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# EXPLORING ENGLISH LANGUAGE LEARNERS (ELL) EXPERIENCES WITH SCIENTIFIC LANGUAGE AND INQUIRY WITHIN A REAL LIFE CONTEXT

A dissertation submitted in partial satisfaction
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

EDUCATION

by

Lisa M. Algee
December 2012

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**Abstract**

**Exploring English Language Learners (ELL) Experiences with Scientific Language and Inquiry within a Real Life Context**

**Lisa M. Algee**

English Language Learners (ELL) are often at a distinct disadvantage from receiving authentic science learning opportunites. This study explored English Language Learners (ELL) learning experiences with scientific language and inquiry within a real life context. This research was theoretically informed by sociocultural theory and literature on student learning and science teaching for ELL. A qualitative, case study was used to explore students' learning experiences. Data from multiple sources was collected: student interviews, science letters, an assessment in another context, field-notes, student presentations, inquiry assessment, instructional group conversations, parent interviews, parent letters, parent homework, teacher-researcher evaluation, teacher-researcher reflective journal, and student ratings of learning activities. These data sources informed the following research questions: (1) Does participation in an out-of-school contextualized inquiry science project increase ELL use of scientific language? (2) Does participation in an out-of-school contextualized inquiry science project increase ELL understanding of scientific inquiry and their motivation to learn? (3) What are parents' funds of

knowledge about the local ecology and does this inform students' experiences in the science project? All data sources concerning students were analyzed for similar patterns and trends and triangulation was sought through the use of these data sources. The remaining data sources concerning the teacher-researcher were used to inform and assess whether the pedagogical and research practices were in alignment with the proposed theoretical framework. Data sources concerning parental participation accessed funds of knowledge, which informed the curriculum in order to create continuity and connections between home and school. To ensure accuracy in the researchers' interpretations of student and parent responses during interviews, member checking was employed. The findings suggest that participation in an out-of-school contextualized inquiry science project increased ELL use of scientific language and understanding of scientific inquiry and motivation to learn. In addition, parent' funds of knowledge informed students' experiences in the science project. These findings suggest that the learning and teaching practices and the real life experiential learning contexts served as an effective means for increasing students' understandings and motivation to learn.

Acknowledgements

First and foremost, I would like to thank the students, parents, science educators, and research assistants who participated in this study. I appreciate their willingness, effort, and committment to fully engage in all aspects of this study. Second, I would like to thank my committee for their continued support throughout my journey as a doctoral student. I appreciate their time, advice, and guidance through the many steps which culminated into this manuscript. Third, I would like to thank my family for their unwavering support and patience.

# Chapter 1: Introduction

## Statement of the Problem

The National Science Education Standards (NSES) state that educating a scientifically literate populace is the *most important task before us as a nation* (National Research Council, 1996). For this reason, the standards delineate what students need to know and understand in order to become scientifically literate at different grade levels. The National Commission on Excellence in Education purports the same claim, "There can be no doubt that scientific literacy…is now *more important than ever before*."

The intent of the Standards is to provide an opportunity for all students to become scientifically literate. The phrase, "Science standards for *all* students" embodies both excellence and equity (National Research Council, 1996, p. 2). The Standards apply to all students, regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science. Different students will achieve understanding in different ways, and different students will achieve different degrees of depth and understanding depending on interest, ability, and context. But all students can develop the knowledge and skills described in the Standards, even as some students go well beyond these levels (National Research Council, 1996, p. 2). What's interesting about this statement is the term different. Who are these different students and what makes them different?

The NSES refers to these different students as those who traditionally have not received encouragement and opportunity to pursue science- women and girls, students of color, students with disabilities, and students with limited English proficiency. According to the NSES, teachers can accommodate these students by (1) how they design their classrooms, and (2) which instructional techniques they use. This will help ensure that all students have equal opportunities to participate in learning activities. For example, students with physical disabilities might require modified equipment; students with limited English proficiency might be encouraged to use their own language as well as English and to use forms of presenting data such as pictures and graphs that require less language proficiency; students with learning disabilities might need more time to complete science activities (National Research Council, 1996, p. 37).

Given the diversity of students' needs, experiences, and backgrounds, and the goal that all students will achieve a common set of standards, schools must support high-quality, diverse, and varied opportunities to learn science (National Research Council, 1996, p. 221). We know, as stated above, that science standards are for all, but English Language Learners (ELL) continue to lag behind their native English-speaking peers in science achievement. For example, as a nation, 43% of eighth graders were below the basic level in science achievement. Of the Hispanic eighth graders in the nation, 67% were below the basic level in science achievement. Specifically, in California, 56% of the eighth graders were below the basic level in

science achievement, and of the Hispanic eighth grader in California, 73% were below the basic level in science achievement (National Assessment of Education Progress, 2005). The question is, "Why are these students so far behind native English-speaking students?"

Unfortunately, there are a plethora of reasons why ELL are not receiving the science education they deserve. Some of the main factors include: inadequate curriculum, lack of teacher preparation, lack of time due to policy constraints, and lack of science supplies (Fradd, Lee & Saxton, 2001; Lee & Avalos, 2002; Lee, 2003; Lee, 2005). These deficiencies ultimately hinder students' development of scientific literacy. With each passing year, the teaching and learning of science becomes progressively more complex and if students are not exposed to scientific ways of thinking and doing in their early years, they are at a distinct disadvantage from those who are. Catching up with both the content and process of science creates an up hill climb for many ELL which unfortunately often leads to discouragement and feelings of apathy and alienation toward and about science.

But perhaps even more problematic is how a lack of instruction in the development of scientific concepts actually impedes the development of a certain degree of voluntary control in scientific thinking. This element of voluntary control is a product of the instructional process itself and "plays a decisive role in determining the entire fate of the child's mental development during the school age, including the development of his concepts" (Vygotsky, 1987, p. 177). Thus, when

children are denied access to science, it is not just an issue of subject matter, but more importantly, the intellectual potential of each child, which, ultimatley affects the collective potential of society for continual and progressive growth and development.

Even the National Science Education Standards state, "Students cannot achieve high levels of performance without access to skilled professional teachers, adequate classroom time, a rich array of learning materials, accommodating work spaces, and the resources of the communities surrounding their schools. Responsibility for providing this support falls on all those involved within the system" (National Research Council, 1996, p. 2).

And who are the participants within this system? Teachers, administrators, science teacher educators, curriculum designers, assessment specialists, local school boards, state departments of education, the federal government, students, parents, scientists, engineers, businesspeople, taxpayers, legislators, other public officials, and those who work in museums, zoos, and science centers (National Research Council, 1996). Essentially, the responsibility belongs to all of us.

**Purpose**

The purpose of this study is to explore ELL learning experiences when the deficiencies stated earlier are addressed. The intent of this study is to provide a group of ELL an opportunity to experience an authentic science experience which fosters the development of scientific language and inquiry skills. By accessing students' intellectual resources: prior knowledge and experiences, everyday and native

language, and parents' funds of knowledge to inform the teaching and learning practices, the hope is that this will create a learning environment which fosters continuity between students' lives and their experiences in this study. Through this intersection, students may not only develop scientific language and inquiry skills, but also interest and motivation to engage in their own inquiry projects and share their knowledge with their families. By building connections between home and school, i.e., in this case, an out-of-school inquiry science project, students may perceive continuity and a connection with science experiences, rather than apathy and alienation toward them.

A ***delimitation*** of this study is that all student participants are ELL, meaning, their first language is not English, but rather Spanish. As a result, findings from this study will pertain only to ELL, and because this is a case study, only to these particular ELL. A potential ***limitation*** of this study is the dual role of the researcher as a teacher (teacher-researcher). To increase objectivity, a research assistant evaluated whether pedagogical and research practices are aligned with the guiding principles in the theoretical framework. Another potential limitation is the small sample size and the inability to make generalizations.

**Research Questions**

**RQ1:** Does participation in an out-of-school contextualized inquiry science project increase ELL use of scientific language?

**(a)** Individual case study analysis

**(b)** Cross case study analysis

**(c)** Interactive instructional group analysis- food webs

**RQ2:** Does participation in an out-of-school contextualized inquiry science project increase ELL understanding of scientific inquiry and their motivation to learn?

**(a)** Individual case study analysis

**(b)** Crose case study analysis

**(c)** Interactive instructional group analysis- modes of inquiry

**RQ3:** What are parents' funds of knowledge about the local ecology and does this inform students' experiences in the science project?

**(a)** Analysis of each parent's funds of knowledge with each case study's inquiry project

## Chapter 2: Review of Literature

It is important to note that the approaches from the literature may inform the learning and teaching practices of science for the participants in this study, however, even though the participating subjects are ELL, they are each unique with different experiences, prior knowledge, funds of knowledge, and interests. Thus, generalizations of effective techniques for ELL in the literature cannot necessarily apply to all ELL, and consequently, may or may not be relevant to the participating ELL in this study.

As Gutierrez & Rogoff (2003) have suggested, attending to individuals' linguistic and cultural-historical repertoires is important in order to understand the propensities of people with certain histories of engagement. When trying to understand the social and cultural influences on learning with a particular group, and for that matter, within a particular group of people, it is important not to make assumptions, namely, that characteristics of cultural groups are located within individuals as "carriers" of culture (Gutierrez & Rogoff, 2003).

Guitierrez & Rogoff offer a very pertinent and profound point for all teachers and educational researchers to consider. That is, that cultural differences are attributed to variations in peoples' involvement in common practices of particular cultural communities. Applying this approach within a learning community would involve students receiving multiple forms of assistance and participating in rigorous learning activities that extend their initial approaches to learning and participation.

As a result, students would have ongoing opportunities to assume new roles and learn new approaches. This includes providing ELL with integrated curriculum, effective instructional strategies, access to educational resources, and multiple points of entry for participation in engaging activities with their peers, parents, teachers, science educators/scientists, and community members.

**Integrated Curriculum**

Appropriate instructional materials are essential for effective instruction, but high quality materials that meet national and state standards are difficult to find and even less likely to be available in inner-city schools where non-mainstream students are concentrated (National Science Foundation, 1996; Barton, 2003). Curriculum which integrates scientific inquiry, home language and culture, and English language and literacy development has proven to be highly effective for ELL because the subject area, in this case science, provides a meaningful context for English language and literacy development, while advancing English skills provides the medium for engagement with academic content (Lee, 2005, p. 492).

According to Stoddart and colleagues (2002), English language learners do not have to learn English before they learn science. In fact, the relationship between science learning and language learning is reciprocal and synergistic, i.e., through the contextualized use of language in science inquiry, students develop and practice complex language forms and functions. And reciprocally, through the use of language functions such as description, explanation, and discussion in inquiry

science, students enhance their conceptual understandings. This synergistic integration not only enhances language development and the learning of science content, but also promotes the development of higher-order thinking skills (Stoddart, Pinal, Latzke, & Canaday, 2002). Thus, learning becomes a three-fold exchange of students' intellectual resources (home language and culture), scientific inquiry, and language and literacy development.

Specific examples of this integration were developed by (Fradd, Lee, Sutman, and Saxton, 2002), for Hispanic, Haitian Creole, and monolingual English-speaking elementary student of White and African American descent. Curriculum units on matter and weather were tested with 4th grade students at six elementary schools in a large urban school district. At the end of the units, the researchers discovered that students from all ethno-linguistic groups showed statistically significant achievement gains in science knowledge and inquiry.

Likewise, additional researchers developed inquiry-based curriculum for 3rd and 4th grade students. Integration of English language and literacy and the incorporation of students' home language and culture were infused within the standard based lessons. Units for 3rd grade addressed measurement and matter and 4th grade units addressed the water cycle and weather. Researchers also trained teachers to use an inquiry framework, which provided both guidance and scaffolding for teachers and students. Initial guidance was explicit at first, but once the students became familiar with the steps of inquiry contained within the inquiry framework

(Questioning, Planning, Implementing, Concluding, and Reporting), instruction became less explicit, more complex, and student initiated. Students were assessed on inquiry skills at the start and end of the school year.

The results revealed significant increases in students' ability to conduct inquiry in general and to employ each of the specific skills of the inquiry framework (Cuevas, Lee, Hart, & Deaktor, 2005). However, the authors reported two limitations: (a) the inquiry framework defines science inquiry as hypothesis-driven investigations and does not include or demonstrate other forms of inquiry; and (b) it does not bring science to the experiences of non-mainstream students in a way to help them critically analyze scientific practices and the role in social, political, and economic power dynamics (p. 342).

These limitations bring an important question to mind, "What is the purpose of teaching science to today's ELL?" For some researchers, as this article suggests, it is to increase students' ability to conduct inquiry in general and to employ each of the specific skills of the inquiry framework. These learning objectives are very important, but, as the limitations state, the learning perspective is narrow, leaving out other forms of inquiry and the social, political, and economic impacts on science.

For others, such as Rosebery and colleagues (1992), Warren and colleagues (2002), Wells (1999), and Lemke (2001), the purpose of teaching and learning science encompasses a "broader, or social view" (Dewey, 1915, p. 5-6). This view involves providing generative learning experiences which stem from students' interests and

intellectual resources to engage collaboratively in an authentic scientific inquiry experience, which, in the end, results in the development and appropriation of scientific ways of thinking and doing.

This view situates the learning within specific contexts and from multiple disciplines (Lemke, 2001). When students learn how science is contextualized with other disciplines such as social science, math, language, technology, and economics, they begin to see the relevancy of learning science because it is a reflection of how they experience their world. Each day is not experienced from single disciplines presented in discrete units over one-hour periods, but rather from interdisciplinary and highly contextualized experiences. Thus, their learning environments should reflect their experiences in life as well. This new approach is far more real and personally meaningful because it echoes their daily life experiences within their world.

**Instructional Strategies**

It is important to strike a balance between the required California science state standards and the most efficient and beneficial ways of teaching them to ELL. According to Merino & Scarcella (2005), science curriculum must be manageable, involving the careful organization of standards to form connections around pivotal concepts (p. 2). Standards based instruction is especially effective with ELL when teachers: (a) organize standards in a coherent and meaningful way; (b) allow ample time for deep,conceptual understanding; (c) use templates, frames, and models for

organizing conceptual knowledge and language development; and (d) make connections with additional core domains which can reinforce science learning and language, in other words, a multidisciplinary approach.

From this it appears ELL tend to learn best when instruction is chunked into meaningful units, spaced over longer periods, and when the instructional format is varied (Gandara, 1989). They also need instruction which in organized in such a way where not only science content is scaffolded, but scientific language is as well. And finally, there appears to be a need to integrate and make connections with other subject areas in a meaningful and relevant way. To unpack this, lets first start by examining effective strategies for scaffolding science content and scientific language.

It is important to first analyze the language demands of a science lesson. Educators need to ask themselves the following questions: What do ELL students need to be able to do with language in order to accomplish the learning objectives? Does she/he possess the necessary vocabulary to understand the lesson? Does she/he understand the semantics of scientific concepts and the multiple meaning of words when situated within particular contexts? Does she/he understand the mechanics of syntax with scientific language when speaking and writing? All of these questions must be addressed before effective instruction can occur. One way to do this is through both individual and small group assessments.

For example, the educator could show a student(s) a list of five scientific concepts that are semantically related and ask the student(s) to organize them in a

meaningful way. A specific example of words might be: sun, plants, herbivore, carnivore, decomposer, and food web. Since the educator is assessing conceptual knowledge, she/he could provide both the word and a picture of the word in case there is limited English proficiency. This type of assessment determines whether a student understands the semantic relationship between the words based on how they position the cards in relation to each other. This is one form of assessment that could take place before teaching a lesson (to determine prior knowledge and experience) and after teaching a lesson (to determine what the student has learned).

Once students' science content knowledge and English language proficiency have been assessed, teachers can then use effective instructional strategies for their development. Some educators have proposed unique ways to incorporate both the scientific content and scientific language into effective, instructional strategies (Hansen, 2006). For example, students' native language, in this case Spanish, can be used as a cognitive resource for understanding scientific concepts in English. These words are called cognates and serve as semantic links from one language to another. For instance, the cognate for mountain in English is montana in Spanish. The cognate for describe in English is describir in Spanish. Thus, one can see from this example that not only are cognates semantic links for nouns, but also verbs. This cognitive resource, which is unique to Spanish speakers, can be used in both the teaching and learning of science content and the appropriation of scientific language.

Another successful instructional strategy for ELL is to show how some words have multiple meanings based on how they are situated within particular contexts. For example, Moje and colleagues (2001) discovered how one student asked for clarification of the word 'quality' after completing an entire unit focused on air quality. This example demonstrates the importance of discussing how words often have multiple meanings based on their specific context. Rice and colleagues (2004), offer an instructional strategy. She suggests creating a word wall where both the teacher and students generate examples of how a particular word, such as force, can have multiple meanings.

These examples demonstrate how students understand this word from their perspective (prior knowledge and experiences). Once this is acknowledged, the teacher can extend students' understanding of this word to how scientists use the word by providing examples embedded in scientific text. In this way, the teacher is creating a connection through instructional congruence by starting from students' prior knowledge and experiences and expanding upon them through the use of a model, or in this case, scientific text (Lee & Fradd, 1998; Lee, 2003).

An additional tool for scaffolding students' understanding of how to structure one's writing, in other words, the proper syntax of scientific writing, is basically through the use of tools, i.e., a large pocket chart with a clear, plastic cover and paper strips with scientific words written on them. The teacher writes each word on a strip of paper and co-constructs with the students how to organize the sentences. For

example, words such as volcano, exploded, huge, violently, and above the mountain, are written on strips of paper (Hansen, 2006, p. 24). The teacher posts the strips randomly onto a large board and asks the students, "If a scientist were writing in his/her scientific journal, how would he/she organize these words into a sentence?" By asking the question in this way, the students become consciously aware as to how scientists speak and write. Consequently, they may reflect upon scientific text they have previously read, or refer to a scientific text in the present moment. From here, students talk amongst themselves as to how they think scientists communicate and one by one, the students volunteer to come up to the chart and place the paper strips where they belong.

This is an effective activity for bringing conscious awareness to the appropriate syntactic structure of scientific language through guided facilitation from the teacher and collaborative interaction with peers. Examples like these are very powerful because the students are taking the words from the board, which are randomly placed, and reconstructing them into their proper syntactic positions. In this example, we see how the theory of systematic instruction and collaborative interaction (Vygotsky, 1987; Wells, 1999) lead to the development of higher mental functions, such as the conscious awareness of scientific syntax.

Carrier (2005) proposes the use of science literacy objectives. These objectives focus on the literacy skills that all students need to effectively participate in science learning. They include the literacy skills needed to read, write, and orally

communicate about science concepts and principles and to participate in science activities in whole class or small group activities. They are based on the specific content objectives of science lessons, and they include not only the vocabulary of science, but also strategies for effective reading, writing, listening, and note taking, in addition to the academic language functions needed to participate in science learning. Lastly, these objectives are written in "student-friendly" language in order to clearly communicate the learning objectives in addition to having students assess their own progress throughout the instructional process (Carrier, 2005, p. 2).

An example of science literacy objectives would state the following two objectives: (a) I can write about the differences between animal and plant cells using scientific vocabulary; and (b) I can give an oral report about my cell observations, describing size, shape, and cell contents (Carrier, 2005). These objectives are often accompanied with another piece of paper, or PowerPoint screen, which contains specific descriptive vocabulary, such as words describing cells: patterned, rectangular, regular, smooth, clumps, random, square, etc., in addition to parts of a cell: chloroplasts, vacuoles, cell membranes, nuclei, and endoplasmic reticulum. Students use these resources in conjunction with sentence frames. These sentence frames serve as templates for students to, not only learn the content and the descriptive words that describe the content, but also how to organize the words appropriately when speaking and writing. Furthermore, students will recognize and comprehend scientific texts

when reading and seeking further information on, in this case, the distinguishing differences between plant and animal cells (Carrier, 2005).

In this example, the teacher actually models how to use sentence frames in addition to the word lists, both orally and in writing. She/he shows students examples of scientific language from texts, thus providing a model. The teacher then draws students' attention to these examples, writes them on the board, and reads them with her/his students. This not only brings conscious awareness of how the words are pronounced, but also the syntactic structure of the sentences. In this example, one can see the theory of imitation in practice. The teacher demonstrates how scientific language is constructed and provides sentence frames to assist students in the action of doing so. Providing demonstrations through the use of templates, serves as a model for effective scientific content knowledge and appropriate scientific ways of speaking and writing. This instructional tool is very much aligned with what Vygotsky had in mind for the function of instruction, i.e., instruction which leads learning and thus development (Vygotsky, 1987).

In Duran and colleagues' (1998) study, they demonstrate how tenth grade Mexican immigrant students learned biological concepts while engaged in instructional activities which showed students how to use semiotic tools to construct and express conceptual meaning. The instructional sequence included: (a) using diagrams, such as a cell, as a visual text and scaffold to identify content and enable students to "ventriloquate" teacher talk; (b) constructing conceptual expressions and

moving from "ventriloquating" teacher talk to expressing concepts and using their own explanations to answer the teacher's questions; and (c) using learned discursive resources to analyze and write an interpretation of a real life experience.

For example, students were able to analyze and interpret the biological concept homeostasis as an organizing framework to interpret change in human functioning. Specifically, they used diagrams and lists of terms as tools for thinking and speaking. They then constructed their own diagrams of homeostasis and generated questions about regulatory mechanisms. As students applied the discursive resources they had learned, they became more actively involved with their instruction (Duran, Dugan, Weffer, 1998, p. 333).

In addition, as students became more proficient with these semiotic tools, the teacher withdrew science authority and students assumed responsibility for constructing meaning using their own discursive resources. The findings demonstrate the importance of this Vygotskian approach to learning and understanding of biological science concepts (Duran, Dugan, & Weffer, 1998).

Another example of facilitating students' scientific ways of speaking, thinking, and writing is through the use of second-hand investigations. According to Magnusson and Palincsar (2004) as cited by Haneda & Wells (2010), second-hand investigations are basically text-base investigations where students read the entries of a 'scientist.' Although the scientist is a fictitious character, created by the teacher, the students believe they are privy to a real-life scientist's notebook. These entries not

only serve as a model for how scientists think and what kinds of questions they ask, but also how scientists construct knowledge and write their findings. In Haneda & Wells (2010) study, they discovered that "students explored basic scientific concepts and the language through which they were expressed, and they also formulated their developing ideas in writing, both in personal reflections and in letters to the scientist" (p. 20). These second-hand investigations served as a semiotic tool for effective approaches to learning scientific inquiry and scientific writing.

**Educational Resources**

Not only can teachers and capable peers lead students' learning and thus development, but tools can play a significant role as well. Having access to books, magazines, maps, globes, diagrams, computers, microscopes, specimens, live animals, video-recorders and tapes, audio-recorders, and other materials can provide multiple-points of entry for all students to co-construct knowledge and also demonstrate, through their own representations, what they have learned (Wells, 1999; Barton, 2003; and Lee, 2005). These tools and procedures become devices that "allow students to extend their everyday experiences of the world and help them organize data in ways that provide new insights into phenomena" (Bradsford & Donovan, 2005, p. 405).

Since many schools lack science supplies, particularly inner city and rural schools, this should not impede teachers from teaching science altogether. With a little creativity and the use of everyday, household items, teachers can do many of the

science inquiry lessons without expensive equipment. In fact, everyday household items may be more meaningful and relevant for students, as well as more affordable and easier to maintain than expensive equipment. An example of how household items can serve as valuable resources for students was mentioned at the beginning of this proposal when discussing how Wells (1999) and colleagues had students bring containers from home to construct their own elastic-powered rollers.

However, sometimes more advanced tools are needed in order to fully investigate a phenomenon. For example, Professor Bell and his student teacher, Bowen (2004), created a research project that integrated the use of digital cameras and digital microscopes to capture images of each developmental stage in the life-cycle of the Painted Lady butterfly. Her high school biology students were often perfectionists, trying to capture the "perfect" image (p. 24). According to Bowen, not only did the images supplement students' journal notes and sketches, but the students also valued the hands-on approach to learning natural phenomena, such as the life cycle of a butterfly, through the use of technology.

Furthermore, with time-lapse videos, students were able to extend their observations in ways that would not be possible without technology (p. 27). In the end, Bowen's students felt proud and viewed themselves as "Painted Lady" experts and developed greater respect for the importance of observations and technology in the development of scientific knowledge. They not only shared their knowledge with

each other, but also extended their knowledge to others in the community, a vital part of scientific research.

Additional educational tools, such as computer programs which scaffold language and science content, are also beneficial for ELL. According to Medina-Jerez and colleagues (2007), on-line learning environments which allow ELL to "freely switch audio and text language" i.e., from English to Spanish and vice versa, have proven to be a valuable resource (p. 55). In fact, according to Johnson & Swain (1997) and Diaz & Flores (2001) as cited by Medina-Jerez and colleagues (2007), "incorporating technology with multilingual scaffolding correlates to findings that the cognitive and social foundations needed for academic success are based in a student's native language" (p. 55). This relates to the instructional power of using cognates with ELL as mentioned earlier by Hansen (2006). Thus, when students' intellectual resources are accessed during the instructional process, it empowers them to make connections with what they know (their native language) and what they are coming to know (English). Interactive tools, such as text-to-speech (from English to Spanish and vice versa) add conceptual richness and create connections between students' native language and school (academic) language.

Another effective educational resource for ELL is visual information in the form of graphic organizers, charts, pictures, videotapes/DVD's, PowerPoint presentations, slide shows, and real-life objects. Visuals are a source of concrete information and assist ELL with making connections between objects and words.

This is particularly helpful to beginning ELL because it makes both content and language more comprehensible. For example, according to Keenan (2004), "videos show students experiments and demonstrations and put much of the content into "kid friendly" terms. They are also repetitive and may even include songs" (p. 49).

In addition, graphic organizers such as diagrams, as mentioned in the Duran (1998) study, "increase the speed in which students learn language and concepts" (Merino & Scarcella, 2005, p. 6). When these semiotic tools are co-constructed through guided facilitation with a teacher and/or through peer collaboration, they serve as valuable learning resources for scientific ways of acting, speaking, and writing. Thus, visual information serves as an effective medium for both learning and teaching, especially when students are either learning a new language or transitioning form one level of English proficiency to another, i.e., from beginning to intermediate English proficiency.

**Multiple Points of Entry for Participation**

In order to foster comprehension in an area of scientific inquiry, students need to learn the content by actively engaging in the process of scientific inquiry. Specifically for ELL, this involves actively attending to and participating in the instruction, rather than simply being "exposed" to it (Gandara, 1997, p. 6). In every article examined for effective instructional strategies for science learning with ELL, hands-on inquiry was discussed. The power of hands-on inquiry lies in students actively engaged in collaborative joint activity.

According to Lee (2005), hands-on activities provide opportunities for ELL to effectively display their understanding of science content in three ways. First, hands-on activities are less dependent on formal mastery of the language of instruction, thus reducing the linguistic burden on ELL. Second, collaborative, small-group activities provide informal opportunities for developing English proficiency in the context of authentic communication about science. Third, inquiry-based science instruction promotes students' communication of their understanding in a variety of formats, including written, verbal, gestural, and graphic. And finally, by engaging in science inquiry, ELL develop their English grammar and vocabulary as well as their familiarity with scientific genres of writing (Lee, 2005, p. 515).

In addition, there are many modes of inquiry, from classroom observations of a particular phenomenon or animal, to conducting investigations to discover solutions to problems, to designing experiments to find answers to questions, etc. Each mode of inquiry involves activity and activity involves people working together (using tools and creating artifacts) in order to achieve a common goal or purpose.

## Chapter 3: Theoretical Framework

Four guiding principles and a model framed this study. **Part 1** will discuss the principles which provide structure to this study. **Part 2** will discuss the process of how students navigated through the learning and teaching experiences of developing scientific language and inquiry using a model, *the spiral of learning and teaching through inquiry* (Wells, 2010).

### Part 1: Guiding Principles

**Principle 1: Accessing students' intellectual resources**

**Principle 2: Facilitating dynamic instruction and assessment**

**Principle 3: Practicing principles of inquiry**

**Principle 4: Providing opportunities to enact conscious awareness and volition in real life contexts**

**Principle 1: Accessing students' intellectual resources.** To begin with, children are naturally endowed with the ability to adapt and absorb their everyday experiences. Whether acquiring funds of knowledge from family members (Moll et al., 1992) or using everyday language for meaning making in or outside school contexts (Vygotsky, 1987; Ballenger, 1997; Wells, 1999; and Ash, 2008) children possess a natural propensity to imagine, create, and express themselves, particularly with respect to what interests them (Dewey, 1915, 1916; Wells, 1999).

In fact, according to Dewey (1916), children have their own natural dispositions. He states, "children are themselves marvelously endowed with: (1) the power to enlist the cooperative attention of others, (2) the flexible and sensitive ability to vibrate sympathetically with the attitudes and doings of those about them, (3) the intensification of interest and attention as to the doings of people, and (4) the native mechanism of their impulses all tend to facile social responsiveness" (p. 43).

From this, we can see that children already possess many mediational and social skills to participate with others in an engaging way, however, they may still need to be "rendered cognizant" of the aims and habits of the social group (Dewey, 1916, p. 3). Thus, the role of the teacher or science educator is to provide a learning environment which facilitates children's natural dispositions with dynamic instruction that "moves ahead of development" (Vygotsky, 1987, p. 212). When instruction leads learning and thus development, it "impels or wakens a whole series of functions that are in a stage of maturation lying in the zone of proximal development" (p. 212). The effects of both dynamic instruction and assessment will be discussed further in the next principle, Dynamic instruction and assessment.

As mentioned earlier, children's funds of knowledge are often acquired from their family. Specifically, this term is defined as "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (Moll et al., 1992, p. 133). These funds of knowledge include a wide variety of specializations, from agriculture and mining to

material and scientific knowledge. It is perhaps the most influential knowledge base from which children draw because it encompasses an accumulation of rich, saturated experiences developed and nurtured over an extensive period of time.

For this reason, it is important that both teachers and science educators tap into these funds and use them to make connections between home and school or informal learning centers. The benefits are four fold: (a) the teaching and learning is motivated by the children's interests and questions; (b) the learning is contextualized in real, authentic activities; (c) children's engagement with family members creates reciprocity and this in turn, builds mutual trust; and (d) children's family members can become cognitive resources for the teacher and students in their classroom (Moll, et al., 1992, p. 138).

Like Moll (1992), Gandara (1989) also proposes the need for building bridges between home and school, however, she suggests the need for community schools which foster participation by parents to help with carpentry, sewing, cooking, etc for fundraising purposes. According to Gandara, not only do parents feel valued, but their children also benefit from having their parents at their school more often. From this, ELL begin to see how home and school can co-exist and work together harmoniously. This can also lead to opportunities for parents to form alliances with their child's teacher, additional faculty members, and other parents to learn the unwritten codes of school success (Gandara, 1989).

In both of these examples from Moll (1992) and Gandara (1989), we see the significance of creating connections between students' homes and school by providing opportunities for parents to share their funds of knowledge within their children's schools and local communities. This connection fosters congruency, a vital and necessary connection which provides not only familiarity and a sense of feeling comfortable, but also a platform from which students can express themselves as whole persons, thus increasing the likelihood of reaching their full potential.

Like students' funds of knowledge, prior knowledge and experiences are often derived from children's learning experiences at home and essentially influence students' perceptions when constructing new knowledge (Bradsford et al., 2005). These concrete experiences build the basis for complex and abstract thinking. As students relate their prior knowledge and experiences to newly constructed knowledge, science learning becomes meaningful and relevant (Lee, O., & Avalos, M.A., 2002, p. 3). For this reason, it is essential to integrate students' prior knowledge and experiences into the curricular and science learning activities.

From the preceding paragraphs, it is clear how children's experiences with family members are highly influential in the development of their intellectual resources. Nevertheless, there still remains one intellectual resource, the most important, that I have not yet spoken of, the acquisition of language. Dewey considered it the "chief instrument" of learning (Dewey, 1916, p. 15). Wells (1999) defines language as a "rich and versatile resource from which a diversity of tools is

constantly being fashioned to mediate the modes of knowing that are involved in the full range of joint activities in which human beings engage" (p. 100). For Vygotsky, language, like other sign systems, metacognition, mnemonic devices, mathematical symbols, hieroglyphics, "acts as an instrument of psychological activity in a manner analogous to the role of a tool in labor" (Vygotsky, 1978, p. 52). For this reason, he considered sign systems, language in particular, the tool of tools.

