in their world and why.

**Linking to Indigenous Knowledge**

Science is a process by which we make sense of the world around us. Therefore, all learners bring prior knowledge to the classroom through their experiences in understanding their surroundings. They each have their own indigenous knowledge. It is the responsibility of the teacher to tap into this indigenous knowledge in order for learners to make meaningful connections to new language and knowledge.

This indigenous knowledge the students bring varies greatly depending on these previous “lived experiences.” Children who have social backgrounds that do not mimic the dominant culture reflected by most schools have particular constraints imposed on them that can significantly impede “progress” in school. For example, some working-class parents cannot provide the same literacy building experiences for their children as can parents with higher education levels and more literacy tools. Recent immigrants do not have the established knowledge of the dominant culture with its community memory and ways of representing experiences (Saville-Troike, 1991). This makes schooling more difficult for the children from working-class and immigrant families since the cultural capital (their wealth of experiences built by early exposure to language, nature, relationships, experiences manipulating materials, etc.) in schools is foreign and different from that found in the home. Cultural differences based on socio-economic conditions augment these difficulties. If ELL students are to be “competitive” in school, the gap between home and school cultures must be lessened.

Science curriculum must be culturally relevant. The conditions that ultimately disadvantage minority students must be addressed through practices that provide students the opportunity to become literate-based on a curriculum with meaningful experiences that integrate their indigenous knowledge, and supplement it when necessary. If it is noted that a student does not have a particular understanding or experience, then the teacher must decide not to base the learning activity on the assumption that the student can tap into prior knowledge. The teacher must either modify or change the requirement that calls for prior knowledge that may be foreign to the student or provide the experience that will allow the student to construct that required knowledge.

For example, the teacher may want the students to understand seasonal changes in trees. Asking students to bring pictures cut from magazines at home that show these changes in trees assumes that the students have had much contact with trees and that magazines are common in their home. The teacher who understands the students’ indigenous knowledge might ask them to select a favorite tree in their neighborhood and keep a journal (words and/or pictures) of how it looks each month throughout the year. The activity can be further contextualized by including the community history during the
tree’s lifetime, the tree’s environmental impact, and representing spirit of the tree in art and music. Students can interview elders about how plants were used in their family.

Asking students to interact with family elders allows for intergenerational knowledge to be used to make connections to new school-based knowledge or concepts. It could be that students will work in Spanish during this experience and then the teacher can bridge to English by matching science words that often are similar due to their Latin origins. The teacher can use the student examples as starting points that allow students to make important connections to the classroom learning. Another example might be to give students a tree-trunk wafer (i.e., a cross section of a tree trunk that shows the growth rings and consequently the age of the tree) to take when they interview a community or family elder. They may ask the person for an interview that recreates a historical timeline based on the tree rings and includes information about how plants/trees have played a role in their life. The teacher can include other questions that will elicit student responses from which he or she will continue on a path of culturally relevant pedagogy.

**STUDENT DISCOURSE TO BUILD UNDERSTANDING**

Inherent in a quality science curriculum for second language learners is a focus on discourse. This focus on discourse is the tool that leads students through the learning journey. They synthesize the information from indigenous knowledge and the new experience into a concept, and then they take the concept through their language center/s and finally present it in words. Therefore, science-learning experiences for English language learners should include learning strategies that are rich fields for the development of discourse.

García’s (1991) analysis of descriptive research documented instructional practices that have led to success for students who bring diverse languages and cultures to the classrooms. He consistently found integrated student-centered curriculum where literacy was pervasive in all aspects of the instruction. Teachers organized instruction so that students worked collaboratively and student-to-student interaction was very common. The students were talking comfortably as they manipulate and interact with real or designed world materials in a safe social environment. The English language learners negotiated with the dominant English students to clarify meaning and vocabulary in this comfortable group setting. The teacher encouraged the conversations through probing questions and suggestions for new ways to explore.