Since language is considered the ultimate mediation tool which enables humans to practice and thus learn the cultural tool kit within interpsychological processes in order to thus transform and develop their higher mental functions (Vygotsky, 1978), it is essential to integrate and value students' everyday language during instruction. Since their everyday language is derived and developed from their daily experiences with their family and friends, it serves as an intellectual resource when constructing new knowledge at school. This resource is saturated with the "child's own rich personal experiences" (Vygotsky, 1987, p. 178).

It is important to note that students' everyday language includes their native language (mother tongue). According to Halliday (1993), a child's everyday language is essentially their foundational language from which all other languages build. Likewise, Vygotsky (1987), states that children use their everyday language to develop scientific language, which consists of abstract generalizations. Contemporary researchers, such as Ballenger (1997), Warren and colleagues (2002), and Ash (2008), have also discovered the significance of students' everyday language

when formulating scientific ways of thinking and doing while actively engaged in activity.

For example, Ballenger (1997) states that when Haitian children participated in 'science talk' during a lesson on mold, students used experiences outside of school as well as inside school. Specifically, students used moral language such as sharing their practices of cleanliness at home when discussing where mold grows and why. They used social intention and anecdotal evidence through storytelling when arguing and theorizing in scientific discussions. In this particular study, Haitian children used non-standard scientific language and everyday experiences to construct and understand science, however, they nevertheless engaged successfully in the steps of inquiry. The students, in their own way, clearly learned how to engage in scientific thinking.

Ash (2008) has also discovered the importance of everyday language in scientific knowledge construction through the use of 'thematic continuities.' According to Ash, thematic continuities are essentially thematic areas of interest which serve as scaffolds for inquiry in addition to frameworks for organizing disconnected science facts. They originate with the learners' everyday interests, and then, through more experience and formal schooling, are extended to a higher level of understanding.

Here we see from Vygotsky (1987), Ballenger, (1997), and Ash (2008), evidence of how students' everyday language is essentially a starting point for further

engagement in the learning process and ultimately with the development and eventual appropriation of scientific ways of thinking and doing.

We also see the critical function of formal or systematic instruction in the development of scientific concepts for it brings the content (scientific concepts) into conscious awareness. When this happens, the verbal definition of scientific concepts actually descends from the abstract to the concrete, and conversely, the everyday concept ascends from the concrete to the abstract. Although everyday and scientific concepts develop differently, they are "closely connected processes that continually influence one another" (Vygotsky, 1987, p. 219). They are also interdependent, with on strengthening the weakness of the other and vice versa (Vygotsky, 1987). For this reason, it is imperative that students' everyday language, which includes their native language, be integrated into the curricular and science learning activities.

Furthermore, Vygotsky believed that the development of scientific concepts was of tremendous significance, and thus should be of primary importance for schools to address since "the development of scientific concepts (i.e., true concepts) will inevitably clarify the most basic and essential general laws of concept formation" (Vygotsky, 1987, p. 167). For him, this was the key to understanding the whole history of the child's mental development. The importance of developing scientific concepts will be discussed in depth in the next guiding principle, Dynamic instruction and assessment.

Finally, one cannot ignore the significance of students' interests, for these often create not only the willingness to learn, but more importantly, the impetus to want to learn. The following quote from Dewey points out how important it is for teachers and science educators to unveil students' interests and to use them to unleash their inherent power (1897):

> I believe that these interests are neither to be humored nor repressed. To repress interest is to substitute the adult for the child, and so to weaken intellectual curiosity and alertness, to suppress initiative, and to deaden interest. To humor the interests is to substitute the transient for the permanent. The interest is always the sign of some power below; the important thing is to discover this power. To humor the interest is to fail to penetrate below the surface and its sure result is to substitute caprice and whim for genuine interest.

Like Dewey, additional scholars have incorporated the importance of students' interests into their research practices. For example, Wells (1999) and his research assistants, who happened to be teacher colleagues, examined how they could arrange for student's questions to play a more generative role in the planning of an energy unit. They started by brainstorming what the children already knew about energy (thus, tapping into their prior knowledge and experiences).

The children then began in the construction of their own elastic-powered rollers (bringing containers from home). Mishaps occurred during the construction and initial trials of winding the bands and seeing how far the containers moved. These mishaps became the object to improve, as the researcher, teachers, and students discussed them in detail and how they could improve upon them. They used paper to

construct a chart which served as a permanent record for their data collection. Testable questions were posed such as, “How far a roller would travel for a given number of turns of the dowel?” They also posed another question, “Why is it that some rollers travel to the left or right rather than straight?” These two questions were based on observations and in the children’s interest to find answers to them.

This is an excellent example of creating a learning opportunity which stems from students’ interests. The fact that Wells and his research group tapped into students’ prior knowledge and experiences about energy and how they connected this learning experience to home (by having students bring a container from home), in addition to extending the unit based on students’ questions and points of interest, is a clear indication that there was a genuine intent to situate the learning from the students’ perspective. In this example, the students’ interests actually set the tone for further classroom and research activity. This example is in alignment with Dewey’s quote about how important it is to discover students’ interests and recognize the power they have when acknowledged and integrated into the curricula, learning activity, and research design.

Like Dewey (1897) and Wells (1999), Barton (2003) also acknowledges the importance of incorporating students’ interests when providing opportunities for science in poor, urban communities where she works with homeless youth. In her book, “Teaching Science for Social Justice,” she and her colleagues set up a building project for students in an after-school science club at Hope Shelter in Well Springs

Texas. They bought ply-board for the students to construct planters for their community garden. Most of the students were excited to build and paint their own planters, however, one student in particular, Claudia, wanted to construct a desk for herself.

Initially, the research team was unsure about how to respond to Claudia since the other students were listening intently and waiting in anticipation for how the research team asked Claudia's request. The team could see that this was something Claudia really wanted to do and because they could see her desire and interest, they granted her request. Claudia "conceptualized, designed, and built her desk with only limited adult help" according to Barton (2003, p. 55).

Barton and colleagues took this opportunity to reflect on how Claudia created a sense of self in science when social norms and expectations promote a more fragmented picture. During this reflection, they also remembered visiting Claudia's home and seeing, for themselves, an empty refrigerator, empty shelves, and only a few pieces of furniture. Perhaps when formulating a response to Claudia's request, they remembered her unfortunate living conditions and could see that Claudia probably needed a desk for herself at home. Thus, not only did Barton (2003) and colleagues acknowledge Claudia's desire and interest to build a desk, they also granted her request based on Claudia's unfortunate real life home circumstances.

This example exemplifies how Barton (2001, 2003) re-crafts the research design to reflect new ideas about what constitutes science and students' identities in

the process. As students begin to recognize and exercise their voice and autonomy, in this case Claudia's request to make a desk for herself, they learn to become agents of change in their own lives and within the discipline of science, using their authority to challenge the traditional cultural practices of science and education (Barton, 2003).

**Principle 2: Facilitating dynamic instruction and assessment.** In order to understand why dynamic instruction and assessment are essential principles for creating an authentic science learning experience for ELL, it is important to discuss how the accumulation of social interactions within particular cultural contexts over an extended period of time determine individual growth and development. At the heart of this idea is Vygotsky's General Law of Cultural Development:

> "Any function in the child's cultural development appears twice, or on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an interpsychological category, and then within the child as an intrapsychological category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition. We may consider this position as a law in the full sense of the word, but it goes without saying that internalization transforms the process itself and changes its structure and functions. Social relations or relations among people genetically underlie all higher functions and their relationships" (1981b, p. 163) as cited by Wertsch (1985, p. 60).

From this quote, we know that higher mental functions (voluntary attention, logical memory, the formation of concepts (particularly scientific concepts), and the development of volition) all develop through social interactions. We also know that Vygotsky viewed higher mental functions as unique to humans because they involved

the use of language and other sign systems in order to guide and mediate cognitive activity (Wertsch, 1985).

Perhaps another reason why he focused on higher mental functions was due to the fact that after the Russian Revolution, he must have seen the toll of war and famine on the children of Russia. This may have influenced him to commit his life's work to helping both physically and mentally handicapped children. More specifically, perhaps he thought higher mental functions could serve as mental building blocks for the creative and ingenious thinking that was desperately needed to reconstruct a new society, and more importantly, to help children reclaim and rebuild their own lives.

If we apply these same principles to education, one could also postulate that the educator's goal is to observe how children actively engage in joint productive activity, i.e., what students do, say, and use (tools, both physical and semiotic) while actively engaged in an activity. From this, the educator can essentially reconstruct, using both individual and group assessments, the student's zone of proximal development. For it is within the child's zpd that "the transition from interpsychological to intrapsychological functioning can be made" (Wertsch, 1985, p. 67). This is no easy task and was precisely the focus of Vygotsky's research, "we shall place this transition from a social influence outside the individual to a social influence within the individual at the center of our research and try to elucidate the

most important moments from which it arises" (1960, p. 116) cited by Wertsch (1985, p. 61).

The following example is a brief summary of how this process occurs. It demonstrates how a child eventually comes to understand the significance of pointing (a sign system):

> A child points and attempts to grasp an object, however he/she in unsuccessful. When the mother comes to the child's assistance and realizes what his/her movement indicates, the situation changes. Pointing becomes a gesture for others, in this case, the mother. Only later, when the child can link his/her unsuccessful grasping movement to the objective situation as a whole, does he/she begin to understand this movement as pointing. It becomes a true gesture only after it objectively manifests all the functions of pointing for others and is understood by others as such a gesture. Its meaning and functions are created first by an objective situation and then by people who surround the child (Vygotsky, 1978, p. 56).

Here we see an example of how a sign system, pointing or grasping, is not understood by the actor (the child) until the sign is recognized or acknowledged by others, in this case, the mother. Once this occurs, the child can make a connection between pointing and successfully obtaining an object. Until this connection is made, the child will not understand how pointing at an object achieves the desired effect, obtaining an object in his/her hands. Thus, "an operation that initially represents an external activity is reconstructed and begins to occur internally for the child" (Vygotsky, 1978, p. 56).

This transformation from an interpsychological process into an intrapsychological process is the result of a long series of developmental events. "The process being transformed continues to exist and to change as an external form

of activity for a long time before definitively turning inward" (Vygotsky, 1978, p. 57). In addition, the use of external signs is also radically reconstructed. This developmental change in sign operations is similar to those that occur in language since aspects of communicative speech as well as egocentric speech turn "inward" to become the basis of inner speech (Vygotsky, 1978).

Based on this child-mother example, it appears that some sort of guided facilitation is required by a parent, another adult, or capable peer in order for the child to transform an external action into a recognized, meaningful action which then, eventually over time, becomes an internalized function with which the child can then, through his/her own volition, act. When this process is nurtured and developed, the child learns, and thus develops, within his/her zone of proximal development. Specifically, he defined the zone of proximal development as:

> The distance between a child's *actual developmental level as determined by independent problem solving* and the higher level of *potential development as determined through problem solving under adult guidance or in collaboration with more capable peers* (ibid) as cited by Wertsch (1985, p. 68).

He introduced the notion of the zone of proximal development in an effort to deal with two practical problems in educational psychology: (1) the assessment of children's intellectual abilities and (2) the evaluation of instructional practices. "With respect to the former, he believed that existing techniques of psychological testing focused too heavily on intrapsychological accomplishments and failed to address the

issue of predicting future growth, a major concern to Soviet psychology even today" (Wertsch, 1985, p. 67).

In assessing a child's mental age, the importance of conducting a separate analysis of the potential level of development derives from the fact that it may vary independently of the actual level. According to Vygotsky, "the state of development is never defined only by what has matured but rather with what is in the process of maturing" (Vygotsky, 1987, p. 208). The potential level of the child must be assessed in addition to the child's actual developmental level. In order to assess the actual developmental level, children are given a series of tests to complete on their own. Conversely, in order to assess the potential developmental level, the child is assisted with "demonstrations, leading questions, and by introducing the initial elements of the task's solution" (Vygotsky, 1987, p. 209).

With regard to the former, Vygotsky placed significant importance on instruction, particularly school instruction:

> "Instruction is only useful when it moves ahead of development. When it does, it impels or wakens a whole series of functions that are in a stage of maturation lying in the zone of proximal development" (Vygotsky, 1987, p. 212).

Furthermore, the kind of instruction Vygotsky had in mind was not concerned with "specialized, technical skills such as typing or bicycle riding, that is, skills that have no essential impact on development" (1987, p. 222), but rather had as its goal "all-round development," such as instruction in formal, academic disciplines, each of

which has a sphere "in which the impact of instruction on development is accomplished and fulfilled" (ibid.) as cited by Wertsch (1985, p. 71).

As stated earlier, Vygotsky believed that the development of concepts, particularly scientific concepts, gave rise to higher mental functions, such as conscious awareness and volition, because these higher mental functions are actually the products of effective instruction in formal, academic disciplines. The following quote elucidates this claim:

> Scientific concepts develop through an instructional process of causal thinking and in the development of a certain degree of voluntary control in scientific thinking. This element of voluntary control is a product of the instructional process itself (Vygotsky, 1987, p. 169).

For Vygotsky, instruction is an extremely powerful force in directing this process and "plays a decisive role in determining the entire fate of the child's mental development during the school age, including the development of his concepts" (Vygotsky, 1987, p. 177). In addition, "the focal point of development for the school age child is the emergence of the higher mental functions, functions which are distinguished precisely by intellectualization and mastery, by conscious awareness and volition (Vygotsky, 1987, p. 187). Vygotsky states this clearly in the following excerpt:

> It is indisputable that conscious awareness and the volitional use of concepts (i.e., the characteristics of the school child's spontaneous concepts that remain underdeveloped) lie entirely within the school child's zone of proximal development. They emerge or become actual in his collaboration with adults. This is why the development of scientific concepts presupposes a certain level in the development in spontaneous concepts, in connection with which conscious

> awareness and volition emerge in the zone of proximal development. Scientific concepts restructure and raise spontaneous concepts to a higher level, forming their zone of proximal development. What a child is able to do in collaboration today, he will be able to do independently tomorrow (Vygotsky, 1987, p. 220).

From these quotes, it is important to step back and think of a concrete example of how and why the development of scientific concepts is of fundamental importance. For example, when a child begins to associate a second concept, rose, to a very familiar and well known word, flower, "there is a long period during which the concept "flower" continues to stand alongside, rather than above, the concept of "rose" (Vygotsky, 1987, p. 193).

Here we see that the child, over time and through guided assistance from an adult or experienced peer, will become consciously aware that, yes, a rose is a flower, however, the rose is merely a type of flower. There are other types of flowers, such as daisies, tulips, gardenias, carnations, etc. With this realization, the child may begin to understand that the word flower is a generalization for all types of flowers and may position the word (concept) flower, above the word rose. This organized, "vertical, taxonomic relationship" of words is how scientific words and concepts are often structured and, according to Vygotsky, it can only be attained through guided facilitation during the instructional process (Wells, 1999, p. 29).

This example shows how the everyday concept, flower, which is initially situated within the concrete everyday experiences of a child, actually ascends to a more abstract level and thus, serves a completely different function. It now becomes

a generalization for specific types of flowers. This may appear to be a simple transition, but it is not. The way this transition occurs is through "systematic instruction" (Wells, 1999, p. 5).

Although Vygotsky does mention that scientific concepts develop through an instructional process of causal thinking and in the development of a certain degree of voluntary control in scientific thinking, he does not explicitly state what happens during the instructional process. He does however mention the significance of imitation. In fact, both he and Dewey mention imitation as a means for learning and thus further development.

For Vygotsky, "demonstrations and introducing the initial elements of the task's solution" enable teachers to both access and assess students' potential developmental level (Vygotsky, 1987, p. 209). For example, through assistance and/ or collaboration with an adult or more capable peer, a child may be able to solve a complex physics problem by watching a demonstration, however, this same child may be incapable of solving a math problem even when the teacher has provided the initial steps.

Thus, through the process of imitation, children are capable of doing much more under adult guidance and in collaboration with others. "In collaboration, the child turns out to be stronger and more able than in independent work. He advances in terms of the level of intellectual difficulties he is able to face. However, there

always exists a definite lawful distance that determines the differential between his performance in independent and collaborative work" (Vygotsky, 1987, p. 209).

Likewise, Dewey believed that imitation of means, which he states as an intelligent act, involves "close observation, and judicious selection of what will enable one to do better something which he already is trying to do. Used for a purpose, the imitative instinct may, like any other instinct become a factor in the development of effective action" (Dewey, 1916, p. 35-36). Here we see both Vygotysky and Dewey very much aligned with the power of imitation as an instructional tool and, if closely observed by students and actually pursued in collaboration with others, leads learning and thus development.

Thus, children not only begin to learn how to approach a problem or topic of discussion, but also develop the higher mental functions, specifically conscious awareness and volition (Vygotsky, 1978) or habits (Dewey, 1916). For Dewey, "modes of thought, of observation and reflection, enter as forms of skill and of desire into the habits that make a man an engineer, an architect, a physician, or a merchant" (p. 48). More specifically, "development, with respect to the special traits of child and adult life, means the direction of power into special channels: the formation of habits involving executive skill, definiteness of interest, and specific objects of observation and thought" (Dewey, 1916, p. 50).

These higher mental functions and habits were of utmost concern and interest for both Vygotsky and Dewey because not only did they elevate the intellectual

potential of each individual, but also the collective potential of society in order to foster continual and progressive growth and development. Thus, it is clear both Vygotsky and Dewey put a particular emphasis on higher, more intellectualized ways of thinking, i.e., higher mental functions and habits involving executive skill, on individual and continual development. They were both very interested in a child's full attainment of intellectual and social growth through collaboration (Vygotsky, 1978) and dependence (Dewey, 1916). They both knew that children needed others, particularly adults and capable peers, to guide and facilitate their potential growth and development.

In addition, they both emphasized the importance of instruction, although Dewey was very much against formal instruction. For him, it was "remote and dead-abstract and bookish" and devoid of any real practice (Dewey, 1916, p. 8). He believed that schooling was just one avenue for learning, and for him, not the best route. He was much more inclined to real, experiential learning. This type of learning fosters relevant and meaningful skills and knowledge. The whole person, both intellectual and social, grows and develops with others in joint action (Dewey, 1916).

Vygotsky, on the other hand, was very much a proponent of school instruction, particularly instruction in formal, academic disciplines as the following quote makes clear:

> All the major mental functions that actively participate in school instruction are associated with the important new formations of this age, that is, with conscious awareness and volition. These are the features that distinguish all the higher mental functions that develop during this period. Thus the school age is the optimal period for instruction. It is a sensitive period for those subjects that depend on conscious awareness or volition in the mental functions. Consequently, instruction in these subjects provides the ideal conditions for development of the higher mental functions which are in the zone of proximal development during this period. Instruction has a decisive influence on the course of development because these functions have not yet matured at the beginning of the school age and because instruction organizes their further development and partially determines their fate. It is important to stress, however, that the same can be said of the development of scientific concepts. The basic characteristic of their development is that they have their source in school instruction (Vygotsky, 1987, p. 213-214).

It may initially appear that Vygotsky and Dewey are diametrically opposed in how they view school learning, but when looking more closely, one will see the words "actively participate in school instruction" at the beginning of this quote. Like Dewey, Vygotsky believed in the power of collaborative interactions. These interactions could take the form of guided facilitation with a teacher or more experienced peer. These guided facilitations could take the form of demonstrations, leading questions, and introducing the initial steps in solving a problem.

Vygotsky would have been a proponent for Dewey's call for a "New Education," which was basically a return to how children learned a few generations ago; within real-life contexts doing real things with a sense of purpose (Dewey, 1915, p. 8). However, Vygotsky would have still focused on instruction in formal, academic

disciplines, each of which has a sphere "in which the impact of instruction on development is accomplished and fulfilled" (ibid.) as cited by Wertsch (1985, p. 71).

**Principle 3: Practicing principles of inquiry.** Wells (1999) defines inquiry using seven principles. His definition is very expansive and also extremely relevant to worthwhile learning and teaching. First, he describes inquiry as not simply a method of discovery, but rather a position toward experiences and ideas. This includes a "willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them" (Wells, 1999, p. 121). Second, the aim of inquiry is to put one's understandings into action in both an informed and responsible way, now, and into the future.

The third is related specifically to education, "inquiry also gives full recognition to the mutually constitutive relationship between individual and society" (Wells, 1999, p. 121). It accomplishes this in two ways: (1) by building on the experiences and interests of individual students and encouraging them to take action and apply what they have learned to real-life contexts and, (2) by bringing awareness to the socially valued ways of thinking and acting in order to both use and develop them (Wells, 1999).

Fourth, "inquiry is rooted in the understandings gained in the past as these are embodied in the culture's practices and artifacts and, at the same time, situated in the specific present of particular classrooms and oriented to the construction of new understandings" (Wells, 1999, p. 121). This inquiry principle is very much aligned

with Vygotsky in that Wells puts a particular emphasis on culture, social practices, tool use, and artifact creation for both the present and future.

The fifth principle of inquiry discusses improving an improvable object. According to Wells (1999) "an important feature of inquiry in practice is its active, object-oriented nature" (Wells, 1999, p. 121). By object, Wells is referring to the intended goal or outcome. For example, when students work collaboratively through joint activity, they work together, using tools, to either find answers/solutions to a particular problem or to work on a common goal, such as creating something. When students share their ideas and improve upon the object or outcome, they are in fact learning very important cognitive skills in addition to socially and culturally appropriate behaviors. This will not only assist them with their peer-to-peer interactions within the classroom, but also, within a broader context, outside the classroom and within their community (Dewey, 1915).

The sixth principle of inquiry is perhaps the most important because it provides both the spark and personal meaningfulness of inquiry. The essential ingredient to this principle is accessing affectivity. When "everyone is involved in personally significant inquiry, there is an additional satisfaction and excitement in sharing what one is doing with others, in hearing what others are doing, and in discovering how these doings and understandings can be related" (Wells, 1999, p. 122). When students are situated within this type of context, how could they not learn the most essential aspects of inquiry? If the experience is personally

meaningful to them and others, this sets the stage for not only worthwhile learning, but also lifelong learning and identity formation because the whole person is involved in this process, not just their intellectual capacities, but their affective and social dispositions as well. It also provides a safe place for learners to take risks and share both experiences and information they may not normally share in purely academic settings. In sum, by tapping into affectivity, you are addressing not just inquiry but how a person thinks, feels, and creates with others within the process of inquiry.

Finally, "a focus on inquiry emphasizes the essential continuity of education" (Dewey, 1938) as cited by Wells (1999). Wells cites Dewey here because this was also of utmost importance to Dewey with regard to the purpose of education as the following quotes demonstrate:

> The purpose of school education is to ensure the continuance of education by organizing the powers that ensure growth. The inclination to learn from life itself and to make the conditions of life such that all will learn in the process of living is the finest product of schooling" (Dewey, 1916, p. 51).

> Growth is not something done to them; it is something they do (Dewey, 1916, p. 42).

For Wells, he is referring to how these principles of inquiry are important to all participants within the institutional levels of education, i.e., not just K-12 grade students, but also their teachers and administrators, and the college professors who taught them, and etc. This, according to Wells (1999) "creates a framework within which individual development and societal transformation are achieved through

people working collaboratively with others, both more and less expert than themselves, on questions and problems that arise from practice and are focused on understanding and improving practice" (p. 122).

Here we see Vygotsky's influence on Wells when discussing "more and less expert" others. This is very much aligned with Vygotsky's zone of proximal development and how this process not only occurs with one individual person, but can also occur collectively and progressively across institutional levels of participants. This expansion of Vygotsky's zone of proximal development from Wells is extremely important for changing and improving upon both teaching and learning contexts within the educational system today.

When reviewing the literature for effective modes of inquiry in practice, two studies exemplify many of the inquiry principles discussed by Wells (1999). The first study (Rosebery et al., 1992), discusses how students engage in inquiry by investigating students' water preference, and the second study (Warren et al., 2002), examines how students design an experiment to answer the question of whether ants prefer light or dark environments.

In the first study, 7$^{th}$ and 8$^{th}$ grade Haitian students were curious as to why most students preferred drinking water from the third floor where their classes were located, rather than from the first floor. To find out, they set out an investigation which performed a blind taste test on student volunteers. The students tasted water from all three floors and ranked which water they liked the best. Surprisingly, most

of the students chose the water from the first floor. The results stumped the students because they differed from what students actually preferred, i.e., drinking water from the third floor.

With a sense of wonder and curiosity, the students diligently continued with their investigation. They organized themselves so that each member in the class was involved in the investigation. Some students measured the acidity and salinity of the water, while others tested bacterial levels and water temperature. With a new set of data collected, students began to analyze and theorize why students chose water from the first floor when they were blindfolded. What they discovered was that the water from all of the fountains, particularly the first floor, had high levels of bacteria. They also discovered that the temperature of the water on the first floor was 20 degrees cooler than the water on the other floors.

With this information, they theorized that the water was naturally cooled as it sat in the city's underground pipes during the winter months. As the water moved from the first to the third floor, it gradually warmed up. With this theorizing, students conjectured that the reason why students preferred the water from the first floor, even though it had more bacteria than the other floors, was because of the cooler water temperature.

From this example, one can see that the investigation was based on students' interest of why students preferred drinking water from the third floor. When they discovered a contradiction to what they had expected, it piqued their curiosity and

sense of wonder as to why students chose water from the first floor when blindfolded. Here we see Wells' first principle of inquiry, a "willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them" (Wells, 1999, p. 121).

When the students organized themselves to investigate their initial findings, we see Wells' second inquiry principle, "to put one's understandings into action in both an informed and responsible way" (Wells, 1999, p. 121). When the students decided to investigate why most students preferred drinking from a particular floor, their investigation was based on their experiences and interest in finding answers. Here we see Wells' third principle of inquiry, "building on the experiences and interests of individual students and encouraging them to take action and apply what they have learned to real-life contexts and bringing awareness to the socially valued ways of thinking and acting in order to both use and develop them" (Wells, 1999, p. 121).

Although students did not gain further understanding of their inquiry from the past, as principle four mentions, their inquiry was very much situated within the specific present, within their classroom. In addition, students used water quality instruments (tools) to gain a deeper understanding of particular water features (temperature, salinity, pH, and bacteria) as potential factors which can influence water preference. Since principle four also discusses the "cultural practices and artifacts used to construct new understandings" (Wells, 1999, p. 121), one can see this

principle applied, i.e., students used water quality instruments (tools) to gain a deeper understanding of potential factors which can influence water preference.

Students were interested in finding answers as to why students preferred drinking from a particular floor. In other words, they had a common goal, and that goal was to perform an investigation to answer their question. This ties to Wells' fifth principle of inquiry, improving an improvable object. According to Wells (1999) "an important feature of inquiry in practice is its active, object-oriented nature" (Wells, 1999, p. 121). By object, Wells is referring to the intended goal or outcome.

Wells' sixth principle of inquiry, fostering affectivity, was very apparent in this study as students worked collaboratively and cooperatively, each taking on a needed and necessary task in order to find answers to their inquiry. Principle six states "when everyone is involved in personally significant inquiry, there is an additional satisfaction and excitement in sharing what one is doing with others, in hearing what others are doing, and in discovering how these doings and understandings can be related" (Wells, 1999, p. 122).

The last principle, "a focus on inquiry emphasizes the essential continuity of education" (Dewey, 1938) as cited by Wells (1999), is more difficult to see in this study because the reader is not privy to how the inquiry experience has impacted the lives of the students, teacher, and even the researchers after the study. Rather, this study is a snap shot of present time and does not lend itself to how the overall

experience has affected its participates over time. A longitudinal study would have informed the last principle.

Moving from investigations to experiments, Warren and colleagues (2002) discovered how three students from ethnic minority and linguistic minority groups used their own resources, such as argumentation, embodied imaging, everyday experience, and informal language to design an experiment to answer the following question: "Do ants have a preference for darkness or light?"

To begin with, students generated several designs to address the question. For example, they used a box and two tubes; one tube was covered with dirt (in order to create a variable for darkness), while the other tube was not (to create a variable for light). One student quickly objected to this and claimed that the dirt was a confounding variable. The other student agreed and they both made modifications to their model.

In addition, throughout the experiment, one of the students imagined himself as an ant and how he would behave in response to changes. This resource helped this student construct a variable (creating darkness) without introducing a confounding variable (dirt). This kind of imaging, of inhabiting a created world to explore what might happen or how something might react, is commonly used as a resource to physicists' thinking, particularly as they work through unresolved problems or explore implications of a model. It is clear that these students accomplished what

scientists do, that is create a sound experiment where no confounding variable obfuscates the one variable in question (darkness or light).

In this example, one can see that the students wondered whether ants preferred light or dark environments. From this, they asked a question, "do ants prefer light or dark environments," and set out to take action to find an answer to their question by designing an experiment. Here we see Wells' first, second, and third principles of inquiry. The fact that students had a sense of curiosity and wonder as to whether ants preferred light or dark and how this informed their hypothesis in addition to designing an experiment to find an answer to their question, is a clear indication that these students are actively engaged in the learning process of scientific inquiry.

**Principle 4: Providing opportunities to enact conscious awareness and volition in real life contexts**. This last principle extends and situates the learning and teaching of science in a "broader, or social view" (Dewey, 1915, p. 5-6). This occurs when students' intellectual resources have been acknowledged and integrated into the learning environment (principle 1), when students have experienced dynamic learning (principle 2), and the principles of inquiry (principle 3) while engaged in *the spiral of learning and teaching through inquiry*. When these three principles are set into motion, the stage is set for broadening the learning and teaching experience from multiple perspectives and also establishing new forms of participation and thus developing new roles (Gutierrez & Rogoff, 2003). This often leads to membership within a community and also identity transformation (Lave & Wenger, 1991). An

example (Darkside) of how this process occurs will be discussed later in this section (Barton, 2003).

When learning is situated within a real life context, in addition to cultivating and developing the three principles stated above, it serves as an effective approach because the "special channels: the formation of habits involving executive skill, definiteness of interest, and specific objects of observation and thought," are open for exploration and thus further development (Dewey, 1916, p. 50). The following paragraphs will discuss two examples which provide convincing evidence of how this approach to learning and teaching is of significant importance for "all round development" (Vygotsky, 1934, p. 222), as cited by Wertsch (1985, p. 71).

The first is from Lemke (2001) who states, "For all that the factual science curriculum is teaching them, are our students any more knowledgeable about the economic, sociological, technological, and political role of science in the modern world?" This is a critical question because it sets both the learning and teaching of science within a "broader, or social view" (Dewey, 1915, p. 5-6). Contextualizing the science content from these perspectives situates the learning environment in (1) real life learning, and (2) a common perspective from which we all share since we are influenced by the economic, sociological, technological, and political perspectives in the modern world.

As stated earlier, the purpose of education is to teach children the knowledge, skills, and social practices to think critically and thus make wise decisions for

themselves, society, the environment, and the many animals which inhabit this planet. If this is the goal, then both learning and teaching practices need to be aligned with what Lemke is suggesting here: (1) the content must address multiple perspectives: economic, sociological, technological, and political, and (2) within both larger (global) and smaller (community and school) social organizations.

Furthermore, Lemke poses this critical question, "If we teach more rigorously about acids and bases, but do not tell students anything about the historical origins of these concepts or the economic impact of technologies based on them, is the scientific literacy we are producing really going to be useful to our students as citizens" (Lemke, 2001, p. 300). This is an interesting question and worthy of analysis.

The typical scenario for many schools is that content knowledge is domain specific, in other words, if a student is taking biology, they are only learning biology and not other disciplines such as chemistry or history. If a teacher were to take the approach that Lemke (2001) is suggesting here, he/she would essentially have to shift from the current stance- single subject teaching, to a more integrated and thus interdisciplinary form of teaching. If this were to occur, both the current learning and teaching approaches would have to change in order for this "new" way of science learning to manifest. The question is how.

As previously discussed, it is known from Vygotsky (1978, 1987); Wells (1999, 2002); Dewey, (1915, 1916); and Lave & Wenger (1991) that learning is a

social engagement and involves participants involved in some kind of activity or action. Within this activity or action, participants use the cultural tools, whether physical tools: books, computers, and microscopes or semiotic tools: language, mathematical/science symbols, diagrams, etc., in order to gather information for the construction of knowledge. Furthermore, when this process occurs, participants eventually reach a mutual understanding because they have constructed the knowledge together (Dewey, 1916; Wells, 1999, 2002).

It is also important to consider that every participating individual is unique and their prior knowledge, experiences, funds of knowledge, interests, and questions are incorporated within the situated learning context in order to cultivate effective learning experiences which can foster not only deep conceptual knowledge and skills, but also social practices for membership within a community of inquirers. In addition, it is important to examine how to move the science learning content across a continuum of different social organizations, from home to school or informal science learning centers, to community, to city, to state, and then globally to the world. This moving across continuums creates not only personal relevancy of the curriculum to the children's lives, but also social relevancy, a "broader, or social view" which is desperately needed with all of the critical environmental and social issues we face today as a global society (Dewey, 1915, p. 5-6). It is important to prepare today's youth for the future of tomorrow.

The second example is from Moje (2001) and provides further evidence of how situating the learning and teaching of science from a "broader, or social view" (Dewey, 1915, p. 5-6), actually cultivates an interest and curiosity about the social influences which can impact a topic in science. This became apparent when examining the type of questions students asked during a unit on air and water quality. For example, students asked: "Why do people keep polluting? How does pollution happen? And, what can we do to stop people from polluting?" It is important to note that students' 'social questions' were in marked contrast to the proposed unit questions: "What is the quality of air in my community?" "What is the quality of water in our river?"

These differing points of view illustrate how important it is for educators to initially expand the focus of the unit in such a way that it welcomes a more inclusive and broader perspective of the content. When educators take the time to allow and validate students' perceptions, questions, and concerns, they are providing an essential channel for reciprocity between students' concerns and interests and the goals and learning objectives of the unit. Students are generally not interested in the narrow focus of a particular aspect of a science unit until their point of view and perspectives are addressed first, and then integrated into the learning objectives of the unit.

In this example, students wanted to understand why people keep polluting when they know it is bad for the environment, and even more, they wanted to take

action in doing something about it, as the following question reveals: "What can we do to stop people from polluting?" From this, when learning is situated within a real life context which addresses and channels students' intellectual resources into socially relevant and personally meaningful experiences, students not only develop an understanding of the content and skills within the unit, but more importantly, self actualize into informed citizens and productive stewards of society. This experience can also have a transforming affect on students' identity as the following example from Barton (2003) reveals.

Darkside is a participant in an after-school science club (Barton, 2003). He lives at Southside Shelter in New York City with his parents and siblings. He's in 10th grade, 16 years old, and his ethnic background is Black Cuban American. Darkside is one of many students who participated in the renovation of an empty lot to create a community garden. Barton wanted to engage students in an after-school science program in "doing science" in ways that were interesting and meaningful to them (Barton, 2003, p. 126). After much collaboration on a variety of topics, the students decided on doing a science project that would "help to make their neighborhoods more beautiful and more safe" (Barton, 2003, p. 126).

Darkside and the other teens engaged in a variety of science activities to transform an abandoned lot into a community garden: documenting lot qualities (size, shape, attributes, climate, and geology); surveying/studying soil and air pollution and their sources to inform cleanup efforts; carrying out a needs analysis of participating

youth/community members for use of the lot space; researching plants, gardening, and garden structures; book and Internet research; interaction with local experts; designing and revising models: blueprints and three-dimensional models; and planting and building.

By participating in a project such as this, students gained not only science content, but more importantly, experienced how science is actually conducted. Darkside viewed his participation as central and described himself as being "very involved" with generating creative ideas and getting more youth involved by encouraging them to attend community meetings and becoming personally involved in the project (Barton, 2003, p. 127). It is clear from the following quotes from Darkside that he was personally invested and had a clear vision of what this project could mean to his community:

> You want to change the environment and make a difference. That is what we are trying to do to this lot over here (Barton, 2003, p. 127). He also states:

> It is important to do things for your community, to make it a better place. That's what we are doing with the lot. Beautify it. Help people want to be there, to spend time there. We need to help our community (Barton, 2003, p. 127).

These quotes involve more than just transforming an empty lot, but are also an indication that perhaps Darkside is undergoing his own transformation while engaging in this project. He sees the critical link between the science and where the science is taking place, within the community. With this link, he is very aware of

how critical it is to get as many members in the community involved in their project. Barton and colleagues see Darkside's story transforming two kinds of spaces: the space of "inner-city neighborhoods," in other words, the physical and sociopolitical community in which he resides, and the space of "doing science" (Barton, 2003, p. 128).

These two spaces converge in how Darkside participates in the science/ community project: (1) he explores ways to make the community more beautiful, (2) he finds ways to involve greater numbers of people to participate in the project, such as Community Day on Saturdays, and (3) he expands on who and how people in the community can participate in the project.

It is clear that through his participation and personal resource of galvanizing others, he is able to expand his vision of how this is not simply a science project, but a community project where people work together in the practice of science and community building for the benefit of everyone. This student has far surpassed what any student in a traditional science classroom could ever achieve. He has the fundamental insight of what relevant, meaningful, science experiences entail and he is using both science content and skills to achieve his goal.

It is through his actions and personal resources that Darkside literally transforms himself and his community. He describes the project as doing science for "ourselves" in urban settings. This is important to him because it "enables him to act on his own needs and also identifies him as an individual who knows how to act on

his own needs in positive and productive ways" (Barton, 2003, p. 133-134). Thus, according to Barton, "the purposes and goals of science were about asking, answering, and acting upon questions to bring justice to a neighborhood that was largely ignored" (Barton, 2003, p. 134).

Through this experience, Darkside and the other students involved in this science project, learned to use science as a tool and vehicle for change in their community. For Darkside, good science entails that an "individual or group would need to engage in such a process in collaboration with those who lived in the community" (Barton, 2003, p. 134). Here we see Darkside echoing Wells (1999), Lave & Wenger (1991), Rogoff (1993, 1994), and Dewey (1915, 1916) about how essential collaborative participation is toward a common goal within one's community.

Perhaps researchers and teachers need to listen to and provide more opportunities for students to enact their own volition in relevant and meaningful contexts. Through personally, meaningful science activities, it is clear that students transform and develop more empowering identities. This manifestation seems far more important than merely learning science for the sake of science. Darkside, as well as the other participants in Barton's book, not only learned science content and skills, but more importantly, how to position themselves within science contexts in order to meet their personal needs and the needs of their community. Through this

action, they learned how science works in their lives as both a tool and vehicle for change.

From this example, it is clear that when students are involved in personally meaningful activities with others within their community, a transformation occurs in their learning. Not only do students develop deep conceptual knowledge in a particular area of interest, but they also learn the skills and social practices scientists use during scientific inquiry. Even more, students develop a sense of agency, a voice, and a position within the community. This position is one to reckon with, for it is a voice which increases awareness, evokes further action, and ultimately improves their lives and the lives of others within their community. As students gain confidence and deeper conceptual knowledge and skills, they can expand into larger contexts, i.e., city functions, state programs, and global initiatives.

**Part 2: The Spiral of Learning and Teaching through Inquiry (Wells, 2002)**

"*The spiral of learning and teaching through inquiry,"* (Haneda & Wells, 2010, p. 13) is a renovated model from Wells original model, "*The spiral of knowing*" (Wells, 1999; Wells, 2002). This model is an effective tool for not only learning scientific concepts, inquiry, and language, but also teaching and assessing students' development of scientific language and inquiry. It includes a circle, or spiral, which contains four quadrants.

The first quadrant is ***experience*** and is located in the upper left corner of the circle. Wells (2002) defines experience as students' prior knowledge and experiences

of the topic about to be explored. He offers a number of suggestions as to how to tap into this knowledge base: (1) launching the unit by reading a book, telling a story, or showing a video about the unit, (2) from this, students write down their ideas, memories of actual events, and personal experiences in their journals, (3) they then share what they have written with a small group of students, (4) as students listen to each other's contributions, they can generate a list of questions, ideas, and areas of interest, (5) in addition, students can bring objects from home, create an artifact, or share a book or magazine they think will be of interest to their peers, (6) once students' interests have been aroused, it is important to ask what questions and issues they would like to explore and also what materials they would need for their explorations, (7) negotiating materials and a schedule of when groups will share is an important part of participating within a community of inquirers, (8) keeping a permanent record of data serves as a reference for information and also as an informational source for whole class discussions and reflections, (9) and finally, having students keep a written record of their ideas in addition to the results of their actions serves as a valuable tool for careful thinking and informed decisions.

The second quadrant is ***information*** and is located in the upper right quadrant of the spiral. Here, I will provide a brief summary of the key aspects of this quadrant. To begin with, Wells (2002) stresses that information is not knowledge, but rather work is needed to transform information into understanding. This process of how this

conversion happens will be discussed when examining quadrants III (***knowledge building***), and IV (***understanding***).

***Information*** can come from a variety of sources: teacher exposition, books, the Internet, media presentations, museum exhibits, and even direct observations on field outings, etc. This information is both intelligible and memorable when it connects to students' initial brainstorming ideas, questions, and areas of interest generated during the launching activity in quadrant I. When students can use the information, and in turn, know how to seek relevant information themselves, the information has a new meaning. It becomes a source for coming to know rather than an abstract and impersonal informational source.

Wells (2002) also stresses that searching for information is only the first part of this activity, and that taking notes and putting the information in an organized framework is absolutely essential. In addition, students may need assistance in both searching for relevant information to inform their ideas, questions, and areas of interest and also with organizing this information. The teacher and/or more capable peer (particularly peers working together on the same topic of interest) can facilitate students in the right direction for seeking information, however, a teacher will most likely need to guide and facilitate students' note taking and organizational skills in a meaningful and informed way.

The third quadrant is ***knowledge building*** and is located in the lower right corner of the spiral. This is where students discuss, review, analyze, and evaluate the

information and evidence gathered during the information seeking stage as discussed above. It is during this knowledge building stage that students collaboratively construct knowledge through the process of consensual discussions on their observations, descriptions, explanations, and/or possible solutions to the inquiry under study. Wells (2002) emphasizes that although mutual consensus is the goal, the views of a student may run counter to the consensus should not be overshadowed, but rather welcomed and considered for further discussions which can often lead to a deeper and improved understanding of the topic.

Wells (1999, p. 112) refers to Bereiter's (1994, p. 7) definition of progressive discourse as not simply sharing opinions, but how the sharing of opinions (through questioning and revising) results in a new and better understanding than anyone's original, individual understanding. Progressive discourse is defined as having four characteristics: (1) to work toward common understanding satisfactory to all, (2) to frame questions and propositions in ways that allow evidence to be brought to bear on them, (3) to expand the body of collectively valid propositions, and (4) to allow any belief to be subjected to criticism if it will advance the discourse.

Wells adds another desirable characteristic for the discourse to be progressive, and that is a knowledge artifact that participants work collaboratively to improve. This focus on an 'improvable object' is always worked on by the subjects or participants using tools and artifacts in order to improve it, thus the 'improvable object' (Bereiter & Scardmalia, 1996). Wells clarifies that the object in the activity

can take many forms depending on the mode of knowing concerned. For example, a material artifact, such as a device for measuring sunlight; a procedure for monitoring the amount of carbon dioxide emitted by a particular energy source; an oral narrative or script for a play; or a web/blog site where students construct information about the real-life issues concerning a particular species. All of these objects are examples of how students would construct knowledge through progressive discourse in order to accomplish their goal/outcome.

Another component of ***knowledge building*** that Wells (2002) discusses is how, during this stage, the teacher's role is to model scientific practices which differ from everydaly practices. Thus, the teacher can build connections between students' everyday concepts and ways of knowing with scientific concepts and ways of doing through systematic instruction, modeling, and, of course, through knowledge construction.

The last stage, or final quadrant IV, is ***understanding*** and is located in the lower left corner of the circle. Here we see the culmination and manifestation of all three stages. Wells (2002) states that "understanding manifests itself in further action", rather than providing answers to "decontextualized questions on a test" (p. 18). He elucidates his claim by stating how this is achieved: (1) in meeting a new challenge, whether taking action to find solutions to a real life problem, or in extending and/or modifying ideas in further dialogue, (2) coming to the realization that one may not have a complete understanding and, as a result, searches further for

a more thorough and deeper understanding, and (3) how one responds when faced with a similar problem or question within a specific and situated context. These forms of action are far more convincing as evidence in determining one's understandings than, as Wells (2002) states above, 'decontextualized questions on a test" (p. 18).

Furthermore, it is the participants themselves who can best determine whether they have developed a deeper understanding of a topic and in what ways. In addition, students' responses will vary since every student has their own, unique experiences, prior knowledge, intellectual resources, funds of knowledge, English language proficiencies, experiences with science, etc.

Finally, Wells (2002) states that since understanding is a mental action, then one must observe students in action to assess their understanding. Examples of this can be seen when students solve a problem on their own or through collaborative interaction with peers. Another example is when a student is engaged in dialogue, either in a discussion or through text when writing a paper. But perhaps the most fundamental course of action for observing understanding is during the third stage, ***knowledge building***. Here the teacher can observe how students come to reconstruct the information they initially sought out into comprehensible units, arranged in such a way to extend their knowledge, and ultimately, understanding.

In addition, this learning experience becomes even more profound when a student experiences cognitive dissonance. This can occur when a student experiences

two, sometimes more, conflicting ideas at the same time. It is often resolved by engaging in the process of metacognition or metathinking, i.e., reflecting on what they know and how they have come to know what they know. When a student has grappled and reorganized his/her ideas into a tenable position, he/she can actually lift him/herself out of the dissonance. As a result, the student essentially raises his/her level of thinking and ultimately restructures their organizational mental frameworks. This mental activity or action within the mind, i.e., metacognition or metathinking, can actually serve as a playing field for the development of higher mental functions such as logical memory, conscious awareness, and volition because students are reflecting, reviewing, searching, re-examining, and evaluating their experiences and knowledge to figure out how to resolve the cognitive dissonance.

As one might imagine, this is no easy task, however the results provide an improved object, or mental framework, from which further activity and reflection can be brought to bear onto new experiences and challenges. This is what Vygotsky spoke of when discussing the zone of proximal development. He states that the zone of proximal development is the sensitive zone where the buds of development are forming, however, in this case, the bud is no longer a bud, but rather has matured into a flower and is on its way to becoming a fruit (Vygotsky, 1978, p. 86).

As one can see, this model is a highly effective tool for learning, teaching, and assessing science content and inquiry within the classroom because students experience the process of how to interact with others collaboratively through joint

activity while engaged in a meaningful activity (Wells, 1999). As a consequence of this process, students begin to develop membership within a community of inquirers.

Wells (1999) situates his term, *communities of inquiry*, as a particular type of "community of practice," acknowledging Lave and Wenger's (1991) development of this concept. He also makes a firm distinction from Rogoff's term "community of learners" by stating that "the problem with this expression is that it places the emphasis on learning itself as the apparent object of the community's practices" (Wells, 1999, p. 123). Instead, Wells is much more aligned with Lave and Wenger's (1991) view of learning as an "integral aspect of participation in practices that have some other object in view," in other words, "the necessary skills and knowledge are learned as mediating means for and in achieving the object of the activity. This certainly does not preclude engaging in actions that directly focus on mastering such knowledge and skills, but always within the context of their functioning as means that mediate the activity as a whole" (Wells, 1999, p. 123).

Lastly, members within this community of inquirers can utilize the tools and knowledge gained in other contexts in order to evoke positive productive change. In doing so, they will continue to develop; (a) productive communication skills which will be advantageous to them in the workplace; (b) expansive research skills which are critical especially in the information age we live in; (c) the ability to reconstruct experiences and information through progressive discourse in order to build knowledge; (d) the ability to think critically and analytically in order to improve the

"improvable object;" (e) a feeling of self efficacy and confidence in oneself; and (f) using the knowledge and skills obtained during this process to not only improve their lives, but more importantly, the lives of others, the environment, and the many animals which inhabit this world.

## Chapter 4: Research Methods

### Study Site

This study took place in five locations: **The Nature Center** at Ramsey park, three sloughs: **Watsonville slough, Struve slough,** and **Elkhorn slough**, and finally **Pajaro Valley High School**. The Nature Center is a small museum with exhibits of the historical, cultural, social, and technological influences on the wetlands. It served as an excellent resource for both the learning and teaching about wetlands from multiple perspectives. For example, students had access to science educators, books, exhibit information, Google satellite topography maps, and a network of partnership opportunities, such as the Watsonville Wetland Watch Program at Pajaro Valley High School. Students often used the computers at Pajaro Valley High School to research their plant and/or animal of interest. They also received training from two high school mentors (interns in the Watsonville Wetland Watch Program) on how to conduct water quality evaluations.

Students conducted their scientific inquiry projects in the **Watsonville slough** and **Struve slough**. The Watsonville slough is located within proximity of **The Nature Center** and extends to the Struve slough along a trail which provides access from one slough to another. Students also made observations and collected data on their plant and/or animal of interest at the Struve slough.

The **Elkhorn slough** was visited once in late August after the students had completed their scientific inquiry projects. The purpose for visiting the Elkhorn

slough was three-fold: (1) to assess whether students could consequentially transition word meanings from one context to another, i.e., Watsonville slough to the Elkhorn slough (Beach, 1999). Although the Watsonville slough is considered a freshwater marsh and the Elkhorn slough a saltwater marsh, these seemingly different ecosystems actually overlap. As a result, many of the specific terms and scientific concepts developed at the Watsonville slough can also be used at the Elkhorn Slough, (2) to assess whether students could demonstrate a working knowledge of the scientific inquiry steps on a question of interest to them (this time, at the Elkhorn slough), and (3) to provide an opportunity for students to actively engage and share their knowledge and experiences with a professional scientist, Kenton Parker.

**Student Participants**

**F**our, female, English Language Learners (ELL) participated in this study. The teacher-researcher has known these students since they were in second grade, having been their teacher in an elementary after-school program in Watsonville. They are now in middle school. Two students (Cecelia and Margarita) attend a public middle school, while the remaining two (Charlena and Jacquelina) attend a private charter school, - although, during the middle of the study, one of the students (Jacquelina) who attended the private charter school transferred to the public middle school because the school was too difficult for her (according to both Jacquelina and her mother). All students' first language is Spanish, although they are proficient in English.

It is important to mention that two students (Charlena and Margarita) participated in a pilot study for six months. One student (Charlena) attends the charter school and the other (Margarita), attends the public middle school. During this pilot study, which started in February 2010 and ended in August 2010, the students participated in experiential learning of tide pools at Natural Bridges and the wetlands in Watsonville. The teacher-researcher and students went out to both locations and observed the environment, plants, and animals. Students had particular interests and the teacher-researcher encouraged them to research more about their interests.

For example, one student (Charlena) was interested in whether robins sing all year round or during particular seasons. The other student (Margarita) was interested in mallard ducks, specifically: (1) what material they use to build their nests, (2) where they build their nests, and (3) how long it takes juvenile male mallards' heads to change from brown to green. Students explored their questions by seeking information and reading more about their topics of interest. What the teacher-reseacher and students discovered was that some of their questions were already answered, however, not within the specific context of the Watsonville slough. Thus, the teacher-researcher encouraged the students to continue with their observations. Since this was a pilot study, the teacher-researcher was not rigorous with formal assessments or providing students with datasheets, semiotic tools, etc., however, students did record their observations and reflections in science journals.

Since these “old timers” (Charlena and Margarita) had prior knowledge and experience with the wetlands, they essentially filled the role of more expert peers, but not for long as the “new comers” (Cecelia and Jacquelina) quickly caught up with these “old timers” since Charlena and Margarita were absent on our first outing where we explored new territory and saw different things (Lave & Wenger, 1991; Vygotksy, 1987).

**Background information on student participants.** The following information provides insights which informed the analysis of the data sources. For example, Jacquelina’s favorite subject in school is none; her least favorite is all. This information is aligned with what both Jacquelina and her mother shared in their interviews, i.e., that she was having a hard time in school, thus needed to transfer from a private, charter school- to a public middle school.

Information about parents’ education informed the analysis with whether students had academic support at home, particular in subject content beyond parents’ level of education. In addition, understanding whether parents speak English or Spanish with their child also informed the analysis of cognates and their effectiveness with students’ development of scientific language.

***Case study 1 (Cecelia).***

**Age:** 12

**Favorite subject:** P.E.

**Least favorite:** Math

**Some interests:** Science, music, dancing, and cheerleading

**Future career:** Dentist assistant

**Mom's age:** 30

**Mom works:** An organic farm

**English:** No

**Education:** Middle school

**Dad:** 36

**Works:** An organic farm

**English:** Understands it, but does not speak English

**Education:** High school

**Sister:** Juana, 9 (4th grade at same elementary shool Cecelia attended, and where teacher-researcher used to teach as an after-school teacher)

**Sister:** Lupe, 1.5

***Case study 2 ( Jacquelina).***

**Age:** 11

**Favorite subject:** None

**Least favorite:** All

**Some interests:** That you learn to go to college

**Future career:** Doctor or teacher (preferable a doctor)

**Mom's age:** 35

**Mom works:** a store

**English:** No

**Education:** No high school, mother (4th grade)

**Dad:** 38

**Works:** Sells produce

**English:** Some

**Education:** No high school

**Sister:** Daniela: 2 years old

**Brother:** Eddie: 15 years old

**Case study 3 (Charlena).**

**Age:** 11

**Favorite subject:** Art

**Least favorite:** Math

**Some interests:** Manga, Anime, Jpop, comic books from Japan, drawing, and writing

**Future career:** Make an Anime Manga Artist (at least an author)

**Mom's age:** 42

**Mom works:** Prepares lunch for patients at a local hospital

**English:** Yes

**Education:** HS graduate

**Dad's age:** 45

**Works:** Truck driver

**English:** A little

**School:** unknown

**Sister:** Shakira, 14 years old (attends same charter school as Charlena)

***Case study 4 (Margarita).***

**Age:** 12

**Favorite subject:** P.E.

**Least favorite:** Social studies

**Some interests:** Modeling; fashion

**Future career:** Model and/or Business owner

**Mom's age:** 40

**Mom works:** House cleaning at a local resort

**English:** a little bit

**Education:** 6 years; no high school

**Dad's age:** 42

**Works:** Maintenance worker at a local harbor

**English:** Yes

**Education:** 6th grade (father)

**Sister:** 17 years old (just accepted at San Jose State University: Business)

**Brother:** 21 years old (graduate from Cal Poly, San Luis Obispo: Business)

**Science Educators**

Two science educators worked at The Nature Center. At least one was present every Saturday from 10 am to 5 pm. The Science club met at The Nature Center for six months, February 2011 to July 2011, during the last two Saturdays of each month from 10 am to 3 pm. The science educators, Cindy and Crysti, were experts on the Watsonville wetlands and essentially served as a resource for answering students' questions, identifying unknown animals and plants, and providing explanations for animal behaviors and/or changes in the local ecology from one season to another. Students interacted with Cindy more than Crysti (due to their work schedules), and preferred Crysti more than Cindy stating, "We get the feeling that Cindy doesn't like us very much." They felt that Crysti, rather than Cindy, took more of a genuine interest in getting to know them.

Students also interacted with Kenton Parker at the **Elkhorn slough**. Kenton assisted the students on their one field day at the Elkhorn slough. The students considered Kenton to be a scientist and appreciated their time with him. He asked students questions, i.e., accessing their prior knowledge and experiences to co-construct meaning with them. Most importantly, he engaged with them in the field, i.e, showing them live animals in ***Whistle Lagoon*** and in the laboratory using high-powered microscopes.

**Role of the Researcher**

Since the researcher had the dual role of teacher and researcher, it was extremely important to provide some sort of objectivity with teaching and research practices. For this reason, a research assistant (Roxanne)- a former undergraduate student the teacher-researcher assisted as a Teaching Assistant for an educational course at the University of California, Santa Cruz- used an evaluation sheet to assess whether teaching/research approaches were in alignment with her proposed theoretical framework. This rating sheet can be found in Appendix A.

In addition, both met at the end of the day to discuss what worked, what didn't work, and most importantly, why things worked or didn't work. The teacher-researcher also kept a reflective journal about her teaching and research practices/ experiences. This served as an effective tool for reflecting on questions, perceptions, beliefs, observations, relationships, experiences, etc., and also for improving future teaching and research practices.

**Role of Research Assistants**

In addition to the former college student (see above), two additional research assistants were instrumental when interacting with parents: (1) Esperanza (a school secretary) translated all correspondences with parents into Spanish in addition to the parental homework assignment, and (2) Lupe (a former colleague who worked with the teacher-researcher as a classroom aid in the elementary after-school program)

translated parent interview questions into Spanish, and parents' responses into English.

**Role of Parents**

Parents played a significant role in the teacher-researcher's understanding of students as whole persons. For example, the parents provided: (a) background information on their family; (b) insights into their child's personality and/or behavior; (c) personal circumstances which may affect their child, for example, financial hardship or chronic illness; and (d) parents' funds of knowledge about the local ecology. Meeting parents for the pre/post interviews often filled in missing information and provided a deeper contextualization of each case study.

**Method of Inquiry**

The method of inquiry used was a qualitative **case study**. Patton (1990) states that case studies become particularly useful where one needs to understand some special people, particular problem, or unique situation in great depth, and where one can identify cases rich in information, i.e., rich in the sense that a great deal can be learned from a few exemplars of the phenomena in question (p. 54). Since the student participants in this study were ELL and the teacher-researcher was exploring their learning experiences within a natural setting over an extended period of time (six months), a case study was appropriate.

Furthermore Patton (1990) states that case studies are particularly valuable when the evaluation aims to capture individual differences or unique variations from one program setting to another, or from one program experience to another. A case can be a **person**, an event, a program, an organization, a time period, a critical incident, or a community. Regardless of the unit of analysis, a qualitative case study seeks to describe that unit in depth and detail, in context, and holistically. The more a program of treatment aims at individualized outcomes, the greater the appropriateness of qualitative case methods. The more a program emphasizes common outcomes for all participants, the greater may be the appropriateness of standardized quantitative measures of performance and change (p. 54). Since individual differences or unique variations in a student's learning experiences will be analyzed and then cross analyzed with other students in the study, a case study is appropriate.

The context of the study includes the learning and teaching experiences that took place in five locations: **The Nature Center** at Ramsey park, three sloughs: **Watsonville slough, Struve slough,** and **Elkhorn slough**, and **Pajaro Valley High School**, and with multiple participants: student participants (four case studies), two high school mentors, two science educators and a scientist, the teacher-researcher, three research assistants, and students' parents.

Within this situated context, students had numerous opportunities to actively engage in a rich array of learning activities and instructional formats. According to Gandara (1997), students learn best when instruction is chunked into meaningful

units, spaced over longer periods, and when the instructional format is varied (p. 6). Likewise, within this situated context, the teacher-researcher had many opportunities to observe students participating in multiple learning activities with a variety of participants.

This learning and teaching experience provided a means to ground observations across multiple settings with a variety of participants in order to gain a better understanding of how dynamic practices contribute to individual learning and development (Gutierrez & Rogoff, 2003). To understand *how* students navigated through this experience, it is important to discuss how Wells' model, *the spiral of learning and teaching through inquiry* (1999, 2002, 2010), served as a vehicle for not only learning and teaching, but also assessing students' development of scientific language and inquiry. The following is a description of how the teacher-researcher applied this model to her study.

As discussed in the theoretical framework, the first quadrant is ***experience***. From this, the teacher-researcher accessed students' intellectual resources: prior knowledge and experiences, everyday language, native language, interests, and funds of knowledge for the following reasons: (a) to inform the learning, teaching, and assessing practices in order to extend students from their actual level of development, to their potential level of development (Vygotsky, 1987, p. 208-209); and (b) to build a connection between home and school, or in this case, between home and the

Science club. This was accomplished through instructional student interviews, parental interviews, and field-note observations.

Instructional student interviews provided a means for tapping into students' prior knowledge and experience, in addition to their interests, concerns, and any questions they had about participating in the study. Likewise, parental interviews provided a means for tapping into parents' funds of knowledge. The hope was that parents would participate in our field outings and serve as cognitive resources in an area of expertise. Field-note observations provided a wide lens for understanding students- as whole persons as they interacted and engaged with multiple participants in a variety of contexts.

Once students' intellectual resources were accessed, we entered the next quadrant: ***gathering information***. Students used material tools, such as: books, articles, Earth Cards (which are pictures of plants and animals with written text), computers (Internet), videos, DVD's, topographic map displays, and exhibits in **The Nature Center** with information panel boards contextualizing wetlands from multiple perspectives: biological, social, historical, and economical.

In addition to these tools, human resources also provided a means for gathering information from: science educators, scientists, the teacher-researcher, research assistants, high school mentors, peers, and parents. Cumulatively, these material, semiotic, and human resources equipped students with the ability to move into the next quadrant: knowledge building.

The ***knowledge building*** quadrant is perhaps the most important of the model because it is during this stage where the co-construction of knowledge occurs, i.e., students utilize the information gathered from the previous stage, deconstruct it, and then reconstruct it in such a way that informs their scientific inquiry projects, the 'improvable object'. This was accomplished through a variety of means.

From this gathering of information (*stage 2*), students encountered scientific language which was unfamiliar to them. As each student encountered specific terms and scientific concepts in researching their plant and/or animal of interest, they highlighted these words in their scientific journals and generated a working **semiotic tool (table)** of specific terms and scientific concepts along with everyday concepts which defined the scientific language. This table was a product of students' learning experiences in the inquiry process of gathering information.

**A second table** was generated as a means for extending students' everyday language to scientific language using cognates. The purpose of this was to provide both a cultural and linguistic bridge from students' native language, Spanish, to scientific language, which consists of Latin based words, thus creating a linguistic continuum. Using cognates provided an effective medium for making connections across languages, thus tapping into students' intellectual resources. For example, the everyday concept *feed*, the Spanish word *forraje*, and the scientific concept *forage*, are all connected with a similar structure (the way the word looks) and function (the meaning of each word). Furthermore, the Spanish word forraje, and the scientific

concept forage are cognates, thus serving as a bridge between students' native language and scientific language. This table was referred to frequently in the field and during student to teacher-researcher discussions and group discussions. It is important to emphasize that the design of these semiotic tables was not pre-planned, but rather generated as a means for both developing understanding of unknown specific terms and scientific concepts and for using scientific language in an appropriate context, i.e., doing science in the field.

**A scientific inquiry template book** was also used as a semiotic tool to provide guided facilitation for students' inquiry projects (Rogoff, 1995). Students first engaged in the inquiry process experientially, i.e., making initial observations, recording preliminary findings, and researching information on their plant and/or animal of interest. As the study progressed, the teacher-researcher introduced a model of a scientific inquiry book which was written and designed by the teacher-researcher, however, the students thought it was from a former student.

This model provided students with a reference of how the scientific inquiry process occurs. After the model demonstration, students were given a template book. They were asked to reflect on their own inquiry projects. This reflection provided an opportunity for the teacher-researcher to assist students with reconstructing their notebooks, which contained separate pieces of the inquiry process, into an integrated whole, i.e., through the use of the template book. Thus, the template books provided a means for students to systematically reframe their inquiry projects and ultimately

come to understand both the process and structure of inquiry. Template books also served as an effective scaffolding tool for planning, organizing, and practicing their student presentations.

An **instructional approach** which led learning through the use of leading questions, prompts, demonstrations (opportunities for imitation), and extending students along their zone of proximal development, i.e., from their actual level of development toward their potential level of development (Vygotsky, 1987, p. 208-209). This occurred during instructional student interviews and field outings as students engaged in their inquiry projects. For example, in the field, scientific words were used during "*teachable moments*" i.e., usually during observations. As a student (Jacquelina) made observations of her animal, for example, the ruddy duck, the teacher-researcher frequently asked questions about what she was observing. As she vocalized, "I'm watching the ruddy duck cleaning himself," the teacher-researcher listened and repeated what she had said, but at the same time, extending her everyday language to scientific language.

For instance, she had said, "I'm watching the ruddy duck cleaning himself," and the teacher-researcher replied, "Yes, the ruddy duck is cleaning himself. Is there another word in your table for clean that you could use instead?" She looked at her table and identified the scientific concept preen for the everyday concept clean. The teacher-researcher asked the studednt to try and restate her observation using the scientific concept. Jacquelina responded, "I see the ruddy duck preening himself."

Affirming her new formulation of her observation, the teacher-researcher made an attempt to once again extend her response with the following question, "What part of himself is he preening?" Jacquelina responded, "his feathers." The teacher-researcher affirmed her response and asked, "Is there another word for feathers that you could use instead?" The student looked at her table and identified the specific term plumage for the everyday term feathers. The teacher-researcher acknowledged her assessment of the alternative word and said, "Now, let's restate the entire observation." Together, they said, "The ruddy duck is preening his plumage." Finally, the teacher-researcher ended with one last extension, one that was more transitional in form than with concepts, "Yes, we could say the ruddy duck has preened plumage."

It is important to note that although this process may appear to be long, tedious, overly staged, etc., it flowed naturally and effortlessly. In so doing, students began to make connections between scientific concepts, their native language (through cognates), and everyday language. They relied on all three languages when describing their observations and providing potential explanations for them.