Several other researchers have found that student-centered inquiry classrooms provide strong language and content development for students learning English (De Avila & Duncan, 1984; Kessler & Quinn, 1987; Mohan, 1986; Nieto, 2000; Thomas & Collier, 1995). The students are actively engaged in the processes of science. They observe, introduce variables, record, measure, predict, infer, inquire, and explore. In the active science classroom, students work in groups to talk out their thinking and planning. The oral language is imbedded in the context and based on commonly understood concepts.

Science classrooms, especially in second language settings, should be full of students talking—explaining their science activities and their science thinking to each other and to their teacher. Repeatedly hearing the new terms, having the opportunity to use the new terms in comfortable settings with their friends, and cueing in on similar word structure enforces the ability to produce the new vocabulary appropriately. Students build their understanding of science terms and concepts by talking about their experiences. This can only happen in social settings with peers, teachers, and family.
Misconceptions and Preconceptions

A benefit of this combination of interactive science and second language learning is the ability to probe deeply into the students’ understanding and vocabulary. The interactive curriculum makes it natural for students to speak about their science, and the choice in the use of languages allows them to do so confidently and comfortably. These are the conditions for learning, and they are critical for ELLs. At this juncture of curriculum and language, the teachers can identify when concepts are developing and when they are formed.

The world is very complex and direct observation does not often explain the underlying complexity. From our point of view, the earth stays still, the sun moves around the earth, heavy objects should not fly, and ice should sink in water. Therefore, the science learners will naturally have pre-conceptions that should be used to guide them to better understandings as they mature and explore more.

For example, after a bike ride one day, Rebecca told her dad that she knew the world is flat, but she wanted to get a good grade on a test at school, so she wrote that the world is round. She said, “If the world were not flat, then how can I ride my bicycle on our land?” Two years later, after a flight over the Atlantic, Rebecca remarked, “Look Daddy, the world is round, you just have to be far enough away to notice it.” Her pre-conception was perfectly legitimate based on her experiences. It was not wrong; in fact, it served her quite nicely until a new experience helped her move to a new perspective and she decided to let go of the old and hold on to the new.

Again, it is essential that the contextualized curriculum provide meaningful experiences which allow the students to make meaning and enhance understanding. In an isolated, teacher-directed curriculum, these pre-conceptions lay buried and form unsound bases for new understandings. However, in a meaningful curriculum, teachers engage students in experiences that expose their thinking. Teachers use this information about their thinking to help students develop and refine concepts. Teachers provide these kinds of opportunities when they provide experiences for students that result in them having to make decisions about their beliefs. “Constructivist teachers engage students in experiences that might engender contradictions to their initial hypotheses and then encourage discussion” (Brooks & Brooks, 1999, p. 112).

ASSESSING DEVELOPMENT TOWARD SCIENTIFIC LITERACY

When students learn science in language-rich social settings, teachers use ongoing, multiple, and varied assessments that do not carry the high stakes of traditional “wait until it is too late to modify your understanding” type testing. Through the oil spill activities, Ms. Loya had many opportunities to assess her students’ understanding of charting, reading graphs, solving problems, language comprehension, the use of a database, and their concern for the environment. Listening to the dialogues provided “spot checks” into their content and language development. Informal and formal evaluations of written work provided evaluative “snap shots” of their progress.

Traditional assessments and high-stakes tests are based in reductionist thought. They emphasize testing at an end point and imply that learning is terminal rather than ongoing. The short-answer tests monitor small bits of information that are heavily dependent on dominant language and vocabulary. True science learning is much more complex than correctly identifying a term. Quality ongoing assessments monitor the learner in her/his progress along the journey of science literacy.

Therefore, in a second-language learning environment, a spectrum of assessments is designed to gather data about the learner’s growth in four realms of understanding: 1) their ability to question about their local environment and, as they mature more, to
question their larger world; 2) their ability to design science investigations; 3) their increasing understanding of science concepts; and 4) their ability to communicate their scientific thinking in the home language and the target language. A variety of tools are used to gather data from the students in each of these areas. The teacher keeps in mind that the learner is developing scientific literacy in two languages, and assesses growth in these four realms.