**Group discussions** occurred during this stage as students reciprocally informed each other based on what their experiences were in their own scientific inquiry projects. For example, students made connections with whether their animal was a prey or predator during an interactive group instructional conversation on food webs. Margarita and Charlena both agreed that their animal of interest, the

polychaete worm, was a prey animal of Jacquelina's animal of interest, the ruddy duck. When Jacquelina heard their mutual agreement, she interjected and said, "Yeah, my animal is a predator of your animal," thus, understanding her animal from another perspective. It is important to note that group discussions were not always consensual, but often required extensive negotiations. Some students were unwilling to waver in their position; however, after reviewing, revising, and reformulating, these students often realized that an alternative view was acceptable to them.

**Community of inquirers** developed during this phase as students began listening, providing feedback, constructive criticism, (sometimes teasing each other, but playfully), etc. Students questioned, provided constructive feedback, checked, rechecked, and cross referenced each other for accuracy and consistency. As a group, we had breakfast together before each meeting (bagels, fruit, and juice). This also provided time for informal discussions, i.e., sharing information, supporting each other, and anticipating future events.

It is clear that the ***knowledge building*** phase is the perfect stage for not only learning and teaching, but also assessment since, as Wells (2002) has discussed, understanding is a mental action, thus, one must observe student's in action in order to assess their understanding. Similarly, Vygotsky also postulated that all phenomena be studied as processes in motion and change, in other words, in action over time. He believed that collaborative interactions with peers and also imitation of a teacher fostered opportunities for students to make progress. He also believed that the zone

of proximal development was fundamental for informing not only whether instructional practices were effective, but also as a form of assessment (Vygotsky, 1987).

As I have already discussed, it is during the knowledge building phase that students' understanding is revealed. However, what makes the initial understandings more influential is when the student can retrieve the knowledge in new challenges, such as taking action on a particular issue or cause, or enhancing/modifying dialogue and or written text in order to improve and thus advance the topic of discussion.

Students' ***understanding*** was assessed 'in action' as discussed in the previous stage, in addition to using a variety of assessments. Essentially, all data sources served as assessment tools for informing understanding. Likewise, two assessment tools, an evaluation sheet and researcher reflective journal, provided insight into whether the teaching and research practices were aligned with the theoretical framework. Finally, student rating sheets informed evaluation of the effectiveness of the learning activities, i.e., level of helpfulness and level of enjoyment.

## Chapter 5: Research Question 1: Scientific Language

### Research Methods

**Data sources.** Data sources for the individual case analysis included: pre/post instrustructional interviews, science letters, post/pre assessment of specific terms and scientific concepts given at the Elkhorn slough, and field notes. A data source for the interactive group instructional conversation included a food web poster.

**Data collection.** Instructional interviews were conducted both before and after the study by the teacher-researcher. Interviews were face-to-face, semi-structured, audio-taped, and transcribed for analysis (see Appendix A for interview questions). The purpose of the interviews was to determine prior knowledge and experiences, interests, concerns, preferences, language use, and understandings. A 5 point-scale rubric was used to assess students' language pre and post study (see Appendix B). Reference to grammatical constructions was also used to determine accurate usage of scientific concepts (see Appendix B).

Instructional interviews also provided an opportunity for the teacher-researcher to extend students' initial understandings by: (a) asking leading questions; (b) providing prompts; and (c) asking for explanations to gain a better understanding of their responses.

Science letters were written to three recipients to: (a) a science educator and/ or environmental graduate student at UCSC; (b) the director of the Watsonville

Wetland Watch Program; and (c) Kenton (a scientist) at the Elkhorn slough. The purpose of the science letters was for students to express their experiences, knowledge, and questions to the recipients. Science letters also functioned as a means for assessing how students used language with scientists, i.e., did they use everyday or scientific language? Students referred to their semiotic tables (see Appendix B) when constructing their science letters. It is important to note that students were not guided to use one language over another, but rather to think about which language would be most appropriate for the targeted audience. Two students, (Jacquelina and Margarita), who met with an environmental studies graduate student at UCSC, referred to their concept posterboard when constructing their first science letter. The teacher-researcher photo-copied all three science letters for analysis.

Post/pre assessment of specific terms and scientific concepts was given at the end of the Elkhorn slough field trip (see Appendix A). The purpose of this assessment was to assess whether students could consequentially transition word meanings from one context (Watsonville slough) to another (Elkhorn slough) (Beach, 1999). Although these two ecosystems differ in that one is strictly a freshwater wetland (Watsonville slough) and the other is a mixture of fresh and salt water (Elkhorn slough), they overlap in plant and animal species. Thus, the purpose of this assessment was to assess whether students could use terms/concepts experienced at the Watsonville slough to describe observations at the Elkhorn slough. In order to assess students' own use of scientific language to describe their observations at the

Elkhorn slough, the teacher-researcher was careful not to use scientific language. The teacher-researcher used only everyday language during group observations. In doing so, students could provide examples of specific terms and scientific concepts asked on the assessment based on their own knowledge, rather than just naming an example observed that day at the Elkhorn slough (short term memory).

For example, the students and teacher-researcher observed pelicans flying overhead while walking on the trails. They also read about pelicans at the exhibits in the visitor center and discussed how pelicans travel to California during the fall and spring, and return to Baja Mexico and Mexico during the winter. When the students took the post/pre assessment, they were asked to name or describe an animal which migrates to the Elkhorn slough, hence, assessing their understanding of the meaning of migrates.

All students encountered the same specific terms and scientific concepts throughout their scientific inquiry projects, however, because each student focused their inquiry project on a particular plant and/or animal, there are some terms and concepts which were unique and specific for each student. These words are located at the end of their assessments, i.e., questions 17-20. For example, Cecelia's are: invasive, restoration, and medicinal.

Field notes concerning students' behavior, attitudes, beliefs, perceptions, etc., were collected throughout the study during social interactions: (a) peer-to-peer engagements; (b) researching their plant and/or animals of interest; (c) field outings;

(d) discussions with science educators and Kenton Parker; (e) discussions with the teacher-researcher, research assistants, and high school mentor; and (f) students' interactions with their parents. These written notes were transcribed and served as an effective tool for understanding students from multiple perspectives and roles.

The interactive group instructional conversation on food webs was audio-recorded and transcribed for analysis. Students used a posterboard, Earth Cards, and specific terms/ scientific concepts written on 3x5 index cards, to co-construct a food web. During this interactive activity, the teacher-researcher asked leading questions and provided prompts in order to facilitate opportunities for imitation.

**Data Analysis**

Instructional interviews were member checked, i.e., member-checking is used to determine the accuracy of the qualitative findings by taking the final report or specific descriptions or themes back to participants and determining whether these participants feel that they are accurate (Creswell, 2003, p. 196). Responses which contained specific terms and scientific concepts were coded and evaluated using two instruments: (a) a 5 point-scale rubric which assessed students' language pre and post study; and (b) grammatical constructions which were used to determine accurate usage of scientific concepts and/or grammatical metaphors. Grammatical constructions are semantic structures which categorize concepts, for example, "X is a kind/type of Y", or signify causal thinking, "X causes Y", etc (see Appendix B or instruments). These semantic structures signify a higher level of thinking. In

addition, the teacher-researcher assessed students' written texts for grammatical metaphors- "an expression of one kind that is followed shortly afterwards by a related expression with a different structual profile" (Halliday & Martin, 1993, p. 206). Like grammatical constructions, grammatical metaphors are both the product and process of thinking and doing science.

Science letters were analyzed using the same 5 point-scale rubric and reference to grammatical constructions (as stated above). The first science letter was considered pre study, since it was written toward the beginning of the study, whereas the second and third letters were considered post, since they were written toward the end of the study.

Post/pre assessment of specific terms and scientific concepts was also analyzed using the 5 point-scale rubric and reference to grammatical constructions and grammatical metaphors. Since the learning of particular specific terms and scientific concepts was not pre-planned, but rather occurred as the students were engaging in their inquiry projects, a pre-test was not possible to employ. Thus, in order to assess the derivation of students' specific term and/or concept development, the assessment asked where each term or concept was learned. This provided a distinction as to whether the students already knew these words before the study, learned them at school, home, etc., or developed them through participation in the study.

Field notes were analyzed using the 5 point-scale rubric and reference to grammatical constructions.

All four data sources were analyzed in two ways: (a) single case analytic induction (Patton, 1990) was used to analyze these data sources for emerging themes, similar patterns, and trends (p. 44). Triangulation was sought through the use of multiple data sources and through the use of multiple methods of data collection (Denzin, 1978); and (b) cross case analytic induction was used to compare/contrast each case study for differences, unique variations, or common outcomes.

For the interactive group instructional conversation on food webs, cross-case analytic induction (Patton, 1990) was used to analyze students' interactive instructional group conversations. This provided a means for assessing students' understanding of specific terms and scientific concepts in addition to their ability to reconstruct their individual understandings of their plant/animal of interest within a larger and interactive context (food webs).

**Defining operational terms.**

***Everyday concepts*.** A word represents an object, for example, a duck

***General term***. An everyday concept which is broad and general, for example duck (Halliday, 1993, p. 109).

***Specific term.*** An everyday concept which is specific, for example a specific type of duck, ruddy duck (Halliday, 1993, p. 109).

***Scientific language*.** Using specific terms and scientific concepts accurately and in appropriate contexts. Accurate usage of scientific concepts will be assessed using: (a) grammatical constructions; (b) grammatical metaphors; and (c) whether students use the concept within a definite system of other concepts, i.e., conveying a relationship between and among all concepts.

***Scientific concept*s.** A word does not represent an object, but rather the word operates in relation to other words (concepts) within a system in order to convey meaning (Vygotsky, 1987). For example, ecosystem is a scientific concept because the meaning conveys an interaction of biotic and abiotic factors within a particular type of environment hence, the words interaction, biotic, abiotic, factors, and environment are all words (concepts) which relate to one another within a definite system in order to convey meaning for the word (concept) ecosystem.

**Instruments**

**5-Point-Scale Rubric Will Assess Students' Language Pre and Post Study**

1= Everyday concepts

2= Everyday concepts and specific terms

3= Specific terms

4= Specific terms and scientific concepts

5= Scientific concepts

**Grammatical Constructions Used to Determine Accurate Usage of Scientific Concepts.**

X is a kind of Y

X is the result of Y

X causes Y

X is found in Y locations/contexts

**Grammatical Metaphor.** A grammatical metaphor is an expression of one kind which is followed shortly afterwards by a related expression with a different structural profile (Halliday & Martin, 1993, p. 206). For example: *will not be refracted enough... for want of a sufficient Refraction*. This example demonstrates how a verb or adjective in the first expression has been reworded in the second as a noun. These grammatical metaphors are a reflection of how grammar has evolved through the practice of science. In other words, grammatical metaphors are both the product and process of thinking and doing science. They are the derivatives of the development of scientific discourse.

**Analysis of Case Studies**

**Cecelia (case study 1).** The following section contains an **analysis of Pre-assessments and Post-assessments.** The pre-assessments include: pre-assessment interview, science letters (first letter), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-notes. The post-assessments include: post-assessment interview, science letters (second and third), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-notes.

***Pre-assessment interview.*** Based on the 5 point-scale rubric, Cecelia's use of language in her pre-assessment interview met category 2 (everyday concepts and specific terms). For example, she used two scientific concepts (**protect** and **water cycles**), however, they were not used in such a way that would qualify them as an accurate use of scientific concepts. For instance, when asked what her thoughts were about studying wetlands, Cecelia stated, "I think it's cool and I like want to learn like um how to protect animals and everything." Her use of the scientific concept protect was vague and did not address any of the criteria for the accurate usage of scientific concepts.

The same can be said for her use of water cycles. For instance, when asked what kind of science she was taking in school, Cecelia reponded, "Um, um, um right now we're on the water cycles science the uh, yeah." Again, Cecelia's response was vague and did not meet any of the established criteria for accurate usage of scientific concepts.

With regard to her use of specific terms, Cecelia used **wetlands** in her response to the following question, "What do you know about wetlands?" Her response, "I know that there's a lot of things in the wetlands, and they're nice to look at." Since wetlands is a specific term, it did not require any of the grammatical constructions established for the accurate usage of scientific concepts. Her use of wetlands was correct, but very general and vague, i.e., focused more on an aesthetic perspective rather than a scientific one. This is understandable, as Cecelia had not yet had an opportunity to study the wetlands on a more profound level.

The majority of Cecelia's language in her pre-assessment interview was everyday language, i.e., using such phrases as: a lot of things, nice, fun, cool things, birds, ducks, animals, family, park, a lot of animals, land, cool to study. She used everyday language to share her prior knowledge and experiences about wetlands. It was understandable that she would use everyday language when discussing her experiences since everyday language tends to be saturated with concrete experiences, i.e., visiting the wetlands with her 5$^{th}$ grade class and also with her family.

Interestingly, there was an instance when Cecelia used everyday language to convey the meaning of the scientific concept (**conservation**), without actually using the word. For example, when asked what her thoughts were about studying wetlands, Cecelia's responsed, "I think it's cool and I like want to learn like um how to protect animals and everything," was a clear indication of an interest in learning about how to

protect animals. The word protect is part of the system of words which convey the meaning of conservation (see definition below).

Furthermore, a follow up question revealed more evidence of the meaning of conservation, "Do you think it's important to study about wetlands?" Her response, "Yeah, cuz um that uh, so we can like save a lot of animals and to have um land for a long time." The fact that she stated 'save a lot of animals and to have land for a long time' was a clear indication of the meaning of conservation. *Note: The American Heritage Dictionary defines conservation as: The controlled use and systematic protection of natural resources.* This of course can be expanded to include the environment and animals which inhabit it.

Although Cecelia's scientific concept usage did not fall within the established grammatical constructions, her thinking about scientific meaning was apparent in her responses. This is important to consider when investigating whether ELL demonstrate comprehension of scientific concepts (meaning), i.e., often times it is there but in the form of everyday language.

Similarly, contemporary researchers, such as Ballenger (1997), Warren and colleagues (2002), and Ash (2008), have also discovered that students used everyday language when formulating scientific ways of thinking and doing while actively engaged in activity. This is understandable as a child's everyday language is essentially their foundational language from which all other languages build (Halliday, 1993).

Furthermore, children use their everyday language to develop scientific language (Vygotsky, 1987). Since the pre-assessment interview was conducted at the beginning of the study, it was understandable that Cecelia's dominant language would be everyday rather than scientific language.

***Science letter (first one).*** Cecelia's first science letter was written to Cindy, a science educator at The Nature Center. Although Cecelia used scientific concepts and specific terms, it appeared that she did not use these concepts or terms on her own accord, but rather had copied information from her research report. Thus, it simply could not count as a legitimate use of scientific language.

However, Cecelia organized her letter with a topic sentence which included the four plants she would discuss in her letter: California Poppy, blue-eyed grass, mosquito fern, and pennywort. She also categorized all four plants as **native** and defined this specific term as: they are all from here. She then proceeded in copying the characteristics of each plant. Thus, using the 5-point scale rubric, Cecelia's letter met category 2 (everyday concepts and specific terms).

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Of the 20 scientific concepts and/or specific terms, Cecelia stated that six were learned from her middle-school science teacher Mr. Murphy. These six words: ecosystem, habitat, wetland, biotic, abiotic, and camouflage were also discussed throughout the duration of the Science club experience, i.e., either in the field at the

Watsonville slough or during discussions with science educators at The Nature Center (see Appendix A for Cecelia's assessment).

It is important to note that this intersection between school and our out-of-school contextualized inquiry project was not planned, but rather a fortuitous coincidence which reinforced Cecelia's learning (Roth & Lee, 2004; Lee, 2005; Beach, 1999). Cecelia was very aware of the fact that what she was learning in school was actually merging with her experiences in the Science club. She mentioned this at the beginning of the study, as the dialogue below demonstrates:

**Me:** You learned a lot of these words from Mr. Murphy?

**Cecelia:** Yeah

**Me:** Biotic, you learned that from him? Abiotic, you learned that from him? Wow, you learned a lot of words from him, huh?

**Cecelia:** Yeah, cuz when we started the project, we were just starting the study of the ecosystem and the life.

**Me:** Okay

With regard to accuracy, Cecelia demonstrated an understanding of both scientific concepts: ecosystem and camouflage. For instance, when asked, "How would you describe the **ecosystem** here at the Elkhorn slough? How is it similar or different from the Watsonville slough? Cecelia's responsed, "The Elkhorn slough has different kinds of animals and it is kind of in the middle. The Elkhorn slough has salt and fresh water." This answer demonstrated that Cecelia understood that the Elkhorn

slough is an ecosystem, but that it is different from the Watsonville slough for two reasons (a) it has different kinds of animals; and (b) it has salt and fresh water. This showed that Cecelia was categorizing the Elkhorn slough as a type/kind of ecosystem that differs from the Watsonville slough.

With regard to the scientific concept **camouflage**, Cecelia provided two accurate examples to the following question, "Can you describe an animal that camouflages well at the Elkhorn slough?" Her response, "I saw lots of snakes and frogs," correlated with two field observations (a) a gopher snake (which camouflaged very well on the ground and into the brush); and (b) a tiny tree frog (which also camouflaged very well against the ground). Both observations qualified as examples of animals which camouflage, i.e., 'X is a kind of Y'.

With regard to specific terms, Cecelia used three of four accurately (habitat, biotic, and abiotic). When discussing whether the Elkhorn slough was a wetland, she thought it was not a wetland because it has saltwater mixed with freshwater. From this, it appeared Cecelia did not make the connection that there are different types of wetlands, i.e., freshwater wetlands (Watsonville wetlands) and a mixture of fresh and saltwater wetlands (Elkhorn slough). In addition, when asked for a synonym for wetland, she said ecosystem. This was not accurate since a wetland is a type of ecosystem. The accurate answer is slough.

***Field-notes (beginning).*** Field-notes at the beginning of the study demonstrated that Cecelia's use of language was broad and inclusive, in other words,

Cecelia used everyday language with some use of specific terms and scientific concepts. For example, when we first went out to a slough off Lee Road, we all noticed red specks in the water, especially Cecelia. We had no idea what it was until we asked Cindy, a science educator in The Nature Center. She explained that there are three floating plants (a) duckweed (which is a tiny green flower); (b) pennywort (which is like a lily pad); and (c) mosquito fern.

She described mosquito fern as duckweed which turns red under certain conditions, i.e., temperature at night drops to almost freezing and during the day it's warm with the sun shining bright. These were the weather conditions when the study began in February. In fact, Cindy showed us an article in the Santa Cruz Sentinel which described the carpeting of red over the wetlands as mosquito fern.

After visiting with Cindy, the students wanted to see the Watsonville slough. Upon arrival, we noticed the red specks on the water's surface once again. When the teacher-researcher asked the students if they remembered the name of the plant, Cecelia was the only one who said, "Mosquito fern!" We also saw pennywort and when Cecelia saw it a second time she called it, "Lily toad." Another time she called it, "Lily wart." Cecelia was also very focused when the teacher-researcher compared the distinguishing features of blackberry bush leaves to poison oak leaves. She repeated words the teacher-researhcer used such as three-lobbed, fuzzy, serrated, and thorns. The teacher-researcher could tell early on that Cecelia had an interest in plants.

Cecelia was also just beginning to learn about ecology from her science teacher, Mr. Murphy, as we started our research project. For example when

- the teacher-researcher asked what bio means, Cecelia said, "Bio means life, living things." When the teacher-researcher asked Cecelia where she learned that from she said from her science teacher, Mr. Murphy.
- the teacher-researcher discussed that a wetland is a type of ecosystem and asked students for another type of ecosystem, Cecelia said, "The ocean," which is a correct response.
- we were out in the field one day, we all saw a black bird with a red bill and wondered what kind of bird it was. We saw a photographer taking pictures of it and decided to ask him. He said it was a moor hen and Cecelia replied back, "It's more than a hen," which the teacher-researcher thought was funny and interesting… a 'play on words'.

Thus, it was apparent that Cecelia's use of language at the beginning of the study met all of the rubric categories, however, the majority of her language use was in category 2 (everyday concepts and specific terms). When speaking with her peers, teacher-researcher, and even the science educators, the context was always informal, thus it was understandable why Cecelia would use everyday language. She was also learning specific terms as we were out in the field making group observations of the environment and the plants and animals we encountered on our walks.

***Post-assessment interview.*** Based on the 5 point-scale rubric, Cecelia's use of language in her post-assessment interview met predominately in category 4 (specific terms and scientific concepts). For example, she used the following specific terms: **aquatic invertebrates, ruddy duck,** and **science** accurately.

**Example 1.** Q9: And what are your thoughts about science now? What do you think? What do you think about science after going through the science club?

**Cecelia:** That it's more important than any other subject.

**Me:** Why?

**Cecelia:** Cuz **science** gives us nature.

**Me:** Mmmm hmmm.

**Cecelia:** And nature helps us live.

From this, it appeared that Cecelia was providing a very profound and significant claim for a twelve-year old student. The fact that she linked **science** with **nature** and nature with **live** indicated that her perspective of science was much broader and encompassing than the traditional view and overall goals established by the National Research Council (1996).

Although Cecelia participated in her own scientific inquiry project, i.e., answering her own research questions, collecting and recording data, analyzing the data, and writing up her results, these did not appear to be brought to bear when asked what she thought about science. This was an interesting assessment and one that reflects similar findings from Moje & Carrillo (2001); Barton (2003); Roth & Lee

(2004), and Bouillon & Gomez (2001). These researchers also discovered that students' perspectives and perceptions of science reflected a "broader, or social view" (Dewey, 1915, p. 5-6), i.e., in relation to the real world and the specific context in which they participated in science.

With regard to her use of scientific concepts, the following example demonstrates her use of them.

**Example 2.**

**Me:** Ummm, so how do you understand wetlands now, after learning about them for six months, how do you understand them?

**Cecelia:** That they're part of the ecosystem and that they help us.

**Me:** How do they help us?

*Note: I'm trying to get Cecelia to extend her answer, elaborate her answer by providing more of an explanation.*

**Cecelia:** They help us by like keeping the **ecosystem balanced**.

**Me:** Mmmm hmmm.

**Cecelia:** And by having **oxygen because of plants**.

*Note: Vygotsky comes into play here…she uses because…(signifies causation) when discussing how plants supply oxygen to the environment.*

Cecelia stated that wetlands are 'part of the ecosystem and that they help us'. When asked how they help us, she expanded her answer to, "They help us by keeping the ecosystem balanced." This statement indicated that wetlands, which is part of the

ecosystem, causes balance. This met two grammatical constructions, "X is a kind of Y", and "X causes Y". Cecelia also used the word balanced with ecosystem, which indicated that she understood a key characteristic of the scientific concept ecosystem, i.e., balance. In fact, the meaning of ecosystem is defined as: an ecological community together with its environment, considered as a balanced unit. Thus, from this, it was apparent that Cecelia was demonstrating an understanding of how these words relate to each other within a system of concepts.

In her following statement, Cecelia stated, "And by having oxygen *because* of plants." The word *because* signifies a causal relationship between plants and oxygen, i.e., the cause (plants) is in relation to the effect (oxygen emission). This causal relationship is a key characteristic of how Vygostsky defines scientific concepts (Vygotsky, 1987).

This example also demonstrates that Cecelia, having focused her scientific inquiry on plants, was using her knowledge when formulating answers during her post-assessment interview. Her logical sequence of (a) wetlands are part of the ecosystem; (b) they help us; (c) they help us by keeping the ecosystem balanced; (d) for example, by having oxygen because of plants, was an accurate chain of thoughts and met the grammatical constructions, "X is a kind of Y", and "X causes Y".

***Science letters (second and third).*** Cecelia's second letter to Noelle (the Education Director for the Watsonville Wetlands Watch project at Pajaro Valley High School) was more focused on what she found interesting about her plants. She used

her own words this time, expressing how all of her plants of interest are **native** and can be found here at the Watsonville wetlands. She stated how the flowers were used in the past for remedies. For example, "They used to place a California Poppy under a child's bed that would help them go to sleep." In addition to this, she discussed the medicinal uses of blue-eyed grass, "They used it for asthma, ulcer problems, and for toothache problems." This was interesting since Cecelia was sick quite often throughout the study with some kind of illness, i.e., cold, cough, flu, allergies, anemia, and asthma. With regard to her use of language, Cecelia had not progressed very far from her first letter, where she also used the specific term **native**.

Cecelia's third letter to Kenton, a science educator at the Elkhorn slough, includes 5 specific terms (**native, non-native, biotic, abiotic**, and **habitat**), in addition to 2 scientific concepts (**camouflage** and **ecosystem**). From this, her rubric score met 4 (specific terms and scientific concepts). All specific terms were used accurately and she provided examples for each term. In addition, Cecelia used both scientific concepts accurately. For example, she provided two concrete examples of the concept camouflage based on her observations at the Elkhorn slough, "I learned how pipefish camouflage with the eel grass. I also saw how the lizard camouflages with the dirt and rocks." These examples signified, "X is a kind of Y".

With regard to her use of ecosystem, she stated, "You guys have a big ecosystem with a lot of habitats. I think the Elkhorn slough has different wetlands from the Watsonville wetlands." One can argue that although Cecelia appeared to

have a vague and incomplete understanding of the scientific concept ecosystem, the fact that she stated that it was big and has 'a lot of habitats' met with one of the grammatical constructions, "X is found in Y locations', in other words, a lot of habitats are found in a big ecosystem, such as the Elkhorn slough. In addition, Cecelia compared/contrasted the Elkhorn slough from the Watsonville wetlands, although, did not specifically state what the distinguishing factor was.

It is important to note that students used their scientific/everyday concept semiotic tables when constructing their letters. Whenever they wrote letters to science educators, scientists, or parents, the teacher-researcher often asked students which language would be more appropriate to use based on two factors (a) what they were going to write about (content); (b) to whom they were going to write their letters to (audience).

The purpose for asking these questions was to try and bring conscious awareness to the fact that the use of language is content, context, and participant dependent. Students appeared to understand that the use of scientific concepts and specific terms was more appropriate when writing letters to science educators and scientists, whereas the use of everyday concepts, general terms, and students' native language (Spanish), was more appropriate when writing letters to their parents.

Cecelia's letters showed a progression of not only the use of more specific terms and scientific concepts, but also expressing her interest in what she was learning by providing specific examples of each specific term and/or scientific

concept she used, particularly in her third letter to Kenton, the scientist at the Elkhorn slough.

There are a number of potential reasons why Cecelia's third letter was more extensive in the use of specific terms, scientific concepts, and observational detail: (a) the fact that it was the third letter and Cecelia had practiced how to use specific terms and scientific concepts in two previous letters; (b) the specific terms and scientific concepts experienced on our field day at the Elkhorn slough were later scaffolded through a group instructional conversation before students constructed their letters to Kenton; and (c) students enjoyed their field day with him.

In fact, three students rated this activity as their favorite of all activities in the study. Students enjoyed collecting water samples and specimens in ***Whistle Lagoon***. They enjoyed listening to Kenton describe how and why non-native species such as the Green European crabs and Japanese cone snails now reside at the Elkhorn slough. They also enjoyed seeing new species such as brown pelicans, snowy egrets, and pipefish. They were fascinated with the power resolution of the high-powered microscopes they used in the laboratory. Students observed many unique aquatic invertebrates, many of which they did not see at the Watsonville slough: polychaete larva, skeleton shrimp, tiny jellyfish, brittle starfish, and bryozoans.

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Of the total 20 scientific concepts and specific terms, 14 were learned from the Science club (see Appendix A for Cecelia's assessment). Of these 14, 10 were

used accurately: **vertebrate, invertebrate, aquatic invertebrate, native, non-native, migration, adaptation, breed, restoration,** and **medicinal**. When the teacher-researcher examined whether the five scientific concepts (**migration, adaptation, breed, restoration,** and **medicinal**) were used accurately, Cecelia provided concrete examples of each scientific concept based on her observations at the Elkhorn slough. For example, when asked, "Can you describe an adaptation that you saw here at the Elkhorn slough?" Cecelia wrote, "I saw pickleweed and it adapts really well to salt water." This qualified as a legitimate use of a scientific concept because by providing pickleweed as an example for adaptation, she was essentially saying that, "X is a kind of Y", i.e., pickleweed is an example of a plant that has an adaptation (can live and grow in salt water).

Similarly, when asked, "Can you tell me what restoration means?" Cecelia wrote, "I think it means when you take non-native plants and plant native ones." This also qualified as a legitimate use of a scientific concept because she was providing an example for restoration, in other words, she was stating, "X is the result of Y," i.e., restoration is the result of taking non-native plants and replacing them with native ones. The fact that Cecelia used two specific terms, non-native and native when conveying meaning for restoration also indicated that she felt comfortable using specific terms, rather than general terms to communicate her understanding of the concept restoration.

In summary, it is apparent that this assessment demonstrated how Cecelia had not only learned a total of 10 specific terms/scientific concepts, i.e, (5 specific terms: **vertebrate, invertebrate, aquatic invertebrate, native, non-native**, and 5 scientific concepts: **migration, adaptation, breed, restoration,** and **medicinal** from the Science club, but also provided concrete examples of each term/concept. It was apparent, when comparing her pre-assessment results, 5 specific terms/scientific concepts from her science teacher, i.e., (2 scientific concepts: **ecosystem** and **camouflage**), and 3 specific terms: **habitat, biotic,** and **abiotic**), that Cecelia was demonstrating twice the level of scientific language development at the end of our study. This indicates that perhaps the instructional strategies (prompting, leading questions, semiotic tools, and group instructional conversations) may have contributed to Cecelia's beginning development of scientific language.

***Field-notes (middle and end).*** It is important to note that at the beginning of the project, Cecelia confided with the teacher-researcher that she was failing in math and science. When the teacher-researcher asked why, she stated that she missed 4 days of school due to not having enough oxygen in her lungs. She described how when she returned back to school, the teachers gave her a tough time because Cecelia felt they did not believe her.

Sensing that this bothered Cecelia, the teacher-researcher felt a need to reach out to her by sharing a personal experience, "You know, last year the same thing happened to me. I got quite ill also…didn't have enough oxygen in my blood and the

doctor told me to walk 3-4 times a week for 45 minutes at a fast pace and also to eat dark green vegetables." Cecelia listened and nodded, appearing to appreciate the information.

In addition, they also talked about when their birthdays were; both pleasantly surprised that Cecelia's birthday was just one day after the teacher-researcher's. The teacher-researcher said, "You're a Capricorn like me." She mentioned the characteristics of a Capricorn: goal oriented, determined, always trying to accomplish, reserved, serious, etc. The teacher-researcher expressed that she was surprised Cecelia was a Capricorn because she appeared to be very outgoing and a joker. Cecelia agreed and said she likes to tease her mom and dad (likes to play with them).

After this discussion, Cecelia appeared to be more involved in the Science club. The teacher-researcher sensed that Cecelia appreciated the open space to share personal information without judgment. In addition, perhaps listening to the teacher-researcher's own health struggles and coming to know that they share the same astrology sign provided Cecelia with another perspective of her as a 'whole person' facing a similar health struggle and born one day apart from her.

Unfortunately after this meeting on March 26th, Cecelia missed the next two Science club gatherings due to illness (ear infection). As a result, the teacher-researcher organized a make-up session for Cecelia to get "caught up." This occurred

on April 30th at the Watsonville Community Hospital. They have conference rooms with large tables and white-boards.

Cecelia and the teacher-researcher worked together in the morning on her scientific inquiry project, i.e., formulating her research questions and designing her data-sheets. Around noon, they stopped and picked up the other students for a day out in the field. During their one-on-one time, the teacher-researcher asked Cecelia if she was healthy most of the time or sick most of the time. Her answer was that she's sick most of the time. She also shared that she helps her mom at work sometimes, i.e., packing vegetables in boxes.

The field-notes also revealed that toward the end of the study, Cecelia expressed that she was no longer failing in math and science. When the teacher-researcher asked what caused the change, Cecelia said, "The Science club has helped me in school." For example, throughout the study, Cecelia had difficulty with understanding negative correlations, such as, when the nitrate level is high, the oxygen level is low. It wasn't until the teacher-researcher provided a real life contextualized example of nitrates and oxygen, i.e., how nitrates (from burnt apples) caused by the Martinelli warehouse fire, contributed to hundreds of fish dying due to a lack of oxygen in the water, that Cecelia finally understood this negative correlation.

Cecelia also expressed how learning about ecology, particularly food webs in the Science club, actually helped her understand and perform well on tests in her

science class. Perhaps having experienced food webs first hand in the Science club provided a 'leg up' if you will to the concepts she most likely encountered in school.

As a result, Cecelia stated at the end of the Science club experience that she was passing her classes in both math and science. This demonstrates that the intersection of the Science club with what Cecelia was learning in science class provided extra support that helped her reach a fuller understanding of the concepts encountered in school.

**Results (case study 1).**

***Triangulation of data sources.*** All four data sources triangulated, thus providing evidence that participation in an out-of-school contextualized inquiry science project increased Cecelia's use of scientific language. For example, when comparing/contrasting the interviews, Cecelia progressed from a rubric score of 1 (everyday concepts) to 4 (specific terms and scientific concepts). Likewise, when comparing Cecelia's first science letter with her second and third science letters, Cecelia's use of scientific language increases from a rubric score of 2 (everyday concepts and specific terms) to 4 (specific terms and scientific concepts).

With regard to the Elkhorn slough assessment, although the rubric scores were the same for the pre and post assessment 4 (specific terms and scientific concepts), the number of terms and concepts differed. Lastly, Cecelia's pre and post field notes demonstrated that at the beginning of the study, Cecelia was using everyday langauge most of the time.

**Discussion (case study 1).**

Not only was there an increase in her use of scientific language, but the quality of her examples demonstrate the beginning development of scientific concepts. For example, one of Cecelia's responses in her post-assesment interview was, "*ecosystem balanced*." This demonstrates using words within a system since part of the meaning of an ecosystem is a balanced relationship between the biotic and abiotic features within a particular ecosystem. In the same assessment, she provided a causal statement, "*oxygen because of plant*." Causal statements are an indicator of scientific thinking, thus these two examples provide evidence that Cecelia was beginning to develop scientific concepts.

In addition, Cecelia used empirical observations to make connections between her experiences in school and the Science club. In one particular example, Cecelia said she heard the bird that makes (she imitated what sounded like a goose) sound at school and wondered what bird it was. This demonstrates a consequential transition (Beach, 1999) because she was reflecting on a previous experience in another context, and applying it to another.

Finally, Cecelia took the initiative to gather more information on an animal that intrigued her- the muskrat. Her sense of wonder and intrigue about the muskrat motivated Cecelia to satisfy her curiosity. It is important to note that this can not be taught, but rather is a consequence of a real life experience which intrigued her. This

is meaningful learning because it evoked action on the part of the learner to seek answers/information in order to expand one's knowing (Wells, 1999).

**Expectations (case study 1).**

*Student's achievements met?*. On the whole, Cecelia's participation in the Science club increased her use of scientific language. During instructional conversations, Cecelia made connections with the words she was learning in school, with the concepts we were experiencing in the field. Thus, these two seemingly different contexts reciprocally influenced each other, i.e., providing reinforcement of particular terms and concepts. This fostered potential for continuance (Wells, 1999).

*Which were not met? And why?*. It was expected that the cognates would function as a bridge between students' native language and development of scientific language. In Cecelia's case, she stated that the cognates helped her to learn Spanish. This was not expected as the whole purpose of using cognates was to access students' native language in order to provide a foundation from which scientific language could develop from. Interestingly, although Cecelia often spoke in Spanish with her peers and family, during her student presentation (which applies to RQ2, but can still be discussed here), she had difficulty translating from English to Spanish.

One reason why is perhaps Cecelia was still coming to know the scientific language, including the cognates. As a consequence, Cecelia stopped short when trying to translate her presentation from English to Spanish. Initially she tried, but found she simply could not do it. This was unfortunate, as her parents had expressed,

"We wish the presentations were in Spanish as well as in English." One student, Margarita, was able to do so, with the remaining three unable to.

The fact that Cecelia had trouble translating her presentation into Spanish was a learning lesson for the teacher-researcher. She learned that one must not assume that a student can achieve this even though they speak Spanish perfectly well in informal contexts. This proves the point that scientific language is a language in and of itself and takes time to develop (Vygotsky, 1987; Wells, 2008).

In summary, Cecelia's participation in the Science club increased her use of scientific language. Not only was there an increase in the use of scientific language, but the quality of her examples demonstrate the beginning development of scientific concepts, i.e., using words within a system and causal statements. She also used empirical observations to make connections between her experiences in her everyday life and the Science club. For example, Cecelia's learning experiences in school intersected with her learning experiences in the Science club. This may have contributed to not only reinforcement of particular terms and concepts, but also a feeling of continuity and connection between these two seemingly different contexts. Lastly, Cecelia stated that the Science club helped her in school, thus demonstrating how these two contexts reciprocally influenced each other.

**Jacquelina** (**case study 2**). The following section contains an analysis of Pre-assessments and Post-assessments. The pre-assessments include: pre-assessment interview, science letters (first letter), post/pre scientific concept and/or specific term

assessment at Elkhorn slough, and field-notes. The post-assessments include: post-assessment interview, science letters (second and third), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-note.

***Pre-assessment interview.*** Based on the 5 point-scale rubric, Jacquelina's language use in her pre-assessment interview met category 2 (everyday concepts and specific terms). Jacquelina used more everyday concepts (fun, nature, caterpillar, birds, etc) than specific terms and/or scientific concepts. For example, she used one specific term, **environment**, accurately.

***First letter (first one).*** Jacquelina wrote her first science letter to Miriam, a graduate student in the Department of Environmental Studies at UCSC. Miriam was studying how natural fumigants from mustard seeds could potentially be used as a natural pesticide on strawberries. She is young and originally from Mexico; she serves as a good role model for the students. Jacquelina and Margarita met her.

Jacquelina's first letter met category 4 (specific terms and scientific concepts) on the 5 point-scale rubric. She used four scientific concepts photosynthesis, food web, predator, and prey) in addition to seven specific terms (aphids, ants, wasps, mummies, stress, pesticides, and wetlands) accurately.

Jacquelina recounted the bizarre relationship amongst aphids, ants, and wasps that Miriam had previously described. Jacquelina's letter demonstrated that not only was she listening to Miriam, but that she remembered the logical sequence of events.

Jacquelina stated that "the sun hits the plants and this process is called **photosynthesis** and then it produces sugar in the leaf." This was an impressive statement because not only did it meet the grammatical construction, "X is the result of Y", but she also defined what photosynthesis means, i.e., the production of sugar in the leaf.

Jacquelina also stated that "when aphids lay their eggs, the ants carry the eggs to another leaf. The wasps then lay their eggs inside the aphid and the aphids then turn into mummies." She described this process as a **food web** because, "the ant and the wasp can be **predators** and the aphids can be the **prey**." This example of a food web met the grammatical construction, "X is a kind of Y", meaning, the relationship between the ant and wasp with the aphid is an example of a food web (predators and prey).

It is important to note that Jacquelina began to develop the meaning of photosynthesis through her interaction with Miriam. The concept had not come up during Jacquelina's inquiry project or during instructional conversations with the teacher-researcher. The fact that she articulated the meaning so effortlessly and completely in her letter indicates that perhaps Miriam's nonfiction narrative may have served as an effective means for Jacquelina's concept development.

Jacquelina also demonstrated her knowing of photosynthesis in another context, i.e., with Kenton in the microscope laboratory. Kenton discussed how the the zooplankton are dependent on the phytoplankton when he suddenly stopped short and

said, “Wait a minute, let me back up. What’s the phytoplankton dependent on ?” The students said, “the sun.” Then he asked if the students knew the process of how the sun provides energy to plants. Jacquelina quickly raised her hand and proudly said, “photosynthesis.” The teacher-researcher briefly met with Jacquelina at the end of the day and asked where she learned the meaning of photosynthesis. Jacquelina said from Miriam.

After seeing Miriam, both Jacquelina and Margarita constructed a concept poster to demonstrate what they had learned; they used a posterboard, foam letters, and markers to create a concept map. Jacquelina, Margarita, and the teacher-researcher generated a list of terms and concepts introduced during their time with Miriam: ecosystem, habitat, animals, plants, photosynthesis, sugars, aphids, ants, wasps, food web, prey, and predator. Jacquelina and Margarita then used these concepts and terms to reconstruct their understanding of the relationship of these words.

Although some of the placements of the words were somewhat arguable, for example, placing food web to the side with only prey and predator connected to it, the teacher-researcher did not correct the students, but rather tried to facilitate a more accurate rendition. Margarita was very adamant about not changing what both she and Jacquelina had created and the teacher-researcher sensed a very strong sense of ownership to leave what they had accomplished as untouched.

Jacquelina also used specific terms (**pesticides** and **wetlands**) to formulate a causal relationship, "pesticides can be really harmful to all of the wetlands *because* when it rains the pesticides wash away and resulting to wash all the pesticides into the wetlands. In causing of that happening the animals that live in any certain kind of wetland, animal that live in the wetlands can get harmed by all of the pesticides." This statement contains two grammatical constructions, "X causes Y", and "X is the result of Y". Even though the words pesticides and wetlands are considered specific terms, Jacquelina used them to convey accurate scientific concepts. In contrast, Cecelia had used everyday language to convey the meaning of a scientific concept, in that case- conservation. It was important that students used grammatical constructions or grammatical metaphors to construct meaning. This qualifies it as scientific language because grammatical metaphors are a reflection of how grammar has evolved through the practice of science. In other words, grammatical metaphors are both the product and process of thinking and doing science. They are the derivatives of the development of scientific discourse (Halliday & Martin, 1993, p. 206).

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Jacquelina stated that she learned all 20 science terms from the Science club. She most likely did not learn them in previous school years, or in other contexts (home, private preparatory school, informal science learning centers, museums, etc).

***Field notes (beginning).*** Jacquelina and the teacher-researcher often worked together when the Science club was in the field. Roxanne (research assistant) usually worked with Cecelia; Charlena and Margarita (two students who participated in the pilot study) were self sufficient, i.e., needing less guided facilitation.

The next vignette illustrates Jacquelina's use of knowledge in the field. The teacher-researcher noticed a ruddy duck and alerted Jacquelina to get her datasheet. They both knew it was a male because of his beautiful, bright, blue beak. Jacquelina used male and female symbols instead of words to indicate gender (this was scaffolded by the teacher-researcher) in addition to arrows to demonstrate directional movement. Both Jacquelina and the teacher-researcher lost sight of the ruddy duck because he swam behind some vegetation. As they walked toward the bridge to get a better view, they noticed crows flying overhead. Jacquelina said they were **predators** of ruddy ducks. The teacher-researcher was not aware of this fact and told Jacquelina that she appreciated the information. Jacquelina probably had learned this as she gathered information for her Research Report. It seemed that Jacquelina was becoming an expert on her animal of interest, as she was able to provide an adequate explanation for the ruddy duck behavior, that is, to hide from crows.

Another event occurred later in the day, when Jacquelina and the teacher-researcher took another walk around the slough and saw another male ruddy duck taking a bath. He was flapping his wings and dipping its body in and out of the water.

The teacher-researcher asked Jacquelina what the ruddy duck was doing, she said, “He’s cleaning himself.” The teacher-researcher responded, “Yes, he’s cleaning himself. Did you know that another word scientists use for clean, when talking about birds, is preen?” Jacquelina nodded no. The teacher-researcher then said, “Let’s try and use preen instead of clean.” “The ruddy duck is preening itself,” they said together. “Good,” the teacher-researcher affirmed. “But what is he preening,” the teacher-researcher asked. Jacquelina said, “His feathers.” “Yes, his feathers. Another word for feathers is plumage. Can you say plumage?” “Plumage,” Jacquelina says. “Okay, so let’s say the whole thing together.” “The ruddy duck is preening his plumage.” “Yes, that’s how scientists would say it and since we are doing scientific research, we’ll use this language, okay?” “Okay,” Jacquelina acknowledged. The teacher-researcher took the opportunity to extend Jacquelina’s everyday language to scientific language.

It is important to note that this brief instructional scaffolding session took about five minutes. Jacquelina appeared to enjoy the dialogue and whenever we saw a ruddy duck taking a bath, Jacquelina used scientific language rather than everyday language. Sometimes she would need additional scaffolding on particular words, but most of the time, she was accurate after the first time.

***Post-assessment interview.*** Using the 5 point-scale rubric, Jacquelina’s responses in her post-assessment interview met category 4 (specific terms and scientific concepts). She used seven specific terms: ruddy duck, aquatic invertebrate,

pelican, cormorant, invertebrates, wetlands, and sloughs accurately, in addition to seven scientific concepts: animal kingdom, foraging, breeding, migrates, endangered, ecosystems, and food web. The following examples demonstrate how each scientific concept qualified as an accurate usage:

**Example 1.** When asked, "What did you learn from participating in this Science club?" Jacquelina said, "I learned that the ruddy duck um eats aquatic invertebrates, and that he's from the **animal kingdom**." This statement met the grammatical construction, "X is found in Y locations/contexts", meaning, the ruddy duck is from the animal kingdom.

**Example 2.** When asked, "What behavior did you see a lot of?" Jacquelina responded, "He he's mostly **foraging**." This indicates that both times Jacquelina had received scaffolding for this word, it facilitated her beginning accurate usage of the term forage. Her statement also met the following grammatical construction, "X is a kind of Y", since foraging is a kind of behavior.

**Example 3.** Jacquelina added another behavior in the following statement, "and and **breeding**."

The teacher-researcher asked, "And breeding? Did we see any breeding?

Jacquelina responded, "Oh no no no, we didn't."

The teacher-researcher said, "Mostly foraging, huh? You're right."

It is important to note that the teacher-researcher provided a scaffold by carefully listening to Jacquelina and affirming when she was correct, and by

reminding her about what she had actually experienced. Jacquelina recalled that she never saw ruddy ducks breeding and corrected her initial response. This demonstrates both co-construction and guided facilitation. Jacquelina did state breeding as an example of a behavior, thus, this met the following grammatical construction, "X is a kind of Y", breeding is a kind of behavior.

**Example 4.** When asked, "What did you learn from going to the Elkhorn slough?" Jacquelina responded, "Um, that the, the crabs the green one..."

Teacher-researcher: "Mmmm hmmm."

Jacquelina: "That that it **migrates** from Europe to the United States."

Teacher-researcher: "Okay, does it migrate or does it somehow get, I guess it kind of does if it gets caught in the water (ballast water from boats), huh?

Jacquelina: nods yes

The word migration was defined in students' semiotic tables as an animal that travels seasonally from one location to another. This definition did not include the means of travel. The teacher-researcher understood how Jacquelina might arrive at her insights, based on her limited experiences with the word migrate. It was not surprising that Jacquelina considered a boat as a means for migrating. This unique example provides a window into how important it is not to make assumptions that a student understands the nuances of a particular concept and also to provide many contextualized examples since concepts develop over time and through numerous instantiations.

At the beginning of the study when visiting The Nature Center, the teacher-researcher indicated an exhibit which provided information on the Pacific flyway (migratory pathway birds take on their yearly migrations from North America to South America and vice versa). She also read a book about the wetlands early in the study which provided scaffolding for the concept as well.

During the Elkhorn slough field trip, there was an exhibit discussing the migratory path of pelicans. Students also observed pelicans in the field and discussed how they travel seasonally to and from Mexico. All are examples of bird migrations.

These multiple exposures to the word migrate probably were not enough for Jacquelina to formulate a more generalized use of this concept. This was a reminder for the teacher-researcher to provide a variety of examples of a concept in different contexts to develop a more accurate understanding of a general concept.

The following three examples demonstrate *causal statements*:

**Example 5:**

When asked, "Do you think studying about the wetlands is important?"

Jacquelina responded, "Yes, it is *because* it's like if there are **endangered** animals in the wetlands, we could help them by going everyday we can see them."

**Example 6:**

When asked, "What do you think about science now?"

Jacquelina responded, "It's pretty interesting *cuz*, yeah, you get to learn all about, like the **ecosystems** and habitats and everything."

**Example 7.** When asked, "Do you think science is important?" Jacquelina stated, "Yes, just *because* you like get to (pause) *because* in science you like you learn about, the, you could there's like you could learn about the earth or like the animals, like how they work with the, how the **food web** works and how the earth works and everything."

Vygotsky refers to causal statements as a form or type of scientific thinking (1987, p. 168-169). These examples include the word *because* or *cuz*, an indicator of a causal statement. Although some statements are vague, if one looks closely enough, there is evidence that Jacquelina made appropriate connections. In **Example 5**, Jacquelina stated that studying the wetlands is important *because* if there is an endangered animal, it could be helped by making daily observations. This is correct, as researchers studying endangered animals often make frequent observations in order to inform their inquiries.

In **Example 6**, Jacquelina used two words- ecosystem and habitat. The word habitat is part of the system of words which make up the meaning of ecosystem since there are many different kinds of habitats within an ecosystem. Although Jacquelina did not explicitly state this, the fact that she used both concepts together indicated that she was conveying the meaning of ecosystem.

In **Example 7**, Jacquelina provided an example of why science is important, i.e., *because* "you could learn about the earth or like the animals, like how they work with the, how the food web works and how the earth works and everything." This

demonstrated that Jacquelina understood that science is important as a process for understanding *how* things work, which is essentially the meaning of science, i.e., science is a way of thinking about the world, but more so, how the world is experienced.

***Science letters (second and third).*** Like Jacquelina's first letter, her second and third letters met category 4 (specific terms and scientific concepts). For example, in her second letter, she used five scientific concepts: breeds, foraging, omnivore, preens, and migrating, in addition to eight specific terms: humid, biotics, aquatic invertebrates, vertebrate, observe, ruddy duck, and plumage accurately. All five scientific concepts met a grammatical construction.

For example, "The ruddy duck **breeds** in some seasons, the months are in June and August," met the grammatical construction, "X is found in Y locations/ contexts" because the ruddy duck breeds in the context of June and August.

For instance, "I mostly go out to observe it. It is mostly **foraging**. The ruddy duck is an **omnivore** and it **preens** its plumage a lot *because* he dives under a lot and he makes splashes that is a sign of something." This causal statement contains three scientific concepts in one stream of thought. Essentially, it is a reflection of her field observations. There is a grammatical construction embedded in this causal statement, "it preens its plumage a lot because he dives under a lot and he makes splashes that is a sign of something," meets, "X is the result of Y", meaning diving is the result of preening. Both Jacquelina and the teacher-researcher observed the ruddy duck

'dipping down' into the water as if it were taking a shallow dive when taking a bath, i.e., preening its plumage.

Even more interesting than an accurate usage of the scientific concepts in this excerpt was that Jacquelina used the same scientific language scaffolded in the field, "it preens its plumage a lot," in her second letter as stated above, "I mostly go out to observe it. It is mostly foraging. The ruddy duck is an omnivore and it *preens its plumage a lot because he dives under a lot* and he makes splashes that is a sign of something." This indicated that the '*in the moment'* instructional conversation in the field was effective for Jacquelina's development of scientific language because she was able to use the same language in another context (written form).

Lastly, Jacquelina used migrating in the following statement, "The ruddy duck is used to migrating in some seasons." Although she was not specific with naming the seasons, nevertheless, she used the word seasons when discussing migrating, i.e., a part of the definition the Science club experienced in The Nature Center exhibit on migration, particularly with regard to the Pacific flyway and how many birds around the world migrate to the Watsonville slough during the fall and spring.

Jacquelina's third letter demonstrated accurate usage of six scientific concepts: camouflage, migrate, breeding, foraging, ecosystem, and diversity, addition to five specific terms: pipefish, pelican, crabs, egret, and slough. The following are examples of how the scientific concepts met one or more of the grammatical constructions for accurate usage of scientific concepts.

Jacquelina used **camouflage** in the following way, “I want to tell you that I loved how you told us that the pipefish does camoflauge with the grass under water.” This statement contains not only the grammatical construction, “X is a kind of Y” since she used the pipefish as an example of camouflage, but also the fact that she used the word love to indicate affect; Wells’ sixth principle of inquiry: the essential ingredient to this principle is accessing affectivity. When “everyone is involved in personally significant inquiry, there is an additional satisfaction and excitement in sharing what one is doing with others, in hearing what others are doing, and in discovering how these doings and understandings can be related” (Wells, 1999, p. 122).

When using the concept **migrate**, Jacquelina stated, “Also that the pelican can also migrate in the summer from Mexico to the USA.” This met the grammatical construction, “X is a kind of Y”, because she used the pelican as an example of an animal that migrates.

Her use of the concept **breeding** was as follows, “The other thing is that the pelican, crabs, and the egret are in breeding season, “summer”. This statement not only met the grammatical construction, “X is found in Y location/contexts”, meaning, the pelican, crab, and egret’s breeding season is found (occurs) during a specific context (summer), but also that she was accurate since the nesting season of brown pelicans is from summer to fall; female European green crabs release their eggs

during the summer months; and the breeding season of egrets (both great and snowy) ranges from February to May.

When using the word **foraging**, Jacquelina wrote, “Another thing is that all type of ducks expecialy the egret and pelican do foraging by there beak in the water and catching closer fish.” Although this was not accurate, in that egrets and pelicans are not ducks, she was accurate in her usage of foraging, i.e., stating how these birds forage with their beaks. This met the grammatical construction, “X is a kind of Y”, in that birds using their beaks to capture food in a kind/or type of foraging.

The last two scientific concepts, ecosystem and diversity were used as follows, “Last but not least that the elkhorn slough is a mixture of salt water and fresh water. That maybe nown as a **ecosystem** for any animal. Also that the **diversity** in the elkhorn slough is higher then the Watsonville slough.” Here, Jacquelina defined the Elkhorn slough as a mixture of salt and fresh water and is known as an ecosystem for many animals.

Although her spelling and grammatical structure was at times incorrect, a positive interpretation suggested that by describing the abiotic (water) and biotic (presence of animals), Jacquelina had included two main features of an ecosystem. Thus, this statement met the following grammatical construction, “X is found in Y locations/contexts” because she was stating that a mixture of salt and fresh water in addition to animals are found/located in the ecosystem of the Elkhorn slough.

Likewise, her statement about diversity, compares/contrasts the Elkhorn slough with the Watsonville slough. This comparison/contrast was correct because the Elkhorn slough has a mixture of fresh and salt water, and therefore has far more species and higher diversity than the Watsoniville slough. Although her statement, "The diversity in the elkhorn slough is higher then the Watsonville slough," did not meet a grammatical metaphor, the fact that she compared/contrasted these sloughs by stating one has a higher diversity than the other qualified as a form of higher level thinking since Vygotsky considered comparison and differentiation as a higher mental function (Vygotsky, 1987, p. 170).

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Jacquelina stated that she learned all 20 from the Science club. Of the 8 scientific concepts (ecosystem, diversity, migration, adaptation, camouflage, breeds, courtship behavior, and foraging), Jacquelina used 7 accurately. Her answer for diversity was vague and did not provide a specific example. The following two examples demonstrate Jacequelina's accurate usage of scientific concepts (see Appendix A for Jacquelina's complete assessment).

For example, when asked, "How would you describe the **ecosystem** here at the Elhorn slough? Is it similar or different from the Watsonville slough?" Jacquelina responsed, "It is different because the Elkhorn slough is a mixture of both salt and fresh water. The Watsonville is only fresh water." This met the grammatical

construction, “X is a kind of Y”. Another example was, “Name or describe an animal that **migrates** to the Elkhorn slough?” Jacquelina responsed, “Pelican.”

With regard to the 12 specific terms (habitat, wetland, slough, biotic, abiotic, vertebrate, invertebrate, aquatic invertebrate, native, non-native, Ohlone indians, and plumage), Jacquelina used only four accurately (wetland, biotic, abiotic, and plumage). However, during the post-assessment interview, the teacher-researcher facilitated a brief scaffolding session of the specific terms Jacquelina missed. With very little prompting, Jacquelina was able to provide accurate examples of each specific terms, but for some reason, two specific terms, invertebrate and vertebrate continued to elude her (see examples below):

**Example 1 Scaffolding of invertebrate**.

**Me:** Now here’s what I get concerned about, an invertebrate is an animal without a backbone. You said lettuce, plants, and algae. These are not animals, right. So does it make sense?

**Jacquelina:** Yeah

**Me:** Okay, so can you name an invertebrate for me. Think of an animal that doesn’t have a backbone.

**Jacquelina:** Polychaete

**Me:** Polychaete, now does it make sense?

**Jacquelina:** Mm hm.

**Example 2: Scaffolding vertebrate.**

**Me:** Now a vertebrate is an animal that does have a backbone, does a plankton have a backbone- no, does a polychaete have a backbone- no, does a mosquito have a backbone- no. What is that?

**Jacquelina:** Larva

**Me:** No

**Me:** So insects do not have backbones, they have their skeletons on the outside of their bodies; it's called an exoskeleton. What is an animal that has a backbone?

**Jacquelina:** Um a vertebrate.

**Me:** Yeah, but name an animal. Any animal that has a backbone.

**Jacquelina:** (pause)

**Me:** Any animal that has a backbone. Think of the food web poster that we just finished.

**Jacquelina:** Does it have to be like an invertebrate or like

**Me:** Name a *vertebrate* (emphasis on vertebrate); a vertebrate is an animal that has a backbone

**Jacquelina:** Could it be like an animal that doesn't live in the water?

**Me:** Sure

**Jacquelina:** Like uh, the uh, like the bobcat.

**Me:** Yeah, most vertebrates do not live in the water, so a bobcat, coyote, or rabbit, okay.

These examples demonstrate how the teacher-researcher provided prompting and leading questions to extend Jacquelina's understanding of the specific terms she missed on her pre/post scientific concepts and/or specific terms assessment at the Elkhorn slough. Vygotsky states that through "demonstrations, leading questions, and by introducing the initial elements of the task's solution," a student can reach their potential level of development (Vygotsky, 1987, p. 208-209). And in fact, Jacqueline does by providing accurate answers during the scaffolding sessions, however, invertebrate and vertebrate required more guided facilitation. Perhaps providing multiple examples throughout the Science club project would have been helpful for Jacquelina in order to accurately categorize plants, invertebrates, and vertebrates.

Finally, it is important to highlight the importance of extending students to their potential level of development during instruction. According to Vygotsky, "Research indicates that the *zone of proximal development has more significance for the dynamics of intellectual development and for the success of instruction than does the actual level of development* (Vygotsky, 1987, p. 209 emphasis in the original). If more teachers understood this, perhaps they would take the time to go over inaccurate answers on quizzes and/or tests to extend students' potential level of development, rather than merely handing students' exams back without any effort to explore together why they were answered inaccurately to begin with.

As one can see from these examples, Jacquelina reached a firmer understanding of the originally missed specific terms. This would not have occurred

if the teacher-researcher did not take the time to extend Jacquelina's initial responses with leading questions when needed. The teacher-researcher could have assessed her actual level of development after this scaffolding session, perhaps a month later, in order to verify if indeed she developed a firmer understanding of these specific terms, but due to time constraints, this was not attempted.

***Field-notes (middle and end).*** Toward the end of the study, Jacquelina and the teacher-researcher noticed a male ruddy duck diving (3 times in a row) for about 23 seconds. Jacquelina and the teacher-researcher took turns counting. They wondered what the ruddy duck was doing. Later in the day, they went into The Nature Center and the teacher-researhcer encouraged Jacquelina to share her observation with the science educator, Crysti. Jacquelina said, "The ruddy duck keeps diving under the water," The teacher-researhcer added, "Yeah, he dives down for about 23-24 seconds three times in a row."

Crysti listened and said, "Sounds like he's feeding." From this, the teacher-researcher took the opportunity to extend the everyday word *feeding* to the scientific word *foraging*, i.e., hoping Jacquelina would make the connection herself.

We continued to talk about the ruddy duck. The teacher-researcher said, "After six months of observational field work, we've only observed foraging and preening, but no courtship behavior." Crysti seemed surprised and said, "You haven't seen that yet?" The teacher-researcher and Jacquelina nodded no. Crysti then

provided a narration (through role playing) of the ruddy duck courtship behavior for us. All of the students listened carefully and watched.

> "The male ruddy duck will slap his beak down on top of the water as if to say, 'Hey, here I am! Look at me!' Then he puffs up his feathers and looks like a big ball of feathers. Then he blows lots of bubbles so that it looks like a jacuzzi; all of these bubbles are bubbling around him. Usually there are a couple of females he's trying to impress. If another male comes and starts the courtship behavior, the original male (the male who was there first) will be like, 'Hey, get out of here!' and he will do his display again.

The students were completely engaged with Crysti. It appeared that they enjoyed her animated description and imitation of the ruddy duck. This reminded the teacher-researcher of how Jacquelina had responded with Miriam, who also provided a narration of the bizarre relationship amongst aphids, ants, and wasps. It was interesting how the students responded favorably to narratives, role-playing, and imitations. This is an important realization to keep in mind for future instructional sessions.

One last point with regard to Crysti's information about courtship behavior was that this demonstrated that not every observer will observe all animal behaviors, thus, it is important to collaborate and share findings. In doing so, they can both essentially reconstruct a more accurate assessment of the animal they are investigating.

**Results (case study 2).**

***Triangulation of data sources.*** All four data sources triangulated, thus providing evidence that participation in an out-of-school contextualized inquiry

science project increased Jacquelina's use of scientific language. In fact, Jacquelina demonstrated the most gain of all case studies in the quantity of scientific language developed post study.

For example, when comparing and contrasting the interviews, Jacquelina progressed from a rubric score of 2 (everyday concepts and specific terms) to 4 (specific terms and scientific concepts). Although Jacquelina's rubric score for her first letter, 4 (specific terms and scientific concepts), was the same as her second and third letters, Jacquelina used more specific terms and scientific concepts in the latter.

With regard to her post/pre scientific concept and/or specific term assessment at the Elkhorn slough, Jacquelina stated that she learned all terms and concepts from her participation in the Science club. After visiting the Elkhorn slough, Jacquelina demonstrated a firm understanding of seven scientific concepts, however, needed more scaffolding with seven specific terms.

Finally, Jacquelina's field-notes demonstrate that she continued to use everyday language to make meaning of her observations, however, through scaffolding and the use of the semiotic tables, Jacquelina began to progressively use more scientific language.

**Discussion (case study 2).** In addition to an increase in her use of scientific language, Jacquelina showed growth in scientific thinking as demonstrated by causal statements. Moreover, Jacquelina provided comparisons and differentiated concepts and terms in order to convey meaning of particular concepts.

Jacquelina was also able to recall and use information learned in one context, and apply it to another. For example, Jacquelina began to develop the meaning of photosynthesis from her short time spent with Miriam at UCSC. Later in the study, she responded to Kenton's question regarding photosynthesis. On another occassion, Jacquelina was able to use scientific language developed during a scaffolding session in the field in her second science letter to Noelle. These examples provide evidence of the beginning development of higher mental functions (comparison, differentiation, logical memory, conscious awareness, and voluntary control) (Vygotsky, 1987, p. 170). Vygotsky states that these are the product of the instructional process of developing scientific concepts.

Finally, Jacquelina was beginning to really flourish toward the middle and end of the study. In fact, when the teacher-researcher asked the students if they would like to continue with the Science club but explore another ecosystem, Jacquelina was very excited about this prospect and said, "Yeah! Let's get in a kayak and explore the Elkhorn slough!"

**Expectations (case study 2).**

*Student's achievements met?* On the whole, Jacquelina's participation and the effects of her participation demonstrate that she was an exemplary student. Jacquelina had the strongest observational skills. This was quite impressive considering the circumstances from which Jacquelina started. For example: (a) her elementary school begins science education at fourth grade; (b) during the study,

Jacquelina was failing all of her classes in sixth grade, the reason for a transfer to a public school; (c) Jacquelina's self esteem at the beginning of the study was quite low; and (d) Jacquelina's parents did not have the time nor the financial resources to spend on informal science learning experiences, such as visiting The Nature Center and/or walking the wetland trails.

Thus, it was quite impressive that Jacquelina was able to make such gains in her use of scientific language. Jacquelina also matured in other ways: she gained a respect for nature and the animals which inhabit it, i.e., adding to our ground rules, "We should not only respect each other, but also our environment and the animals" and (b) she also gained confidence through her keen observational skills. Jacquelina must have been aware that she saw things no one else even noticed, and for this reason, the teacher-researcher often affirmed her impressive insights.

*Which were not met? And why?* In Jacquelina's post/pre scientific concept and/or specific term assessment at the Elkhorn slough, she had initially missed 8 specific terms. This surprised the teacher-researcher, so she reviewed these missed terms during the post-assessment interview. The teacher-researcher discovered that Jacquelina needed very little prompting for an accurate example, but, two specific terms continued to elude Jacquelina: invertebrate and vertebrate. The teacher-researcher led Jacquelina through a series of questions, i.e., redirecting Jacquelina to her own field observations in order to reach the correct response. Eventually,

Jacquelina arrived at correct examples for each specific term, i.e., invertebrate-polychaete, and vertebrate- bobcat.