The tools used to assess this growth are often embedded in the learning context rather than isolated testing experiences. Therefore, the teacher keeps ongoing reports about the students’ learning using a variety of tools. These include, most often and most naturally, listening to the student’s dialogue about their science experiences. This often leads the teacher to use probing questions to elicit more explanation from the students in order to get better insight into their thinking. Sometimes, the teacher may interview students to help determine how they are connecting the new experiences to prior knowledge, how they are modifying their conceptual understanding, how they are connecting to the non-school world, and to determine their feelings about their own learning progress.

Written and short answer assessments can also be important components of the assessment spectrum. The use of written assessments deserves a word of caution, however. Often students’ science concept development in a rich learning context outpaces their written, and sometimes, their oral vocabulary. Converting the complex thought in science literacy into oral language (it is even difficult in the first language, and more so in the second language) elevates the stress and difficulty level. Then, to further convert it into a written language forces the student to use a narrow tool as a descriptor of their complex learning. Therefore, written and short answer assessments can and should be used as part of the spectrum of assessment, but the complexity of the learning demands other assessments as well.

Teachers assess ELLs by monitoring student language use to make sure they are both understanding content as well as progressing in their acquisition of English and comprehending what is being discussed in written and oral information sources. On one of the neighborhood clean-up walks, Ms. Loya’s students noticed a line of ants on the sidewalk. Diana placed a stick in their path to see what would happen. The ants climbed over the stick and continued on. Ms. Loya asked her to explain what happened. Then she asked Diana if she could design a test to see if the ants always stayed in the line. Diana moved the stick with the ants on it a few inches out of the line. They watched, and Diana began telling Ms. Loya why she thought the ants were moving back to the line. She tried moving the stick even farther away several times while observing the results. She went on to elaborate about ants she had seen at her house, using English and Spanish. In this experience, Ms. Loya was able to assess Diana’s desire to explore and investigate, her ability to design investigations, her respect for life, her explanations about the event, and her language development. With this information, Ms. Loya knew how to design the next learning experiences. Back in the classroom, Ms. Loya offered Diana opportunities to learn more about ants using a search engine such as Ask Jeeves or Google.

CONCLUSION

Scientific literacy is an important goal for all world citizens. Unfortunately, in schools across our nation, those who are marginalized and assigned to scientific illiteracy are often ELLs who have been underrepresented in science education in U.S. schools. The idea is that they need to learn English first before they can “handle” content. The consequences of this perception are severe. ELLs will learn English but at the expense of their education. The education experience often determines for the learners their job
opportunities, their opportunities for higher education, their ability to communicate and problem solve in society, and their ability to confidently contribute to home and society. If we do not provide the empowerment that comes with science literacy, science education continues to serve as a gatekeeper, limiting English language learners' understanding about their world and the ability to access societal roles of power and control. The scientifically literate English language learner has the potential and ability to influence public life and contribute to the social good. This citizen is empowered through her/his understanding of the world and the ability to explore and address problems and issues therein.

We call for an inclusive science education that values the contributions of all learners and builds scientific literacy so that all citizens can effectively navigate a personal journey through life in a manner that is molded by culture and personal desire. Therefore, that science will be learned in an integrated context that is relevant to the learner’s world and enmeshed in a language-rich environment. Knowledge grows as concepts develop and language is the tool to communicate the concepts. Language skills and science concepts develop together in a natural context rather than in an isolated and fragmented manner. The following ideas are important when working with ELLs in the teaching of science:

- Traditional science teaching has a role in reducing English language learners' scientific literacy and their access to societal roles of power and control.
- Science education embedded in the integrated context of environment and culture is more inclusive for English language learners and builds scientific literacy.
- This integrated and contextual science education is constructivist and interactive, is linked to the personal and indigenous knowledge that the learner brings to the classroom, and allows many opportunities for students to discourse about their learning.
- The English language learner's understanding of science should be assessed via an ongoing spectrum of varied and multiple methods to provide a record of the student's progress along the journey to scientific literacy.

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