From this cognitive dissonance, the teacher-researcher realized how important it is to provide a variety of examples in different contexts. Jacquelina had difficulty naming a vertebrate water animal. She had no problem naming a vertebrate land animal, as her answer (bobcat) suggests. Thus, the teacher-researcher realized that when scaffolding the word vertebrate, it would have been helpful for Jacquelina if they had originally generated a list of vertebrate animals: fish, shark, amphibians, reptiles, birds, land mammals, and water mammals. Students could have used their Earth Cards to construct this semiotic tool.

In summary, Jacquelina demonstrated the most gain of all case studies in the quantity of scientific language developed post study. She also showed growth in scientific thinking as demonstrated by causal statements. Moreover, Jacquelina provided comparisons and differentiated concepts and terms in order to convey meaning of particular concepts. In addition, she was able to recall and use information learned in one context, to another. These examples provide evidence of the beginning development of higher mental function (comparison, differentiation, logical memory, conscious awareness, and voluntary control) (Vygotsky, 1987, p. 170). Lastly, Jacquelina had the strongest observational skills.

**Charlena (case study 3).** The following section contains an analysis of Pre-assessments and Post-assessments. The pre-assessments include: pre-assessment interview, science letters (first letter), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-notes. The post-assessments include: post-assessment interview, science letters (second and third), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-note.

***Pre-assessment interview.*** Based on the 5 point-scale rubric, Charlena's use of language in her pre-assessment interview met category 4 (specific terms and scientific concepts). For example, she used one scientific concept in two forms (protect and protective), in addition to seven specific terms: mallards, robins, house finch, hummingbird, wetlands, the study of life (defining biology), and science, accurately.

When asked, "Do you think it's important to study about wetlands?" Charlena responded, "I think so *because* we get to know *how* to **protect** it and what bad for it." This response not only demonstrated a causal statement- an indicator of scientific thinking, but also a process or functional statement through the use of the word *how*. The word *how* here indicates a means of understanding either a process or function, which means some kind of action. Considering this was her pre-assessment interview, her use of language here was impressive.

When asked, "What would you think about your family coming with us one day and walking the wetlands and looking at all of the life?" Charlena responsed, "I

don't know, my, well, they might be a little over **protective**," demonstrated another form of the word protect.

Interestingly, Charlena used the word protect as a verb in her first statement, and then as a noun in her second. This is an example of a grammatical metaphor, which then is an indicator of scientific discourse (Halliday & Martin, 1993). Even though the topic of discussion changed from how to protect the wetlands to over protective parents, the teacher-researcher would argue that Charlena had reconstructed this word in her first response as a verb, to a noun in her second response, hence, the very definition of what a grammatical metaphor is. Note: There is no need to qualify these two forms of the word protect to meet the grammatical constructions since (a) Charlena used a causal statement when using protect; and (b) both of her responses combined qualified as a grammatical metaphor- an indicator of scientific discourse.

***Science letter (first one).*** Using the 5 point-scale rubric, Charlena's first letter met category 4 (specific terms and scientific concepts). She used one scientific concept: hermaphrodite, and eight specific terms: wetlands, habitat, biotic, abiotic, polychaete worm, aquatic invertebrate, marine animal, and robin accurately. Accurate usage of the scientific concept, hermaphrodite was demonstrated in the following example.

Charlena states, "The most interesting fact that I learned was that the polychaete worm is a **hermaphrodite**!!! I really didn't see that one coming!"

Although Charlena does not define her understanding of this word, the fact that she was surprised in learning that the polychaete is a hermaphrodite leads one to think that she does understand the meaning of this word- one that has both female and male sex organs. Her use of the word hermaphrodite met the grammatical construction, "X is a kind of Y", meaning, a polychaete worm is a kind or an example of a hermaphrodite.

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Of the 19 scientific concepts and/or specific terms, Charlena states that she learned four prior to the study, i.e., three scientific concepts: migration, camouflage, and cannabalism; and one specific term: wetland. Thus, her rubric score for this assessment was 4. The following examples demonstrate accurate usage of the three scientific concepts. Note: Charlena states that she learned these concepts from previous grades.

When asked, "Name or describe an animal that **migrates** to the Elkhorn slough," Charlena provides the following example- brown pelican. This met the grammatical construction, "X is a kind of Y", meaning, a brown pelican is a kind of migratory animal.

When asked, "Can you describe an animal that **camouflages** well at the Elkhorn slough?" Charlena provided the following example, "Skeleton worm looks like a twig." This met the grammatical construction, "X is a kind of Y", meaning, the skeleton worm is an example of an animal that camouflages. Although the correct

name is skeleton shrimp, she was accurate in her usage of this animal as an example of camouflage, i.e., as the students could barely see this animal in the microscope laboratory because it blended into the vegetation in the petri dish amazingly well.

Finally, when asked, "Can you tell me what **cannibalism** means?" Charlena writes, "Eats someone of the same species." This was accurate and impressive, because instead of using the word animal, she used species. It also met the grammatical construction, "X is a kind of Y", meaning a species who eats someone of its own kind is an example of cannibalism.

***Field-notes (beginning).*** At the beginning of the study, Charlena demonstrated that she had remembered information from the pilot study and that she was making connections with words. For example, on one of our first field days in the study, the teacher-researcher asked if Charlena could remember anything about the black birds (cormorants) perched on the posts, she said, "Aren't those the birds that don't have an oil gland and they have to dry their wings out?" This impressed the teacher-researcher since the pilot study was over six months prior to the doctoral study.

Charlena also demonstrated an inquisitiveness with making connections with words. For example, when the teacher-researcher was discussing the meaning of ecosystem and asked students for additional examples of ecosystems (other than wetlands), Charlena raised her hand and asked, "Is the word ecology similar to ecosystems." This demonstrated a willingness to extend her own learning.

On another occasion, when discussing how to use the water quality kit, the teacher-researcher had mentioned- acids are in the 1-6 range, neutral substances, such as water are at 7, and alkaline (basic) solutions are in the 8-14 range. When the teacher-researcher provided examples of each one, "Okay, where would lemon juice be on this scale- to the left, middle, or to the right?" The students responded and said, "To the left." Just after the teacher-researcher affirmed their answer, Charlena raised her hand and asked, "Is that why lemon juice is called citric acid?" This showed that not only was Charlena listening and understanding the water quality demonstration, but that she was making connections between her prior knowledge (citric acid) and new information.

***Post-assessment interview.*** Using the 5 point-scale rubric, Charlena's responses in her post-assessment interview met category 4 (specific terms and scientific concepts). Although Charlena used only one scientific concept: maintain, and three specific terms: wetlands, estuaries, and nursery, what was most interesting was the fact that she used comparison and differentiation when discussing wetlands and estuaries (two specific terms), and causal statements when using everyday language, however, the everyday language conveys the meaning of conservation, preservation, and restoration, three scientific concepts that were overarching themes which threaded through Science club discussions and experiences in the field.

To begin with, Charlena used the scientific concept- **maintain** in the following way. When asked, "Do you think science is important?" Charlena

responded, “It’s important *cuz* we can get smarter and also learn how to maintain the Earth.” Not only does Charlena use a causal statement- a form of scientific thinking, but she also provides two reasons why science is important- the later conveying action. The use of the word **maintain** is a semantic link to conservation- a word commonly used during the study.

The next three examples demonstrate signs of scientific language development through comparison/differentiation and causal statements (even though she uses only specific terms and everyday language).

First, Charlena compares and differentiates wetlands and estuaries in the following example:

**Example 1.**

**Me:** What did you learn from participating in the Science club?

**Charlena:** I learned a lot about the **wetlands** and that **estuaries** are when rivers meets the seas and some wetlands have salt water and some have fresh water and one has more animals than the other.

**Me:** And which one has more animals than the other?

**Charlena:** The Elkhorn slough has more than the Watsonville slough.

**Me:** And why do you think that is so?

*Note: Prompting for an explanation*

**Charlena:** Maybe *because* the Elkhorn slough is bigger?

**Me:** Ahhh haaa, the Elkhorn slough is bigger, huh? What's another reason why, do you think maybe?

*Note: Prompting for an alternative explanation*

**Charlena:** Maybe because there's more saltwater animals than freshwater?

**Me:** Because it's a mixture of freshwater and saltwater? That you get more animals, cuz it's a mixture of habitats? Okay. It's like a different ecosystem, huh? Alright.

From this example, Charlena not only used two specific terms accurately, but more importantly she successfully compared and differentiated the Elkhorn slough from the Watsonville slough as (a) having more animals; (b) is bigger in size; and (c) has saltwater. These differentiations were indeed correct, however, prompting from the teacher-researcher was used in order to extend Charlena along her zone of proximal development.

It is important to note that Vygotsky considers the ability to make comparisons/differentiations a higher mental function. Thus, in this case, Charlena is demonstrating a higher mental function which is often the product of the instructional process of the development of scientific language. This is an interesting statement because Charlena was not technically using scientific concepts, but rather specific terms and everyday language. Based on this fact, it appears that what qualifies as scientific language in this example was not a matter of words (concepts), but how the language was used.

The same case can be made for the following two examples which demonstrated causal statements (using only everyday language):

**Example 2.**

**Me:** What are your thoughts about wetlands now after learning about them?

**Charlena:** I think they're really good to have them in the world but the problem is that they get hurt so easily.

**Me:** They do, huh. How do they get hurt so easily? Can you give me an example?

**Charlena:** By making like, like how the Struve slough used to be a farm, they like took it down, but then they had to stop *because* all the water coming in.

Although Charlena used everyday language, her causal statement of how farming (cause) hurts the wetlands because of flooding (effect) was a form of scientific thinking. Charlena used the Struve slough as a historical reference of what can happen when man manipulates nature. Exhibits in The Nature Center and also discussions with the teacher-researcher and Cindy discussed how the Struve slough was a very successful dairy farm in the Watsonville region, however, due to periodic flooding, the dairy farm closed and nature took over.

**Example 3.**

**Me:** Do you think studying about wetlands is important?

**Charlena:** Yeah, *because* if everyone learned then maybe they'd stop making things that would hurt them.

Although Charlena does not provide specifics as to what things would hurt the wetlands, her causal statement is clear: stop making things (cause) that would hurt the wetlands (effect). As stated previosuly, these examples appear to convey a message of conservation, preservation, and restoration, three scientific concepts that were overarching and embedded in our Science club discussions and experiences in the field. Charlena appeared to have remembered these as they appear in her responses during her post-assessment interview.

***Science letters (second and third).*** Like Charlena's first letter, her second and third letters met category 4 (specific terms and scientific concepts). For example, in her second letter, she used two scientific concepts: **cannibalism** and **hermaphrodite**, and two specific terms: polychaete worm and aquatic invertebrate, accurately, however, without an explanation or specific examples.

For example, she stated, "I also learned that it uses cannibalism." This was a true statement, but Charlena did not elaborate, expand, or provide any detail to this claim. The same can be said for her use of the word hermaphrodite, "And the MOST interesting thing that I learned was that the polychaete worm is a hermaphrodite!!" Again, Charlena did expand on how she understands the meaning of this word.

Perhaps one reason why Charlena's second letter lacked luster was because the recipient of this letter was a stranger to her, i.e., Charlena had never met Noelle, the Education Director of the Watsonville Wetlands Watch Program at Pajaro Valley High School. Although the teacher-researcher mentioned Noelle in the context of

providing both material (water quality tools) and human resources (high school mentors), it may have not been enough for Charlena to feel a connection, thus the reason why her second letter lacked effort.

In her third letter to Kenton, she used two scientific concepts: adapted and camouflage, and four specific terms: habitat, aquatic invertebrate, skeleton worm, and non-native accurately. In this letter, she also provided specific examples and detail. The following example will illustrate this point:

Charlena wrote, "I also learned how the animals adapt to their habitat. For example, the gopher snake **adapted** to its habitat because it **camouflages** really well into the sticks and twigs. I also realized how accurate animals are at camouflaging, especially the aquatic invertebrates. For example, the skeleton worm *because* I didn't notice it in the plants until it started moving." This written text not only demonstrated an accurate usage of scientific concepts, but also detail when providing explanations which are based on her experiences at the Elkhorn slough.

For instance, Charlena used the gopher snake as an example of how the snake has adapted to its environment, i.e., by camoflauging. This met the grammatical construction, "X is a kind of Y", meaning camouflaging is a kind of adaptation. She expanded her understanding of camouflage using another animal in a different context, i.e., the skeleton worm (which is really a skeleton shrimp) blending into the plants. This demonstrated that Charlena had a well rounded understanding of

camouflage because she was able to articulate two specific examples of two different animals in two contexts.

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Of the 19 scientific concepts and/or specific terms, Charlena stated that she learned five scientific concepts: ecosystem, diversity, adaptation, breeds, and hermaphrodite, in addition to ten specific terms: habitat, slough, biotic, abiotic, vertebrate, invertebrate, aquatic invertebrate, native, non-native, and Ohlone Indians, from her participation in the Science club. Examples, but not all examples for the sake of brevity, for accurate usage of scientific concepts are as follows:

When asked, "How would you describe the **ecosystem** here at the Elkhorn slough? How is it similar or different from the Watsonville slough?" Charlena's written response, "Full of plants and places to hide. It is similar to Watsonville *because* they both have a large variety of animals. They are different because Elkhorn has salt water." This response was not only a causal statement, but also containws elements of comparison/differentiation. First, Charlena stated that the Watsonville slough is similar to the Elkhorn slough because they both have a large variety of animals. Second, she differentiates each slough by stating that the Elkhorn slough has salt water. Both assessments wer accurate.

Another example of an accurate usage of a scientific concept was with the word **diversity**. For example, when asked, "How would you describe the diversity of life here compared to the Watsonville slough? Is there a higher diversity of life here

at the Elkhorn slough, or lower diversity of life?" Charlena's written response was, "The diversity is larger because I saw more animals and plants."

This response demonstrates her understanding of the meaning of diversity and also how she used her observational experiences at the Elkhorn slough as an example of evidence. Thus, it is interesting how Charlena used a concrete, saturated experience to convey meaning of a scientific concept. Perhaps the action of contextualizing an abstract concept- such as diversity, to a real life example- (through experience), in addition to the scaffolding of this concept during instructional conversations, supported the downward development of this concept from its abstractness to its concreteness (or at least becoming more concrete). The following quote from Vygotsky sheds light on this developmental process:

> "*The strength of the scientific concept lies in the higher characteristics of concepts, in conscious awareness and volition*. In contrast, this is the weakness of the child's everyday concept. The strength of the everyday concept lies in spontaneous, situationally meaningful, concrete applications, that is, in the sphere of experience and the empirical. The development of scientific concepts begins in the domain of conscious awareness and volition. It grows downward into the domain of the concrete, into the domain of personal experience. In contrast, the development of spontaneous concepts begins in the domain of the concrete and empirical. It moves toward the higher characteristics of concepts, toward conscious awareness and volition. The link between these two lines of development reflects their true nature. This is *the link of the zone of proximal and actual development"* (Vygotsky, 1987, p. 220, emphasis in the original).

Thus, this is the reason why instructional conversations were instrumental for students' development of scientific concepts because it provided a means for students to draw upon their empirical observations in the field in a more conscious way. For

example, students became more aware of the meaning of their empirical observations after an instructional conversation with the teacher-reseacher who often prompted, probbed, asked leading questions, asked for explanations, asked for examples, asked for clarification, etc. In doing so, this awakened students to become more consciously aware of word meanings and how to frame and categorize concepts in such a way that each is placed in relation to other concepts within a particular system, in our case, ecosystems. From this instructional process, students' learning was essentially extended from their actual level of development (everyday experiences in the field) to their potential level of development (restructuring those experiences into systematic frames, categories, and ultimately understanding word meanings (concepts) within a system).

***Field-notes (middle and end).*** This field-note entry was recorded on our last outing at the Elkhorn slough. It demonstrated how Kenton interacted with the students, what he showed them, and how they listened, offered suggestions, and ultimately, in the end, learned how and why the European green crab became an invasive species to the Elkhorn slough.

On our last day with Kenton, when he was discussing how the **European green crab** is **non-native**, he asked the students *how* they thought the crab got to the Elkhorn slough. Jacquelina said, "By whale," while Charlena countered with, "By boat." Kenton extended Charlena's answer and discussed how boats fill their ballasts with water to balance cargo weight. When boats reach their port of destination, they

release the ballast water into another location. If the ballast water contains **larvae**, those larvae enter a new **ecosystem** and grow into adults. The adults **breed** and take over **native species' habitat** and food source. This is how the European green crab wound up here in the Elkhorn slough. The students appeared intrigued, especially Charlena.

As one can see from this excerpt, there are specific terms and scientific concepts embedded in the language Kenton used with the students. Because students had experienced many of these words at the Watsonville slough, they were able to follow and understand this new information, particularly Charlena. In fact, Charlena expressed on her student rating sheet how the learning/teaching activities with Kenton were not only the most helpful to her learning, but also the most enjoyable.

**Results (case study 3).**

***Triangulation of data sources.*** All four data sources triangulated, thus providing evidence that participation in an out-of-school contextualized inquiry project increased Charlena's use of scientific language. Even though Charlena's rubric scores are the same, 4 (specific terms and scientific concepts) for both pre and post assessments, she not only used more scientific language in her post assessments, but also provided better explanations and greater detail in her responses.

For example, when comparing/contrasting the interviews, Charlena used the same number (one) of scientific concepts in her pre and post, and in fact more specific terms in her pre than post, however, Charlena's responses in her post-

assessment interview demonstrated the use of comparison and differentiation (a higher mental function) and two causal statements which convey the meaning of three scientific concepts: conservation, preservation, and restoration. Thus, what was more important actually was not the quantity of specific term/scientific concept used, but rather the quality.

With regard to science letters, the rubric score for the first and second/third letters was 4, however, Charlena used more scientific concepts and specific terms in her second and third letter than in her first. In addition to this, Charlena's third letter demonstrated more detailed examples based on empirical evidence, i.e., her observations at the Elkhorn slough, than her first letter (pre-assessment).

Charlena's post/pre specific term and/or scientific concept assessment at the Elkhorn slough demonstrated that she knew the meaning of three scientific concepts and one specific term prior to the study, i.e., from previous grades. Charlena's growth in the development of scientific language grew post study to five scientific concepts and ten specific terms, all of which were used accurately and met a grammatical construction.

Lastly, Charlena's field-notes demonstrated an inquisitive student making connections between word, i.e., ecology and ecosystem; lemon juice as a citric acid (semantic link); and recalling information about cormorants learned during the pilot study. These impressive displays of knowing were revealed at the beginning of the doctoral study. Post study, Charlena also demonstrated a willingness to know more

about a novel species- the European green crab. Charlena successfully interacted with a scientist, provided accurate responses to his leading questions, and ultimately, in the end, appropriated many of the specific terms and scientific concepts used in the discussion (non-native, breeds, species, and larvae).

**Discussion (case study 3).** It is important to note that Charlena grew in other ways throughout the study: (a) she overcame her shyness to a greater degree toward the end of the study; (b) she appeared to feel more comfortable with sharing her prior knowledge and experiences, interests, and hobbies to not only her peers, but also teacher-researcher, research assistants, and science educators; (c) she demonstrated her inquisitive potential; (d) she made impressive connections; and (e) she showed tenacity in studying and researching her animal of interest (polychaete worm) even though the likelihood of finding one at the Watsonville slough was low.

**Expectations (case study 3).**

***Student's achievements met?*** Charlena exceeded the teacher-researcher's expectations. As stated previously, even though her pre and post assessment reflect the same rubric score- 4 (specific terms and scientific concepts), Charlena used more scientific language in her post-assessments and the quality of her responses is higher, i.e., using comparison/differentiation, causal statements, and a greater degree of detail when providing explanations or examples.

Having said this, it is important to ask why Charlena's rubric score pre study were 4's rather than lower scores. There are a number of potential reasons. First,

Charlena participated in the pilot study six months prior to the study. During the pilot study, both Charlena and Margarita experienced many of the specific terms and scientific concepts in the field. Perhaps this experience impacted Charlena's beginning development of scientific language. Second, Charlena attended the same private charter school that Jacquelina transferred out of. This is a rigorous, college prepatory middle school and unlike Jacquelina, Charlena was doing quite well. Third, Charlena's mother is a high school graduate and speaks English. Although the mother states she did not have time nor enjoys outdoor activities such as camping, she had taken her daughters to Ramsey park (which is where the Watsonville slough is located) to play. This indirect exposure to the wetland trails and The Nature Center may have provided an opportunity for Charlena and her sister to explore beyond the park boundaries. Fourth, Charlena's parents are financially secure. Both parents work long hours, six days a week, but they have the monetary means to meet their children's needs.

As one can see, Charlena has more access to resources which can aid in her intellectual development. These factors combined may be the reason why Charlena came into the Science club knowing and demonstrating more than Cecelia and Jacquelina, the new comers of the project, i.e., Cecelia and Jacquelina did not participate in the pilot study.

***Which were not met? And why?*** It was not expected that Charlena would rate Science club learning activities centered on the development of scientific

language as not helpful to her learning and also, not enjoyable. For example, when asked to rate, "When Ms. Lisa brought awareness to the fact that there are words in Spanish, such as plume (feather), that have the same root name and meaning as the specific term plumage," Charlena rated this 1 (not helpful). With regard to level of enjoyment for this activity, Charlena rated it 1 (not fun!)

This low rating reminded the teacher-researcher of her post parent interview with Charlena's mother (Maria). The teacher-researcher and Maria were discussing the students' science inquiry presentations and Maria expressed how impressed she was with Margarita's presentation, i.e., translating her presentation into Spanish for the parents who only understood Spanish. Charlena was in the room during this parent interview and appeared annoyed with her mother. Charlena's mother said, "I try and encourage Charlena to speak Spanish, to become more bilingual, but she resists." The teacher-researcher asked Charlena why this was so. Charlena responded, "Because we live in the United States and people here speak English, not Spanish."

Interestingly, Charlena uses Spanish to communicate with her father (who is semi-fluent in English), but not with her mother (fluent in English). Her attitude about speaking English and not Spanish may explain the low rating for the cognate activity, i.e., using Table 4 to bridge student's native language (Spanish) to scientific concepts and/or specific terms.

Charlena also rated writing science letters a 2 (a little bit helpful). This was understandable as Charlena mentioned in a post interview statement that, "she gets tired and sleepy when she has to write about something she doesn't want to write about." This was apparent in her first letter to Cindy and in her second letter to Noelle, however, her third letter to Kenton demonstrated not only enthusiasm, but also specific examples and explanations of her experiences both in the field and in the microscope laboratory at the Elkhorn slough.

In summary, Charlena exceeded the teacher-researher's expectations. Even though her pre and post assessments reflect the same rubric score- 4 (specific terms and scientific concepts), Charlena used more scientific language in her post-assessments and the quality of her responses was higher, i.e., using comparison and differentiation, causal statements, and a greater degree of detail when providing explanations or examples.

**Margarita** (**case study 4**). The following section contains an analysis of Pre-assessments and Post-assessments. The pre-assessments include: pre-assessment interview, science letters (first letter), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-notes. The post-assessments include: post-assessment interview, science letters (second and third), post/pre scientific concept and/or specific term assessment at Elkhorn slough, and field-note.

***Pre-assessment interview.*** Based on the 5 point-scale rubric, Margarita's use of language in her pre-assessment interview met category 4 (specific terms and

scientific concepts). For example, she used five scientific concepts: pollution, damaged, percent, data, scientific, and six specific terms: owl, nocturnal creature, mallard ducks, environment, wetlands, and duck accurately. The following are examples of how Margarita used the scientific concepts accurately.

Overall, it appears that her pre-assessments showed that she had somewhat of a foundation of scientific concepts and specific terms.

**Example 1.**

**Me:** Do you think studying about the wetlands is important?

**Margarita:** It is *because* you never know how many trash we can two out of a percent, like 5% out of trash in the wetlands, or, how does the trash get to the wetlands? How does the **pollution** stop? How does um everything that's being bad to the wetlands, how can we resolve it so it won't be **damaged** as it is right now.

This statement was not only causal- Vygotsky refers to causal statements as a form or type of scientific thinking (1987, p. 168-169), but also demonstrated an understanding that trash is a kind of **pollution**, meeting the grammatical construction, "X is a kind of Y". Margarita's use of the word damaged signified that the wetlands are **damaged** as a result of pollution. This met the grammatical construction, "X is the result of Y", meaning damaged wetlands is the result of pollution.

What was most interesting about Margarita's entire statement was her awareness of a problem (polluted wetlands) and her will (volition) to not only understand how to stop the pollution, but also what we can do as a Science club to

change it (evoke positive, production action). This was very impressive to say the least, as this was a pre-assessment interview. The hope of this study was that students would arrive at this point at the end of the study. Margarita showed that she was already there.

Examining Margarita's statement further reminds the teacher-researcher of the Moje & Carrillo (2001) study where students' questions reflected 'social concerns' rather than factors which contributed to air/water pollution: "Why do people keep polluting?" "How does pollution happen?" And, "What can we do to stop people from polluting?" In both cases, Margarita and the students in Moje & Carrillo's study, demonstrated how students' initial questions reflect a "broader, or social view" (Dewey, 1915, p. 5-6).

As stated previously in Cecelia's case study (*Case study 1*), it is important for teachers and researchers to be aware of the fact that when initially presenting a science unit to students, at least in the Moje & Carrillo study (2001) and my study, to establish a broad contextualization of the area, topic, and anticipated concepts that will most likely be explored in the unit. This provides students with 'something to hold onto,' i.e., refer to and use to make meaning and build a firmer foundation of understanding.

Many students, particularly minority, ELL, and urban youth unfortunately do not have high quality science experiences, thus, when an opportunity arises, they need to see and understand the 'bigger picture,' i.e., the purposes for engaging in the

science experience. For example, instructional conversations about the following questions throughout the unit would be beneficial for these students: (1) "Why are we doing this?" (2) "Why is this important?" (3) "What are the issues centered around this particular area, location, environment?" (4) "What can we do to investigate or solve one of these issues?" (5) "What are the concepts we will need to understand in order to do this inquiry?" (6) "What kind of information will we need to gather in order to investigate this issue?" (7) "How can we work together to fully do this inquiry?" (8) "What role will each of us play in this inquiry?" (9) "What kind of tools, instruments, equipment, and data will we need and why?"

**Example 2.**

**Me:** What are your thoughts about science, in general?

**Margarita:** Um, science is a kind of more like, it's like, you don't do too much experiences, but you try and figure out the **percent** of this and that and then you kind of try to figure out what you need to *cuz*, you're not doing experience, but you're actually trying to find the results of **data** that you're trying to get so you do a lot of research for science.

This example demonstratesd two findings. First, her lack of understanding that science does indeed include experiments, although, Margarita said experience. Second, understood that math, particularly using percents, is important "*cuz*, you're not doing experience, but you're actually trying to find the results of data." This

causal statement demonstrated that Margarita understood that using math is part of doing science. In fact, it meets one of the National Science Education Standards of scientific inquiry (1996), i.e., part of doing science is using math to organize, analyze, and interpret data. Although she did not provide evidence for her understanding of percentage, she did in the following example.

**Example 3.**

**Me:** Do you think that science is important?

**Margarita:** Mmm, actually I do think *because* if you want to figure out like how many ducks are in the wetland, you can do, like you can research to find the data of the whole, out of a 100, how many are still left, right here in the wetlands.

This example provided a specific example of percentage. This demonstrated she understood that a percentage is part of a whole. The fact that she used a causal statement and provided a specific example of percentage, "X is the result of Y", meaning, using a percentage was the result of trying to find the result of data, indicated that Margarita was using scientific language accurately.

Lastly, Margarita showed an understanding of the meaning of scientific language, as the following example demonstrated:

**Example 4.**

**Me:** And how would you feel if your family came and joined us on one of our field trips?

**Margarita:** I would feel proud *because* they would actually, like they would be more **scientific** like we are, *because* they would be studying the same as we are, so if we went home to tell them something, oh this and this happened at the wetlands, and we like found out how many percent of the mallard ducks are left, they would actually understand like if they went on a field trip before and got all that information to my parents *cuz* they would know, oh yeah, I remember the mallard ducks, you know, but yeah, there were this many now there are this many so I know the data how many you found out, the data you found out, like how many mallard ducks are left now, and the last year, so yeah.

When Margarita used the scientific concept **scientific**, she was referring to how her parents 'would be more scientific' like the students in the Science club because 'they would be studying the same' content and learning the same language; thus, her parents would 'actually understand.' This was a critical insight because it appears from this statement that Margarita is fully aware of the differences in the type of language used in the Science club (scientific language) from the language used at home (everyday language) with her parents. She appeared to want to bridge these differences in order to better communicate with her parents about what she was learning and experiencing in the Science club.

The next two examples demonstrated how Margarita used everyday language to convey the meaning of scientific concepts. This had already been demonstrated in the previous case studies. Margarita demonstrated this in the following examples:

**Example 1.**

**Me:** What do you know about wetlands?

**Margarita:** That, that's the animal's life. Where they live.

**Me:** Tell me more. You know more than that.

**Margarita:** Um, *there's a lot of animals and creatures that we can't see during the day cuz they're sleeping and then some of them come out in the night hunt, hunt food for themselves.*

**Me:** Can you give me an example?

**Margarita:** Um, an owl?

**Me:** An owl?

**Margarita:** Yeah

**Me:** Tell me more? An owl does what?

**Margarita:** *An owl, it sleeps in the day and it goes hunt for food in the night, so it's a nocturnal creature?*

**Me:** Very good. Anything else you can remember?

**Margarita:** No

**Me:** Really? All those birds?

**Margarita:** Oh, the, the mallard ducks, they have their babies like in secret areas *cuz* they don't want like other birds or any other creature to like eat them and like damage them, so they want to have a safe um environment for their for their little mallard ducks.

This example not only demonstrated the use of causal statements, but also how the instructional process extended Margarita further along the continuum of her zone of proximal developement. For example, initially Margarita had stated, "There's a lot of animals and creatures that we can't see during the day *cuz* they're sleeping and then some of them come out in the night hunt, hunt food for themselves," however, after the teacher-researcher asked for an example and details, Margarita provided a more fully articulated statement, "An owl, it sleeps in the day and it goes hunt for food in the night, so it's a nocturnal creature." This demonstrates how important it is for educators to ask, prompt, push, and lead a student's learning.

This example also demonstrate how, toward the end of the discussion, the teacher-researcher prompted Margarita for, "Anything else you can remember...all those birds?" The purpose in doing so was to awaken Margarita's memory of her experiences during the pilot study, i.e., when she studied the mallard duck.

After a brief moment of reflection, Margarita was able to recount her experiences, "Oh, the, the mallard ducks, they have their babies like in secret areas *cuz* they don't want like other *birds or any other creature to like eat them* and like damage them, so they want *to have a safe um environment* for their for their little mallard ducks." This statement not only signified a causal statement, but also the scientific concept **predator** from the phrase, "birds or any other creature to like eat them," and the scientific concept **protect** from the phrase, "to have a safe um environment". Again, the instructional process provided a means to extend her

beyond what she could provide at the moment. In doing so, the instructional process led Margarita's learning.

**Example 2.**

**Me:** What do you, what do you think about studying about wetlands? What are your thoughts?

**Margarita:** Um, my thoughts are that wetlands can become better *if we actually do more community service* and we actually *take care of them* more and if we can help in a way ***ducks*** or ***birds*** or ***creatures*** that live here in the wetlands, we should do that.

This demonstrated two things: (1) semantic links across the following words: ducks- birds- creatures. This demonstrates a horizontal display of similar word meanings (synonyms) (Halliday, 1993, p. 99), and (2) the phrases, "if we actually do more community service", and "take care of them" convey stewardship and advocacy, but also an understanding that the Watsonville wetlands are a place for migratory animals. Conservation, restoration, preservation, stewardship, community service, and advocacy appear to be integrated threads running through this example, and it is not surprising as these concepts were the overarching themes during the pilot study.

***Science letter (first one).*** Using the 5 point-scale rubric, Margarita's first letter met category 4 (specific terms and scientific concepts). She used two scientific concepts: scientific and cannibalism, and five specific terms: aquatic invertebrate, polychaete worm, bristles, marine, and burrows accurately. The following examples pertain only to the two scientific concepts:

**Example 1.** "Even thought i'm berly going in to 7th grade and i'm only 12 years old, I am glad that doing this project actually helped me learn words, that college people and high schoolers now about and I didn't, now that I am involved in this science club I know a lot of **scientific** words."

This statement revealed that Margarita was aware of the fact that she was developing an understanding of scientific language, even though she felt she was far too young to be learning words that college and high school students use. Margarita's use of **scientific** is accurate in that she used the word as an adjective to describe the type/kind of words she is learning in the Science club, "X is a kind of Y", meaning a scientific word is a kind of word.

**Example 2.** "Well now I am going to talk to you about my aquatic invertebrate I am studying about, it is called a polychaete worm it has bristles. It lives in the marine and burrows. Something that is incredible is that is a **cannibalism** aquatic invertebrate."

Although her grammar was somewhat off, i.e., should have said, "Something that is incredible about this aquatic invertebrate is that it practices cannibalism." However, the fact that she said, "Something that is incredible," signified something unusual or extraordinary, and the meaning of cannibalism conveys something extremely unusual and extraordinary, i.e., there aren't too many animals that eat their own kind.

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Of the 19 scientific concepts and/or specific terms, Margarita states that she learned two specific terms: habitat and native, from previous grades. She provided accurate examples for each term. Her rubric score met 2 (everyday concepts and specific terms). Interestingly, Margarita also had Mr. Murphy (the same science teacher Cecelia had), but did not mention having learned any concepts or terms from him.

***Field-notes (beginning).*** Throughout the study, Margarita was 'meaning making' with scientific concepts (Wells, 1986). For example, when first learning about the types of wetland birds, Margarita came to the realization that the Great egret and the Great blue heron were both herons, i.e., in the same family. This met the grammatical construction, "X is a kind of Y", meaning both the Great egret and Great blue heron are types of herons. Margarita tried to verify this with the teacher-researcher, but she did not know. Displeased with the teacher-researcher's lack of affirmation to her claim, she asked the teacher-researcher if they could look it up. Together, they obtained a field guide from the science educator. It turned out that Margarita was indeed correct.

During interactive group instructional conversations, Margarita demonstrated her tenacity to know and also her astute ability to correctly state the semantic links the teacher-researcher was hoping the students would be able to do. For example, Margarita challenged the teacher-researcher when she used the sun as an example of

an abiotic thing, stating, “The sun expands and we’re **dependent** on it, so why isn’t it **biotic**?” The teacher-researcher explained that biotic means it’s a living, breathing, growing thing like a plant or animal.

When discussing the words **ecosystem** and **wetland** and placing the ecosystem card (3 x 5) above the wetland card, the teacher-researcher asked the students, “How do these two words relate to each other?” Margarita looked at the positioning of the cards and said, “A wetland is a type of ecosystem.”

When the teacher-researcher placed the **biotic** card next to the **abiotic** card, and put the **wetland** card above both words, she asked the students, “How are these words related to each other?” Margarita responded, “There are biotic and abiotic things at the wetlands.”

Lastly, when the teacher-researcher introduced the word **biome**, she said, “A biome is the interaction of biotic and abiotic things…hmmm, this word sounds like another word we have learned…a synonym, not cinnamon, but a synonym with another word…does anyone know?” Margarita raised her hand and said in a matter of fact tone, “Ecosystem.”

Finally, when the Pajaro high school mentors came to show the students how to properly collect a water sample in order to obtain aquatic invertebrates, one of the mentors asked the students, “Why do you think we want to collect a water sample near the vegetation?” Margarita responded, “Because there’s food there.” As one can see, Margarita was very adept with co-constructing knowledge with others.

***Post-assessment interview.*** Using the 5 point-scale rubric, Margarita's responses in her post-assessment interview met category 4 (specific terms and scientific concepts). She used four scientific concepts: ecosystem, photosynthesis, poisonous, and variable, and six specifif terms: environment, habitat, polychaete, gopher snake, wetlands, however, she did not provide examples or convey meaning for ecosystem or photosynthesis, as the following example reveals:

**Example 1.**

**Me:** What did you learn from participating in the Science club?

**Margarita:** I learned, um, scientific words, like environment, and then **ecosystem**, habitat, um **photosynthesis**, and yeah.

Although Margarita used these scientific concepts, they did not qualify as an accurate usage of scientific language because neither: (a) met a grammatical construction; (b) was a causal statement; or (c) a grammatical metaphor. However, Margarita's use of **poisonous** did qualify as an accurate usage of a scientific concept because she provided an example:

**Example 2:**

**Me:** What lesson or activity did you find interesting?

**Margarita:** Um, where, at the Elkhorn slough or Watsonville?

**Me:** Anywhere

**Margarita:** The Elkhorn slough *cuz* I like it when we saw the gopher snake.

**Me:** You liked that, huh?

**Margarita:** Yeah

**Me:** What did you like about that?

**Margarita:** Um how that that, um, I thought it was **poisonous** but when you said it wasn't, so,

**Me:** Mmmm, hmmm

**Margarita:** like I was nervous.

*Note: The snake was actually a garter snake: black with a yellow stripe down it's full body length, beautiful snake just sunning itself to warm up.*

**Me:** So you like, the activity was just going for a nature walk

**Margarita:** Yeah

**Me:** And seeing what we see, could see- you liked that?

**Margarita:** Yeah

**Me:** Okay

The causal statement, "*cuz* I like it when we saw the gopher snake," and "I thought it was poisonous but when you said it wasn't," met the grammatical construction, "X is a kind of Y", meaning, "I thought the gopher snake was a kind of poisonous snake." Even though gopher snakes are not poisonous, her use of the word qualifies as an accurate usage of a scientific concept.

Lastly, Margarita used the concept **variable**, however, it appeared that she meant to use the word variety instead:

**Example 3.**

**Me:** And how do you understand wetlands now? We've been learning about them for six months, so how do you understand them now?

**Margarita:** Um that wetlands are where a habitat of of **variable** animals?

*Note: Variable not used correctly, I think she's trying to use the word variety, but she's trying to use a new concept. She feels comfortable to take a risk!*

**Me:** Mmmm, hmmm.

**Margarita:** So, it's not just like, just um

**Me:** A variety of animals?

*Note: Trying to clarify what she's trying to say, i.e., variable or variety?*

**Margarita:** Yeah, it's not just like animals that live like outside water, it's also like water animals like aquatic invertebrates and frogs and stuff.

**Me:** Mmmm hmmm

**Margarita:** Yeah

To clarify this, the teacher-researcher followed up with a question using the word variety, "A **variety** of animals?" When Margarita responds, "Yeah, it's not just like animals that live like outside water, it's also like water animals like aquatic invertebrates and frogs and stuff," both the teacher-researcher and Margarita were on the same page as to which word she actually meant to use.

Interestingly, this also occurred during the pre-assessment interview (Example 2) when Margarita used experiences instead of experiments. Even though Margarita used some concepts and terms incorrectly (variable instead of variety; experiences

instead of experiments), the fact she tries demonstrated that she was extending herself to take risks with developing scientific language. It also showed that she felt safe to make mistakes.

***Science letters (second and third).*** Using the 5 point-scale rubric, Margarita's second letter received a rubric score of 2 (everyday concepts and specific terms). She used no scientific concepts and five specific terms: polychaete larva, non-native, aquatic invertebrate, native, and vertebrate. Margarita's low rubric score of 2 was surprising because the recipient of her second letter was Kenton. Students' letters to Kenton generally entailed the use of multiple scientific concepts. However, Margarita's use of the specific terms demonstrated detail and specific examples of the terms:

**Example 1.** "I liked how the Elkhorn slough looked a lot different than the Watsonville slough. For example, how their were way more sea animals, like the non-native European green crab, the aquatic invertebrates like the skeleton shrimp, little brittle starfish and the jelly fish."

As stated previously (*Cecelia's case study*), a potential reason why students' letters to Kenton demonstrated more detail and specific examples was because prior to their letter writing, the teacher-researcher and students reviewed the concepts and terms experienced that day and shared their observations with each other. The teacher-researcher also reminded the students that Kenton was a scientist. She asked the students, "Since Kenton is a scientist, which language do you think would be

more appropiate to use- everyday or scientific?" Students unanimously said, "Scientific."

Margarita's third letter to Miriam received a rubric score of 4, i.e. using five scientific concepts: ecosystem, photosynthesis, food web, prey, and predator, in addition to three specific terms: aphids, ants, and wasps. Since Margarita was absent on the day the students wrote their first letters, Margarita had a 'make up' session at the end of the study to write her letter to Miriam, thus becoming her third letter rather than her first.

Margarita used the five scientific concepts (ecosystem, photosynthesis, food web, prey, predator) and three specific terms (aphids, ants, wasps) accurately, however, she did not make explicit connections between words.

**Example 2.** "Miriam, an **ecosystem** is consisted of plants and animals. Plants create **photosynthesis** were there it creates a **food web** causing, **prey** and **predator**. Then it form the leaf that has sugar where aphids are caried by ants/wasps to put their eggs in the aphid and the aphid becomes a mummy."

Her use of **ecosystem** was correct in that she stated the main components of this system- plants and animals, "X is found in Y locations/contexts". However, her use of photosynthesis was vague and incomplete. She did not make the connection that sunlight is the driving force and how this process leads to the production of sugar, oxygen, and water. It is understandable why Margarita's understanding of this concept was incomplete because the only scaffolding she received for the

development of this concept was from Miriam. Miriam had mentioned during her narrative that photosynthesis creates sugar in the leaves, hence, Margarita appeared to try and reconstruct what Miriam had shared with her.

The concept **food webs** was used somewhat accurately in that she linked **prey** and **predator** to this concept, however, she states that photosynthesis created the food web. This was somewhat correct in that the foundation for a food web is dependent on photosyntheis, but it does not create it.

Interestingly, the logical sequence of events in the bizarre relationship amongst aphids, ants, and wasps was correct. Overall, Margarita did not provide or extend the meaning of concepts and terms to convey a firm understanding of them. It was only when Margarita and Jacquelina discussed their poster with Cecelia, Charlena, and the teacher-researcher and answered their questions that it became apparent that Margarita had a firm grasp of the concepts and terms in her letter.

There are three potential reasons(a) Margarita learned these words through verbal communication with Miriam in a story like format (narrative); (b) she constructed a poster (concept map) which may have assisted with the development of concepts and terms (how the concepts and terms relate to one another), and (c) she thoroughly enjoyed meeting Miriam and appreciated her time.

Since Margarita and Jacquelina encountered these words verbally, perhaps using them in written text (letter) was a bit of a cognitive leap as writing is a very abstract form of communicating (Halliday, 1993, p. 109-111; Vygotsky, 1987, p.

202-203). Writing about scientific concepts and specific terms was, in a sense, a double abstraction, thus it is understandable why Margarita's letter did not come across as having a full and complete comprehension of the concepts and terms used in her letter to Miriam.

***Post/pre scientific concept and/or specific term assessment at the Elkhorn slough.*** Of the 19 scientific concepts and specific terms, Margarita stated that she learned 17 from the Science club and the remaining two (habitat, native) from school. Of the eight scientific concepts (ecosystem, diversity, migration, adaptation, camouflage, breeds, hermaphrodite, cannibalism), Margarita used six accurately (migration, adaptation, camouflage, breeds, hermaphrodite, cannibalism) and two vaguely (ecosystem, diversity). With regard to the nine specific terms (wetland, slough, biotic, abiotic, vertebrate, invertebrate, aquatic invertebrate, non-native, and Ohlone Indian), Margarita used seven correctly (slough, biotic, vertebrate, invertebrate, aquatic invertebrate, non-native, and Ohlone Indian). Thus, Margarita received a rubric score of 4.

For the sake of brevity, only four uses of scientific concepts will be discussed. For instance, when asked, "Can you tell me what **hermaphrodite** means?" Margarita wrote, "Both female and male." This was accurate and demonstrated that she understood the meaning of hermaphrodite.

When asked, "Can you name an animal that **breeds** here in the Elkhorn slough during the summer months?" Margarita provided the following example, "The eggs

in the European green crab." It is true that the European green crabs breed during the summer months and that the eggs are the result of breeding. The eggs will, eventually with time, develop into larva, and then into crabs which will then breed. Even though Margarita did not provide this lineage of development, she was correct. Her statement met, "X is the result of Y", meaning the eggs are the result of breeding.

When asked how she would describe the Elkhorn **ecosystem** and whether is was similar or different than the Watsonville slough, she stated, "It is similar like the Watsonville wetlands because it is a habitat to some animals." She did not mention that both have freshwater, yet the Elkhorn slough also has saltwater.

Likewise, she did not remember the meaning of **diversity** (at least it appeared so based on her written statement, "Don't remember Elkhorn slough." However, during the post-assessment interview, the teacher-researcher went over this assessment with Margarita and asked her, "Can you tell me what diversity means now? The following excerpt is from that discussion:

**Excerpt 1.**

**Me:** Diversity, can you tell me what diversity means now?

**Margarita:** Um, it's like the probability of what you're going to find. Like, there would be more diversity in the Elkhorn slough than in the Watsonville slough.

**Me:** Right, so it means different kinds of animals

**Margarita:** Yeah.

**Me:** Different kinds of animals.

**Margarita:** It's like the quality you would like find, different, it's like if you were gonna go to the mall, and you're going to buy something, huh, the mall is like, um, it's like in two different sections like in different habitats for the animals that would be an example.

*Note: Interesting analogy of a mall to a more diverse ecosystem, such as the Elkhorn slough*

**Me:** Okay, so a mall would have a higher or lower diversity than a corner store?

**Margarita:** Yeah

**Me:** Higher or lower?

**Margarita:** Higher

**Me:** Okay

This excerpt demonstrated that Margarita did in fact understand the meaning of the word diversity, however, she did not, or could not articulate it in her writing. As stated previously, perhaps one reason why was due to the fact that writing is an abstract means of communication and when a student is just beginning to develop word meaning, also an abstract act, the two combined (writing about abstract words) becomes a double abstraction for the student. Thus, Margarita was able to articulate the meaning of diversity verbally, even using an analogy of a mall to represent high diversity in comparison/contrast to a corner store (low diversity).

***Field-notes (middle and end).*** Toward the end of the study, Margarita demonstrated an understanding of mathematical relationships (correlations), the

meaning of hypothesis, and a tenacity for accuracy with regard to word usage. For example, when discussing water quality and the relationship between nitrates and dissolved oxygen, Margarita had a firm understanding that when the nitrate level is high (from the natural decomposition of organic matter or fertilizer), the dissolved oxygen is low. She also understood the reverse i.e., when nitrate levels were low, the dissolved oxygen was high.

On another occasion, when discussing their inquiry books, we were talking about hypotheses and the teacher-researcher asked the students if they knew what a hypothesis was. Margarita said, "It's an educated guess."

Lastly, one day when the teacher-researcher was reviewing the students' inquiry books, she noticed that Margarita had used the word *antlers* to describe the *sensory tentacles* of the polychaete worm. The teacher-researcher decided not to correct it, but rather to wait and ask Margarita if she meant to write *antlers* or something else. When Margarita saw what she had written, she appeared upset and tenaciously requested for the replacement of the word *antlers*, for *sensory tentacles*!

**Results (case study 4).**

***Triangulation of data sources.*** All four data sources triangulated, thus providing evidence that participation in an out-of-school contextualized inquiry science project increased Margarita's use of scientific language. When comparing Margarita's pre and post results, it appeared that her pre-assessments showed that she had somewhat of a foundation of scientific concepts and specific terms. For example,

in her pre-assessment interview, Margarita's rubric score was 4, demonstrating the use of specific terms and scientific concepts. Interestingly, Margarita used more scientific concepts accurately in her pre-assessment interview (pollution, damaged, percent, data, and scientific) than in her post-assessment interview (poisonous).

With regard to science letters, Margarita showed growth in her third letter, i.e., using five scientific concepts correctly, compared to using only two in her first letter. However, some of her usage of the scientific concepts in her third letter lacked strong conceptual connections, such as how sunlight is the driving force of photosynthesis and how sugar, water, and oxygen are the end products. Margarita appeared to articulate her understanding of photosynthesis and food webs more completely when both she and Jacquelina shared their concept poster with the teacher-researcher, Cecelia, and Charlena. It was apparent to the teacher-researcher that Margarita had a firm understanding of not only the scientific concepts, but also the specific terms (aphids, ants, and wasps), i.e., describing the bizarre relationship amongst these insects.

With regard to the post/pre scientific concept and/or specific term assessment at the Elkhorn slough, Margarita knew two specific terms prior to the study, however, developed an understanding for six scientific concepts and seven specific terms post study. This assessment demonstrated the largest gain in scientific concept development.

Lastly, the field-notes demonstrated that coming into the study, Margarita had surmised that the Great egret and Great blue heron were in the same taxonomic family. When the teacher-researcher checked her claim, she was indeed correct. Margarita also used the scientific word *dependent* when challenging the teacher-researcher about why the sun isn't considered a living thing. Margarita showed continued growth in the field-notes toward the end of the study. For example, an accurate understanding of negative correlations, the meaning of hypothesis, and a determinism for accuracy with regard to word usage, i.e, using sensory tentacles instead of antlers.

**Discussion (case study 4).** In addition to an increase in her use of scientific language, Margarita grew in other ways throughout the study: (a) Margarita started to become more collaborative and less competitive toward the end of the study; (b) she also expressed her feelings about Cindy (science educator) and how she felt unwelcomed by her; (c) she also felt safe to share with members of the Science club that her social science substitute teacher gave her a C- because she challenged him when he referred her to 'figure it out with her peers' instead of receiving assistance from him; and (d) she called the teacher-researcher to share information she had learned from the local news station about the plane accident which had occurred at the Watsonville Community Hospital, i.e, where the Science club met periodically. Luckily, we were not there when the plane crashed!

**Expectations (case study 4).**

*Student's achievements met?* From the start, Margarita demonstrated a knowing and strong conviction about what we can do as a Science club to evoke positive change for the wetlands. She mentioned picking up trash as a form of community service in order to decrease pollution. In addition, the teacher-researcher was impressed with Margarita's accurate use of five scientific concepts and six specific terms in her pre-assessment interview. From this, she realized that Margarita had remembered information from her interest of study- the mallard duck, during the pilot study, in addition to concepts and terms experienced in the field.

The teacher-researcher also appreciated Margarita's ability to challenge her, i.e., questioning whether the sun was an example of an abiotic thing and insisting that the Great egret and Great blue heron are in the same family. Perhaps some reasons why Margarita demonstrated a strong knowing pre study has to do with the fact that (a) she participated in the pilot study; (b) her father has both knowledge and experience with nature, some of which was historical information about the wetlands; (c) she spends time with her family in nature, i.e., camping, walks along the levee, and visiting the llamas, and (d) her parents and siblings provide a strong network of support for Margarita. This last point was very apparent as Margarita's father often commented about how he attended parent school meetings to become informed with how he can help his children. It was very clear that this had been highly effective, as both of Margarita's older siblings have either graduated from college (her older

brother), or are currently in college (her older sister) majoring in business administration.

*Which were not met? And why?* Like Charlena, it wan't expected that Margarita would rate the cognate activity as 'a little bit helpful' to her learning, and 'a little bit fun' with regard to level of enjoyment. The teacher-researcher expected that by introducing cognates, the students would appreciate how their native language could potentially 'give them an edge' with developing scientific language. Based on these rating, it appeared that Margarita did not see nor appreciate the power of cognates.

In addition, the teacher-researcher expected Margarita's post-assessment interview and second science letter to Kenton to demonstrate a strong use of scientific language. Instead, these assessments fell somewhat short compared to her third science letter and post Elkhorn slough assessment.

In summary, from the beginning of the study, Margarita demonstrated that she had somewhat of a foundation of scientific language (a) formulating many causal statements using everyday language to convey the meaning of scientific concepts; and (b) she understood that animals with similar characteristics are categorized in the same taxonomic family. She was also a strong advocate for community service, stating that we as a Science club should do something to protect the wetlands. Throughout the study, Margarita often pushed the teacher-researcher for answers to her questions. This tenacity was apparent with her peers as well. However, toward

the end of the study, Margarita appeared to collaborate more with her peers rather than compete with them.

**Cross Case Analysis**

There are many ways a cross case analysis can occur. For this study, I (a) cross analyzed the old timers' (Charlena and Margarita who participated in the pilot study) pre-assessments with the new comers (Cecelia and Jacquelina); and (b) cross analyzed the old timers learning gains with the new comers.

*Note: Refer to Appendix B: Tables 5 and 6.*

To begin with, when comparing all case studies pre-assessments, both Charlena and Margarita received rubric scores of 4 across all pre-assessments, except Margarita recieved a 2 for her pre Elkhorn slough assessment. These high rubric scores indicated that both were not only using specific terms and scientific concepts accurately prior to the study, but also demonstrating additional forms of scientific thinking.

For example, Margarita used many causal statements using everyday language to convey the meaning of the following scientific concepts: conservation, restoration, preservation, migratory place, stewardship, and advocacy. She also demonstrated an understanding of how animals with similar characteristics are categorized in the same taxonomic family.

Charlena demonstrated her ability to recall information experienced in the pilot study, i.e., which was six months prior to the doctoral study. For example, on

our first day in the field, we all noticed large black birds perched on posts in the middle of the Watsonville slough. The teacher-researcher asked Charlena if she remembered anything from the pilot study about these birds. She said, "Aren't those the birds that have to dry their wings out because they don't have oil glands?" This showed the teacher-researcher that Charlena, through experiential experiences during the pilot study, remembered this information and was able to retrieve it on her own.

In addition, Charlena made connections during our first instructional conversation on scientific language, i.e., asking if the words ecosystem and ecology have the same meaning. On another occasion, i.e., during a demonstration on water quality and determining the pH, Charlena surmised that the reason why lemon juice is called citric acid is because on a pH scale, it meets the acidic range.

These examples from the old timers demonstrate perhaps how and why both Margarita and Charlena demonstrated more prior knowledge and experiences about the ecology of the wetlands in addition to scientific language than the new comers (Cecelia and Jacquelina). Participating in the pilot study may have contributed to this, but other factors such as experiences in school and at home should be considered as well.

For example, Margarita's father had many childhood experiences in nature, and even considered himself as, "not a city person". He also shared historical information about the wetlands, i.e., how a portion of the Struve slough used to be a dump prior to the new development of condos. In addition, he stated that he takes his

children camping and that Margarita and her mother take walks around the levee where they see animals.

Charlena's mother's (Maria) funds of knowledge may have influenced and informed Charlena's prior knowledge and experiences as well. For example, during the parent interview, Maria expressed a concern about litter and how everyone can do their part by picking up trash and recycling. She also stated that although she does not like camping, she will take her daughters to the park to play on the playground structures. It is important to note that the playground is located in Ramsey park and the Watsonville slough is adjacent to the park. This proximity provided an opportunity for Charlena and her family to visit The Nature Center and walk the trails, thus learning more about the wetlands.

When comparing these old timers' pre-assessments with the new comers, the differences are apparent. Unlike the old timers high rubric scores of 4, the new comers' pre-assessment scores met mostly 1 and 2 (everyday concepts and everyday concepts and specific terms) with the exception of 4 for Cecelia's pre Elkhorn slough assessment, and Jacquelina's first letter written to Miriam.

For example, Cecelia used mostly everyday language during her pre-assessments, however, in her interview, she used everyday language to convey the meaning of a scientific concept- conservation. Her pre Elkhorn slough assessment revealed that she knew two scientific concepts and three specific terms from her science teacher, Mr. Murphy. Cecelia stated early in the study that she was learning

about ecosystems in school. Thus, this intersection between school and our out-of-school contextualized inquiry project was a fortuitous coincidence which reinforced Cecelia's learning of scientific language. Finally, Cecelia's pre field-notes demonstrate that she knew the meaning of the prefix- bio and could provide an example, other than wetlands, of an ecosystem- ocean.

Jacquelina's pre-assessments reveal that the majority of her language use was mostly everyday language, with some use of specific terms. However, her first letter to Miriam demonstrated the use of specific terms and scientific concepts, i.e., meeting a rubric score of 4.

There are a number of reasons why Jacquelina's first letter demonstrated the accurate use of scientific language: (a) Jacquelina and Margarita had met with Miriam and experienced the meaning of scientific concepts and specific terms through the context of a non-fiction narrative; (b) both were intrigued with the bizarre relationship amongst the aphids, ants, and wasps, thus heightening their attention; and (c) Jacquelina and Margarita co-constructed a concept map using the following words: ecosystem, habitat, animals, plants, photosynthesis, sugars, aphids, ants, wasps, food web, prey, and predator. Cumulatively, these three factors contributed to Jacquelina's accurate use of scientific language in her first science letter to Miriam.

With regard to the second part of this analysis- learning gains, it appeared that all of the case studies made gains, however, in different ways. For example, the old timers (Charlena and Margarita) use of scientific language increased somewhat from

their pre-assessments, but more importantly, the quality of their use of scientific language increased. For instance, Charlena's responses in her post-assessment interview demonstrated the use of comparison and differentiation (a higher mental function), and two causal statements when using everyday language to convey the meaning of three scientific concepts: conservation, preservation, and restoration. In addition, her third science letter to Kenton demontrated more detailed examples based on empirical evidence, i.e., from her observations at the Elkorn slough.

Lastly, Charlena's post Elkhorn assessment demonstrated that she learned and provided specific example for five scientific concepts and ten specific terms, compared to having known the meaning of only three scientific concepts and one specific term prior to the study.

Margarita demonstrated learning gains most noticeably when discussing her concept poster (based on words she used in her third letter to Miriam) to the teacher-researcher, Cecelia, and Jacquelina. She appeared to be better able to accurately describe the relationships of the scientific concepts and specific terms in her poster, than in her third letter to Miriam. This demonstrated that perhaps using these words in writing may have been a cognitive leap in that writing itself is an abstract form of communicating.

Margarita also showed gains in her post Elkhorn slough assessment, i.e., providing detailed and accurate examples of six scientific concepts and seven specific terms, compared to having known only two specific terms prior to the study.

Lastly, Margarita gained an understanding of mathematical concepts, specifically the negative correlation of nitrates and dissolved oxygen. She also expressed the meaning of hypothesis, and showed concern for accuracy with regard to word usage, i.e., using sensory tenacles instead of antlers, post study.

The new comers (Cecelia and Jacquelina) also demonstrated learning gains, most noticeably in quantity, i.e., the number of scientific concepts and specific terms developed post study, compared to pre study. In addition to this, the quality of Cecelia and Jacquelina's post-assessment responses demonstrated the use of causal statements in addition to greater detail and specific examples of both scientific concepts and specific terms.

For instance, Cecelia used two scientific concepts in her post-assessment interview compared to none in her pre-assessment interview. Even more than this was how she used these scientific concepts, i.e, demonstrating the relationship between words within a system (ecosystem balanced) and a causal statement (oxygen because of plants). These usages of language demonstrate that she used scientific language (a) within a definite system of related concepts to convey meaning, and (b) as a form or type of scientific thinking (Vygotsky, 1987, p. 168-169).

In addition, Cecelia used two scientific concepts and five specific terms in her third letter to Kenton, but even more importantly, provides detailed and specific examples of her observations.

Her Elkhorn slough assessment revealed knowing only two scientific concepts and three specific terms pre study, to five scientific concepts and five specific terms post study. But again, the examples she provided in her post Elkhorn slough assessment were more detailed and she used specific examples to provide evidence for her understanding of concepts and terms.

Lastly, Cecelia demonstrated that by the end of the study, she finally understood a mathematical concept which continued to elude her thoughout the study- negative correlations. She also commented how learning about food webs in the Science club helped her in school. Thus, in the end, Cecelia expressed that her participation in the Science club helped her in school, i.e., no longer failing in math or science.

Jacquelina demonstrated the most gain of all case studies in the quantity of scientific language developed post study. For example, Jacquelina grew from using only one specific term accurately in her pre-assessment interview, to using seven scientific concepts and seven specific terms accurately, in addition to providing examples in her post-assessment interview.

With regard to her science letter, Jacquelina demonstrated growth from her first science letter to her second/third letter, i.e., using four scientific concepts and seven specific terms in her first letter (which received an impressive rubric score of 4), to five scientific concepts and eight specific terms in her second letter, to six scientific concepts and five specific terms in her third letter.

In addition to demonstrating gains in her science letters, Jacquelina expressed that prior to the study, she did not know any of the scientific concepts or specific terms on the Elkhorn slough assessment. Thus, this assessment demonstrated that she learned seven scientific concepts and four specific terms from her participation in the Science club. Although Jacquelina provided inaccurate examples for some of the specific terms, when the teacher-researcher met with her post study, Jacquelina was able to provide accurate responses.

Lastly, Jacquelina's field-notes demonstrated how she excelled in the field with transitioning from everyday language to scientific language. In fact, Jacquelina used the same scientific language developed during an instructional conversation in the field, "the ruddy duck preens his plumage," in her second science letter to Noelle, "it preens its plumage a lot". This demonstrated that Jacquelina had appropriated, or at least was beginning to develop, accurate scientific language (Vygotsky, 1987; Wells, 2008).

One reason why the new comers demonstrated greater gains than the old timers has to do with their pre and post scores, as stated previously. The new comers pre-assessments were in the lower rubric range (1 and 2), while their post-assessments were at 4. In contrast, the old timers' pre-assessment scores were 4 for both pre and post-assessments, thus, the new comers demonstrated more of a gain.

Aside from quantitative gains, *all* students made improvements in the quality of language used in their post-assessments. There are three learning and teaching

practices which were highly effective- either in the classroom or outside: (a) instructional conversations, whether one-on-one with the teacher or during group conversations, served as a highly effective means for extending students from their actual level of development toward their potential level of development; (b) semiotic tools enriched the instructional conversations because students co-constructed meaning with the teacher-researcher and peers. Students reached not only mutual understandings through negotiation, but also new and improved understandings on the intended goal or outcome; and (c) students' field experiences provided an opportunity to experience abstract concepts in a concrete way. This occured when the teacher-researcher suggested to students to look at their semiotic tables for the scientific concept of an everyday concept they were using. In addition, the teacher-researcher provided many opportunities for the students to experience empirical observations which informed their inquiry projects. These concrete, saturated experiences made learning abstract scientific concepts easier.

It is important to note that these new comers' home lives differed from the old timers, in that: (a) their parents did not speak English; (b) their parents were often not home due to long working hours; (c) they experienced financial hardship throughout the study; (d) Cecelia suffered from some kind of illness throughout the study; and (e) Jacquelina's self esteem was very low because she was failing all of her courses at the charter school, thus, had to transfer to a public school. For these reasons, it was understandable how and why these new comers would demonstrate greater gains

from pre to post assessments, because coming into the study, they were experiencing unfortunate circumstances.

A common thread running through all case studies is how students used everyday language to convey the meaning of scientific concepts. This was a pleasant surprise to say the least because it provided evidence that students use their foundational language (everyday) to build additional languages (scientific language). This evidence adds to the literature of studies that have reported similar findings: Halliday (1993), Vygotsky, (1987), Wells, (2008), Ballenger (1997), Warren and colleagues (2002), and Ash (2008).

Another interesting thread has to do with how the students viewed the use of cognates. Interestinlgy, the old timers rated this activity as 'not helpful' or 'a little bit helpful' in addition to 'not fun' or 'a little bit fun'. One potential reason why these old timers rated this learning activity low could be due to the fact that their parents, or at least one of their parents, i.e., Charlena's mother and Margarita's father, speak English. Perhaps Charlena and Margarita did not see the significance in the cognates because they speak English at home with their families.

Conversely, the new comers (Cecelia and Jacquelina) did see the significance in the use of cognates as 'helpful' to their learning and also 'enjoyable'. Cecelia's parents and Jacquelina's parents speak only Spanish.

**Interactive Instructional Group Conversation Analysis on Food Webs**

There are 9 excerpts worthy of analysis. These excerpts will be presented in sequence of time, excerpt 1 occurred at the beginning of the instructional conversation, while excerpt 9 occurred at the end.

**Excerpt 1:**

**Me:** Okay, who studied the polychaete, Margarita and Charlena?

**Students:** Yeah

**Me:** Do ducks eat polychaetes?

**Students:** Yep, the **ruddy duck**

**Me:** Oh, the ruddy duck does, okay. I wonder if the mallard duck does too?

**Jacquelina:** It eats **aquatic invertebrates** and **polychaetes**.

This excerpt demonstrates how Jacquelina connects the polychaete to her animal of interest, the ruddy duck. She knows the ruddy duck eats polychaetes based on her gathering of information for her research report at the beginning of the study. However, she has not researched the mallard duck, but extends the fact that the mallard ducks also eats polychaetes and aquatic invertebrates. This provides some evidence to the fact that Jacquelina is categorizing these two specific terms (ruddy duck and mallard duck) into a general category of ducks.

Although this may appear not to be significant, it is a form of organizing information vertically and horizontally. For example, Jacquelina has, from a cognitive perspective, placed the word duck above two types of ducks (ruddy duck

and mallard duck). This vertical categorization demonstrates that she is organizing specific terms into their proper places. These two specific terms are then placed next to each other (horizontally) because they share a common diet, i.e., aquatic invertebrates and polychaetes. This provides evidence to the fact that, "the scientific concept blazes the trail for the everyday concept. It is a form of preparatory instruction which leads to its development" (Vygotsky, 1987, p. 169).

It's interesting how Jacquelina does not distinguish the fact that a polychaete is a type of aquatic invertebrate. Instead, she mentions both together without categorizing one as a type for the other. Her categorization is more horizontal than vertical.

**Excerpt 2:**

Although the students do not use any scientific concepts and specific terms in this excerpt, it still demonstrates how effective the Earth Cards were in co-constructing a food web on a poster board, i.e., becoming an interactive picture/ concept and term board.

**Me:** Okay, now what's going to eat the frog?

**Student:** Um coyote and rat?

**Cecelia:** The snake

**Me:** The snake

**Me:** This is a gopher snake (showing Earth Card). Is this the snake that we saw at the Elkhorn Slough?

**Cecelia and Margarita:** No

**Me:** Doesn't look like it, does it?

**Jacquelina:** It was like a red one.

**Cecelia:** It had red and a blue stripe or something like that.

**Me with student:** (putting tape on Earth Card and kind of mumbling)

**Cecelia:** (sneezes and says) And the snake is gonna eat that rat too (sneezing).

It's important to note that even though Cecelia is sneezing excessively, she's still participating and interacting with the Earth Card poster board activity. This demonstrates that co-constructing knowledge with students using visual pictures is a highly effective and engaging way of learning and teaching.

**Cecelia:** Eey, give her that rat.

**Charlena:** What about the bunny?

**Margarita:** It's snakes and coyotes.

**Jacquelina:** The snake eats the bunny and the rat.

**Me:** Okay, the snake (emphasis on snake) can eat lots of things, huh? The snake can eat, let's see, how do we want to do this

*Note: I'm allowing the students to do it rather than just me showing them. This is where the co-construction of the food web really becomes apparent.*

**Margarita:** Put the rat, put this thing first and then you put the snake and then you put the coyote.

**Me:** The snake can eat the frog, the snake can eat the bunny

**Charlena:** and the mouse

**Me:** and the mouse, do you have the mouse?

**Cecelia:** So the snake that we saw at the Elkhorn Slough wasn't a gopher snake.

**Me:** No it was something else.

**Cecelia:** It was another kind of snake.

**Me:** Cuz when we saw it, it was black and it had a yellow stripe down

**Cecelia:** Ohhhhhhh! I'm gonna look it up.

*Note: By not telling Cecelia the kind of snake we saw (garter snake, it procures intrigue and wonder, which is what teaching and learning must evoke in order to develop life long learners, the ultimate goal of education, in my opinion.*

**Students:** (talking, but inaudible)

This excerpt demonstrates three things: (a) the co-construction of what the snake eats (prey); (b) tapping into students' collective memory about a shared experience at the Elkhorn slough (seeing the snake) and sharing descriptive information about the snake; and (c) the teacher-researcher withholding information in order to propel a student (Cecelia) to seek information to find an answer in order to quench her wonder and curiosity.

When the teacher-researcher asks the students what's going to eat the frog, the focus shifts to what the snake eats (prey). Cecelia takes the lead in stating that the snake eats the frog and also the rat. Even though Cecelia is sneezing excessively, she still manages to contribute to the conversation. Charlena adds bunny to the list of prey items, while Jacquelina provides a summative assessment (although not yet complete), "The snake eats the bunny and the rat."

The teacher-researcher reassesses the prey items by stating, "Okay, the snake can eat lot of things, huh? The snake can eat, let's see, how do we want to do this?" This question provides an opportunity for students to step in and show both the teacher-research and each other how to display all of the snake's prey. Margarita steps up and provides direction to the teacher-researcher, "Put the rat, put this thing first and then you put the snake and then put the coyote."

As the teacher-researcher adds the Earth Cards to the board in addition to drawing arrows which signify the flow of energy from one food source to another, she says, "The snake can eat the frog, the snake can eat the bunny," while Charlena adds to the snakes menu, "and the mouse," which the teacher-researcher affirms, "and the mouse, do you have the mouse?" This interaction demonstrates a concerted effort to co-construct part of the wetland food web. During this meaning making activity, all students' attention was on the board and everyone appeared actively engaged.

Another aspect of this interactive instructional conversation was to stimulate students' memory of a shared moment, i.e., the snake observed at the Elkhorn slough.

Before the students co-constructed what the snake eats, the teacher-researcher held up an Earth Card of a gopher snake and asked, "Is this the snake that we saw at the Elkhorn slough?" This triggered students' memory as each student provided a response. Cecelia and Margarita both said, "No." Jacquelina added, "It was like a red one." Cecelia adds, "It had red and blue stripe or something like that."

This part of the excerpt demonstrates how the teacher-researcher is attempting to tap into students' collective memory of a shared experience. The purpose of this is to demonstrate how every student's memory adds to the total picture of the actual experience. In doing so, students begin to realize that collective memory is far more accurate than any one person's memory of a shared experience.

Finally, later in the conversation, after co-constructing what the snake eats, Cecelia comes to the following realization, "So the snake that we saw at the Elkhorn slough wasn't a gopher snake?" "No it was something else," the teacher-researcher responds. Cecelia says, "It was another kind of snake," as if trying to find out what kind of snake it was. The teacher-researcher senses Cecelia's wonder and curiosity and rather than tell her what kind of snake it was, she provides a description instead, "Cuz when we saw it, it was black and it had a yellow stripe down." Cecelia, excited to eventually identify it says, "Ohhhhhhh! I'm gonna look it up."

This part of the excerpt demonstrates how important it is for teachers to sometimes refrain from providing answers to students' questions. When a teacher

does this, it allows students to lead in their own learning, thus promoting life long learners in search of seeking information to fulfill their own curiosities.

**Excerpt 3:**

**Me:** Now, would you call this a food chain or a food web?

**Students:** **Food web**

**Me:** Why is it a food web?

**Charlena:** *Because* there's more

*Note: Margarita cuts Charlena off*

**Margarita:** *Because* it's connected to a bunch of different animals.

**Me:** Uh huh.

**Margarita:** And it's kind of going like a circle instead of like not straight but it

**Cecelia:** Yeah

This excerpt demonstrates two things: the distinction between a food chain and a food web; and Margarita's competitive nature (outspokenness). When the teacher-researcher asks the students if the board displays a food chain or a food web, all of the students respond, "food web." When the teacher-researcher pushes the students to provide an explanation as to why it is a food web, Charlena begins to formulate a response, "Because there's more," however, Margarita interrupts Charlena with her own explanation, "Because it's connected to a bunch of different animals."

Although Margarita is correct in her explanation, the fact that she 'stepped on and over' Charlena in order to do so was, in my opinion, unfortunate. Margarita could have let Charlena finish her response and then, once Charlena had finished, added to it, rather than "mowing Charlena down." This type of competitiveness from Margarita appeared throughout the study and some of the students, particularly the student who dropped out of the study, did not appreciate Margarita's competitiveness.

**Excerpt 4:**

*Note: This excerpt demonstrates co-constructing word meaning together.*

**Me:** Okay, do you guys know what **primary producers** are?

**Jacquelina:** Ummm

**Cecelia:** The ones that eat first.

**Jacquelina:** The ones that

**Cecelia:** These! (pointing)

**Charlena:** get eaten

**Jacquelina:** the ones that (inaudible)

**Margarita:** the ones that are in the middle!

**Jacquelina:** The ones that are doing the eating

**Me:** Wait. What, what do you see in that word?

**Cecelia:** Umm, I can't see.

**Cecelia:** Produce

**Me:** Produce

**Margarita:** Ohhh my God (laughs, I think Margarita was shocked that Cecelia figured it out so quickly)

**Cecelia:** (laughs)

**Me:** What's produce? What do you think I'm gonna go to the store and buy produce, what are you going to buy?

**Student:** Ahhhh

**Cecelia:** Plants!

**Charlena:** (sounded like plant loaf?)

**Margarita:** Something to eat

**Jacquelina:** Like vegetables

**Me:** Okay, so what are the primary producers?

**Cecelia:** The plants

**Me:** plants

This excerpt demonstrates how opening up a conversation with a question, such as what are primary producers, provides an opportunity for students to co-construct the meaning with some facilitation from the teacher-researcher by sharing their knowledge and working together as a team to eventually arrive at the meaning of this concept.

Although it took time for the students to get there, this type of teaching and learning is well worth it because it provides students with a goal (obtaining the meaning of a word) and an opportunity to 'play off each other' to eventually arrive at

the meaning. The teacher-researcher's role in this teaching and learning episode is to initially provide the goal (which in this case is a question), and then, if needed, refocus the students' attempts in a particular direction in order to facilitate their course of action. Once the students are on the right track, she let's them go at it once again, thus, arriving at the meaning on their own.

**Excerpt 5:**

**Me:** What are the animals that eat plants?

**Margarita:** **<u>Herbivores</u>** (says yawning)

**Cecelia:** Butterflies

**Me:** and the duck

**Cecelia:** and the duck

**Margarita:** We don't have the banana slug.

This excerpt demonstrates Margarita's understanding of the meaning of herbivores. It also shows her disposition during this activity (very tired). This activity occurred toward the end of a very long day. Margarita lost her stamina, while the other students were able to maintain more of a pace together. Cecelia's contribution of butterflies is accurate, as butterflies are plant (nectar) consumers. She also affirms the teacher-researcher's addition of duck as an herbivore. This is not entirely correct, as ducks not only eat vegetation (duckweed), but also eat aquatic invertebrates (animals). Thus, they are considered to be omnivores. Not only is Margarita losing steam, so is the teacher-researcher (me). Finally, Margarita's

assessment of banana slugs not inhabiting the Watsonville wetlands is accurate. Throughout the pilot study and doctoral study, not once did we find a banana slug. These animals are more frequently found in wooded areas, such as redwood forests in Santa Cruz.

**Excerpt 6 :**

**Me:** What are **aquatic invertebrates**?

**Margarita and Charlena:** um little animals that live in the water

**Charlena:** and that don't have a backbone

**Me:** Okay

This brief excerpt demonstrates that both Margarita and Charlena (the two students who chose the polychaete worm as their animal of interest for their scientific inquiry projects) understand the literal meaning of an aquatic invertebrate: an animal that lives in the water; and an animal without a backbone. This demonstrates a concerted effort of co-constructing a firm understanding of the meaning of aquatic invertebrates. This time, Margarita collaborated with Charlena instead of 'beating her out' of responding. Interestingly, Charlena completes the remaining meaning on her own without interruption from Margarita (a sign that Margarita is indeed tired!)

**Excerpt 7 :**

**Me:** Okay, what do we call animals that eat other animals?

**Margarita and Charlena:** **Predators**

**Cecelia:** **Carnivores**

**Charlena:** Oh, no carnivores

**Me:** Carnivores, because we're talking about primary and secondary and all that

**Margarita:** Oh, I thought, well predators yeah

**Me:** So what would be a carnivore here?

**Student:** The frog

**Jacquelina:** The bobcat

**Me:** All of these guys (pause), even the hawk, huh?

**Margarita:** You like my hair?

**Me:** So all of these guys here

**Me:** What would we call this? Would this be an herbivore?

**Cecelia:** Yeah

**Jacquelina:** Yeah

**Margarita:** Yeah

**Me:** Uh huh.

**Me:** What do we call an animal that eats both plants and animals?

**Cecelia, Jacquelina, and Charlena:** **<u>Omnivore</u>**

**Margarita:** Omnivore!

**Margarita:** Eat carne y plantas.

**Jacquelina:** Like an omnivore

**Student:** Naturvore

**Me:** What's an example here of an omnivore?

**Margarita:** I think it's gonna be a

**Charlena:** bullfrog

**Jacquelina:** the hawk

**Cecelia:** the duck

**Me:** No the hawks do not eat plants.

**Student:** the ducks

**Me:** I think maybe the frog

**Charlena:** What about the ducks?

**Me:** they eat insects and I think they eat some plants too.

**Charlena:** the mallard duck

**Cecelia:** the frog and the snake

**Me:** the frog and, snakes do not eat plants

**Student:** they don't?

**Charlena:** What about the duck?

**Me:** The duck? Yeah. The duck is good because they eat duckweed and they also eat polychaetes, so let's put the omnivore here.

**Cecelia:** They have carne?

**Me:** Huh?

**Cecelia:** They're made of meat?

**Me:** Well, they're an animal, an animal, yeah.

**Cecelia:** Oh

This excerpt demonstrates three things: (a) the use of scientific concepts (predator, carnivore, and omnivore) accurately; (b) Charlena pushing her answer (what about the duck) through for recognition; and (c) Cecelia's surprised realization that polychaetes are made of meat (carne), i.e., with the teacher-researcher providing somewhat of an explanation, "Well, they're an animal."

To begin with, when the teacher-researcher asks the students, "What do we call animals that eat other animals," both Margarita and Charlena respond, "Predators." Although this is correct, the response the teacher-researcher was looking for was carnivores since we were discussing primary and secondary consumers. Cecelia follows Margarita and Charlena's response with, "Carnivores." Charlena realizes this is the correct response, "Oh, no carnivores," based on the context in which these words were being used. The teacher-researcher provides an overall explanation as to why carnivores is the correct response, "Carnivores, because we're talking about primary and secondary and all that." Margarita then follows with a response, i.e., suggesting she's still holding on to her original response of predators, "Oh, I thought, well predators yeah." When asked for an example of a carnivore, one student says frog, while Jacquelina says bobcat. These examples are correct, although frogs are typically referred to as insectivores rather than carnivores.

The teacher-researcher then moves on to another question, "What do we call an animal that eats both plants and animals?" Three students, Cecelia, Jacquelina, and Charlena say together, "Omnivore." Margarita follows with, "Omnivore! Eat

carne y plantas." Margarita adds the meaning of omnivore in Spanish after her exclamatory response. This demonstrates assertiveness, or perhaps that she's tired and wants the lesson to end. Following Margarita's response, a student uses an interesting word, "Naturvore." Interestingly, this word follows the same structure as carnivore and omnivore, but with nature as a prefix. This demonstrates creativity and awareness of word structure.

When the teacher-researcher asks the students for an example of an omnivore, a variety of answers are provided: bullfrog, hawk, and duck. As the teacher-researcher provides information as to what each animal eats, some animals are eliminated because they only eat meat (hawk). During this process of elimination, Charlena perseveres with having the teacher-researcher examine whether the duck is indeed an omnivore, asking three times, "What about the duck?" Finally, the teacher-researcher responds to Charlena, "The duck? Yeah. The duck is good because they eat duckweed and they also eat polychaetes, so let's put the omnivore (word card) here (on the board). This part of the excerpt demonstrates Charlena's tenacity to assert her request until it was 'picked up' by the teacher-researcher. This shows that Charlena, toward the end of the study (this was our last day) developed a sense of confidence and outspokenness.

Finally, when the teacher-researcher had mentioned that ducks eat polychaetes, Cecelia appears very surprised and asks, "They have carne?" Not understanding her question, the teacher-researcher asks for clarification, "Huh?" She

clarifies by asking once again, but in English, “They’re made of meat?” Finally, the teacher-researcher understands what Cecelia is referring to (the polychaete) and responds, “Well, they’re an animal, an animal, yeah.” Cecelia, still surprised at the response says, “Oh.”

**Excerpt 8 :**

This excerpt is in relation to a fire which occurred at a fruit warehouse (Martinelles) near the Watsonville slough. The soot and ash from the burnt apples expelled into the slough, thus killing hundreds of fish (high nitrate level, low dissolved oxygen). The purpose in tying this incident into the food web conversation was to revisit students’ understanding of water quality and how a high nitrate level correlates to a low dissolved oxygen level, hence the reason why hundreds of fish (and most likely aquatic invertebrates) died.

**Me:** Okay, whenever we have pollution, let’s say this is like an oil spill

**Student:** Oil

**Me:** or the Watsonville fire and all that ash and soot from the burnt apples went into the water, when that happens, guess what happens to the oxygen, what happens?

**Cecelia:** it goes down

**Charlena:** it burns

**Me:** it goes down, right. We lose the oxygen and what do we get in its place?

**Jacquelina:** Car carbon, CO2

**Me:** Yeah we get CO2 in its place, right?

**Student:** Yeah

**Me:** And if we get CO2 in its place, can the fish live in the water?

**Students:** No!

**Me:** No

**Student:** They die

**Me:** They wind up dying, huh? That's what happened. Thousands of fish died because of the pollution, right. All of the nitrates in the water sucked up all that oxygen and you got a bunch of carbon dioxide and the fish died, guess what else died?

**Margarita:** Mmmm mmm mmm (like…I don't know?)

**Cecelia and Charlena:** the tadpoles

**Me:** the tadpoles died

**Student:** Ahhhh (sounding disappointed)

**Me:** And if we take the fish out of the food web (pause), does that affect the food web?

**Cecelia:** Yes!

**Me:** Who does it affect?

**Cecelia:** All of, the duck, the bullfrog, the egret and that

**Students:** the hawk

**Cecelia:** the hawk

**Cecelia:** mostly every single

**Margarita:** Mmm, it affects a lot of animals

**Me:** It affects especially what?

**Jacquelina:** The egret!

**Cecelia:** the egret

**Me:** and the, if all the fish died, Margarita and Chantal, what animals is it going to affect?

**Margarita:** the fish

**Charlena:** the ones that eat the fish

**Me:** the ones that eat the fish and

**Charlena:** and it sort a affects the one that eats them (meaning the predators of those that eat fish).

This excerpt demonstrates three things. First, Cecelia finally understanding the negative correlation of nitrates and dissolved oxygen. Throughout the study, this had eluded Cecelia, however, in this excerpt, she arrives at the correct response. This demonstrates that sometimes it takes a while for a student to reach an understanding of a particular concept or idea. What's most important for a teacher is to be patient and provide numerous examples, especially contextualized examples such as this one. Providing a context to a question or problem often assists students with enough information to solve it.

Second, students' understanding that animals cannot survive without oxygen, and how this was the reason why so many fish died. When the teacher-researcher

asks the students, “What else died?” both Cecelia and Charlena say, “the tadpoles.” When the teacher-researcher affirms their response, the students respond, “Ahhh,” as if they are disappointed by this fact. This shows care and empathy for the tadpoles, i.e., an affective response. The teacher-researcher continues to ask who and what is affected in the food web with the loss of so many fish. Cecelia responds, “All of, the duck, the bullfrog, the egret and that.” These answers are all correct. Another student adds hawk to the list. Margarita sums it up by stating, “Mmm, it affects a lot of animals.” Although this response is correct, it is far too general with where the teacher-researcher was hoping both Charlena and Margartia would go (see next paragraph).

Finally, the teacher-researcher directs the following question to Margarita and Charlena, “And the, if all the fish died, Margarita and Charlena, what animals is it going to affect,” hoping they will recognize that the polychaete’s population (their animal of interest) could rise with all of the fish dying, since fish are predators of aquatic invertebrates. Instead of thinking of the preceding animal, i.e., the animal that the fish eats (polychaetes), the students were thinking of successive animals, the animals that eat the fish (egret, heron, and hawk). This is a correct approach, but not the way the teacher-research had hoped they would go. The teacher-researcher was hoping students would predict what would happen to their animal of interest (polychaete) with the loss of so many fish. This prediction never occurred. This is an example of the teacher-researching steering the direction of teaching and learning,

rather than facilitating a more natural, student centered approach. Perhaps this is the reason why the students did not 'take it up.' Note: A learning lesson for the teacher-researcher (me).

**Excerpt 9 :**

The students had just completed a food web assessment from Enchanted Learning, and we were going over it together.

**Jacquelina:** Can I read this one?

**Me:** Yeah, the last one, go head.

**Jacquelina:** Some organism's position in the food chain can vary as their diet differs. For example, when a bear eats berries, the bear is acting as a primary consumer. When a bear eats a rodent, the bear is functioning as a secondary consumer.

**Jacquelina and Cecelia:** (*Note: Cecelia joins Jacquelina and they read together.*) When the bear eats salmon, the bear is functioning as a tertiary consumer. This is because salmon is a secondary consumer, since salmon eat herring, that eat zooplankton, that eat phytoplankton (laugh because they got off track).

Jacquelina: energy from the sunlight. Think about how people's place in the food chain varies, often within a single meal

**Me:** Okay, so the interesting thing about that is if you're a vegetarian and you eat basically plants,

**Charlena:** and you're an **herbivore**

**Me:** yeah, if you're an herbivore and you eat mostly plants, do you think you're getting more energy from the sun?

**Cecelia:** No

**Me:** Think about it?

**Cecelia:** Yeah

**Me:** Yeah

**Me:** Now, let's say you eat a lot of meat. Do you think you're getting more or less energy

**Cecelia:** less

**Me:** from the sun?

**Me:** You're getting less because, right? You're not as close to the sun. What's the closest thing to the sun? Plants!

**Cecelia:** Plants

**Me:** Vegetables, fruits. So do you see why it's so important to eat vegetables and fruits?

**Cecelia:** Yeah

**Me:** Because you're getting more energy, you're more healthy, you have more vitality. Does that make sense?

**Margarita:** Ah huh.

**Me:** I never really thought about it that way, but that's a good way to think about it. Okay.

**End of lesson**

This excerpt demonstrates how a teacher-research can arrive at an "Ahhh haaa" moment during an instructional conversation. When discussing how energy is transferred from one source to another in a food web, the teacher-researcher realizes that the closer food sources are to the sun (plants, i.e., vegetable and fruits), the more energy is consumed by the consumer and this is the reason why vegetables and fruits are healthier and provide more vitality than other food sources, such as meat (which are further away from the sun in the food web). The teacher-researcher states, "I never really thought about it that way, but that's a good way to think about it," because she is looking at food and energy from another perspective for the very first time.

This demonstrates how teaching and learning through inquiry is a reciprocal process which can, and did in this case, situate the teacher as the learner. It also provides the students with an example, a model, of how one comes to know something from another perspective. As the teacher-researcher was speaking and reconstructing her understanding of food webs from a more personal perspective (a vegetarian), the students were listening and watching her reach a new understanding of why vegetables and fruits promote health and vitality, because these food sources are primary producers, thus more energy is transferred from the sun to vegetables and fruits. The fact that the students observed the teacher undergoing a 'learning moment' perhaps brings awareness to the fact that even teachers are learners.

## Chapter 6: Research Question 2 Scientific Inquiry

### Research Methods

**Data sources.** Data sources for the individual case analysis included: pre/post instructional interviews, student presentations, post assessment of scientific inquiry at a different context (Elkhorn slough), and field notes. A data source for the interactive instructional conversation included a model of an inquiry template book and a book about Jane Goodall as a chimpanzee field researcher.

**Data collection.** Instructional interviews were conducted both before and after the study by the teacher-researcher. Interviews were face-to-face, semi-structured, audio-taped, and transcribed for analysis (see Appendix A for interview questions). Students were asked the same questions even though their topics of interest and mode of inquiry differed from one another. Specifically, the teacher-researcher was interested in students' response to the following question pre/post: "Based on your area of interest, how do you think you might find an answer to your question of interest?" The teacher-researcher's expectation was that students' post response would include the sequential steps of the inquiry process, whereas the pre response would not.

Students' presentations occurred toward the end of the project. Students used their scientific inquiry books to construct their presentation posters. They presented their inquiry projects in a conference room at the Watsonville Community Hospital to

their families, the teacher-researcher, and the research assistant (Lupe) and her husband. The teacher-researcher took notes and audio-taped students' presentations. The notes were rewritten and the audio-tape transcribed.

Post assessment of scientific inquiry was in the form of a template book, i.e., the same template students used for their scientific inquiry projects at the Watsonville slough. The purpose of this assessment was to assess whether students could use a template scientific inquiry book (the same template used to guide students in their inquiry projects at the Watsonville slough) in another context (Elkhorn slough).

Students were asked to choose a plant, animal, or environmental feature at the Elkhorn slough of interest to them and then go through the 'framed' steps of inquiry. For example, students posed a research question, determined if it was testable, ascertained the correct mode of inquiry to answer their research question, determined what kind of tools they would need to carry out their inquiry, conjectured the kind of data they might collect, provided an analysis of their 'imagined' data, provided an explanation of their findings, provided an alternative explanation of their findings, and finally, provided a conclusion.

Field notes were collected throughout the study during social interactions: (a) peer-to-peer engagements; (b) researching their plant and/or animals of interest; (c) field outings; (d) discussions with science educators and Kenton Parker; (e) discussions with the teacher-researcher, research assistants, and student mentors, (f) students' interactions with their parents; and (g) students' behaviors, attitudes, beliefs,

perceptions, etc. These written notes were transcribed and served as an effective tool for understanding students from multiple perspectives and roles.

The interactive group instructional conversation on modes of inquiry was audio-taped and transcribed for analysis. The teacher-researcher used a variety of examples to demonstrate each mode of inquiry. For example, to demonstrate the mode of inquiry- *observations*, she brought a Jane Goodall book and showed pictures of the scientist using binoculars and a notebook to record her observations.

To demonstrate the mode of inquiry- *investigations*, the teacher-researcher asked the students what they thought of when they heard the word- investigations. One student said, "murder." We then co-constructed, as a group, how a detective investigates a murder: interviews suspects, collects evidence, creates a timeline, reconstructs the crime scene, etc.

In addition, the teacher-researcher reminded the students of a real life example they had encountered one Saturday morning that could apply to the investigative mode of inquiry. She reminded the students of the dead juvenile cormorant they discovered in the parking lot in front of The Nature Center. She asked the students, "If we wanted to investigate how the cormorant died, what could we do?" With no responses from the students, the teacher-researcher prompted students with suggestions:

> If we took that dead cormorant and took it to the lab and took tissue samples to see if it ate something toxic; if we opened up it's stomach to see if it ate a

piece of plastic; if we ran tests on it; if we ran an x-ray on it to see if there's any broken bones, that would be an investigation, okay? So is that clear?"

These specific, concrete scenarios not only contextualize how one would investigate the death of a cormorant, but they also provide a mental picture of what a scientist or lab technician would actually do. Contextualizing content through the use of imagry is an effective strategy in teaching and learning with ELL.

To demonstrate the mode of inquiry- *experiments*, the teacher-researcher used an example from her literature review (Warren et al., 2002), i.e., four students testing whether ants prefer light or dark environments. The teacher-researcher discussed the features of the experiment, i.e., how students designed the experiment (even creating variables), and their findings.

**Data Analysis**

Instructional interviews were member checked in order to ensure accurate statements and information for the pre/post instructional interviews. Questions which addressed scientific inquiry were categorized into the inquiry group. Students' responses were examined for evidence of understanding inquiry, i.e., examples, explanations, reference to whole group discussions on modes of inquiry, etc.

Students' presentations were analyzed for: (a) overall performance; (b) command of knowledge gained from their inquiry projects; and (c) sufficient answers to the audience's questions.

Post assessment of scientific inquiry was assessed using a 3 point-scale rubric which addressed nine steps of the inquiry process (see Appendix B). Three points were possible for each step (9 steps), for a total of 27 possible points.

Field notes were analyzed for examples of students engaging in any of the three modes of inquiry and/or inquiry steps, whether from their projects or in other instances.

All four data sources were analyzed in two ways: (1) a single case analytic induction (Patton, 1990) was used to analyze these data sources for emerging themes, similar patterns, and trends (p. 44). Triangulation was sought through the use of multiple data sources and through the use of multiple methods of data collection (Denzin, 1978), and (2) cross case analytic induction was used to compare/contrast each case study for differences, unique variations, or common outcomes.

For the interactive group instructional conversation on modes of inquiry, cross-case analytic induction (Patton, 1990) was used to analyze students' interactive group instructional conversation. This provided a means for assessing not only students' understanding of the modes of inquiry, but how they perceived their own inquiries. Having this information allowed students to determine for themselves the mode of inquiry they employed for their own scientific inquiry projects.

**Analysis of Individual Case Studies**

**Cecelia** (**case study 1**). The following section contains an analysis of Pre-assessments and Post: assessments. The pre-assessments include: pre-assessment interview and field-notes. The post-assessments include: post-assessment interview, presentation, template book at Elkorn slough, and field-notes.

***Pre-assessment interview.*** The purpose for the questions in the pre-assessment, particularly Examples 1 and 2, was to probe students' interest and wonder, two vital principles for engaging in inquiry (Wells, 1999, p. 121). These examples revealed Cecelia's interest and curiosity about two things (a) the red stuff floating in the water (mosquito fern) and; (b) the cross at the memorial site on Lee Road (first slough visited).

Interestingly, Example 2 demonstrates Cecelia's curiosity about why people throw garbage. She stated she noticed a tire and other things. The first three examples demonstrate two social perspectives (cross and garbage) and one biological (mosquito fern). This is reminiscent of students' initial concerns and interests in the Moje & Carrillo (2001) study, i.e., where students' questions reflected a social concern as to why people pollute and how students can stop people from polluting, rather than the narrowly defined unit question: "What is the quality of water in our river?"

**Example 1.**

**Me:** Did you see anything that interested you or made you wonder at the Struve slough?

**Cecelia:** The cross. Um, the red things in the water.

**Me:** Okay.

**Example 2.**

**Me:** Is there anything that interests you more about wetlands after going to that one?

**Cecelia:** Why do people throw garbage at them?

**Me:** Did you notice garbage at that one?

**Cecelia:** Yeah

**Me:** I noticed some too. What was it?

**Cecelia:** A tire, um, um, I don't know (laughing)

**Example 3.**

**Me:** Do you have any questions or concerns about the wetlands?

**Cecelia:** What was the um stuff on the wetlands and why there was a cross too?

**Me:** Uhhh huh, what was the stuff floating on top of the water; the red stuff? And why there was a cross?

**Me:** Anything else?

**Cecelia:** Oh no.

Example 4 demonstrates how the teacher-researcher was trying to assess how Cecelia would come to find an answer to her question about the red stuff in the water. This question was probing what means Cecelia would use to seek an answer to her

inquiry. Cecelia stated that she would ask other people. Although not a traditional scientific approach, her response does convey seeking information from others, i.e., which scientists often do, whether in person or through a literature review when initially beginning their research.

**Example 4.** Q8: How do you think we might find out what that red stuff is on top of the water? How would we find out what that stuff is?

**Cecelia:** By asking other people.

**Me:** Asking other people?

**Cecelia:** And um, uhh, ummm, like, uhmmm, I don't know.

**Me:** Okay

***Field-notes (beginning).*** On the first day, Cecelia demonstrated an interest and curiosity about plants. For example, she was the first student to notice red specks in the water and wondered what they were. She took the initiative to ask the science educator (Cindy). After Cindy's identification of the red specks (mosquito fern) and providing an explanation as to what it was (duckweed) and why it turned red (certain weather conditions), the students and teacher-researcher headed out to another slough, the Watsonville slough. Upon arrival, the same plant covered the water's surface. When the teacher-researcher asked the students if they remembered the name of the plant, Cecelia was the only one who did, "Mosquito fern!"

***Post-assessment interview.*** Cecelia's post-assessment interview reveals three things: (a) what she learned in her scientific inquiry project; (b) how important the

presentation was to her; and (c) how she felt she could be an active voice for educating others about wetlands.

First, Cecelia stated that she learned blue-eyed grass was used for medicine and that the poppy was used to assist children with going to sleep, i.e., by placing a poppy under the child's pillow or bed. Throughout the study, during her discussions with Crysti, peers, and the teacher-researcher, Cecelia was fascinated with the medicinal properties of plants.

As mentioned previously in RQ1, perhaps one reason why Cecelia had a predilection for the medicinal qualities of plants has to do with the fact that throughout the duration of the study, Cecelia was ill most of the time. In fact, Cecelia has asthma and one of her plants of interest, the blue-eyed grass, was used by the Ohlone Indians to treat asthma. Cecelia also states that she learned how plants get energy from the sun, although she does not expand on this insight. When asked how she felt about her experiences in the field, i.e., measuring plants and surveying the amount of mosquito fern on the water surface, Cecelia said she liked that.

Second, of all the activities and events experienced in the Science club, Cecelia stated that her favorite was the presentation. When asked what she learned from doing the presentation, the teacher-researcher added, "Did you learn that you can do it?" This question stemmed from the day of the presentation, when the students, particularly Cecelia and Jacquelina, were very concerned as to whether they could stand in front of an audience and present their inquiry projects.

Cecelia acknowledged the teacher-researcher's question with, "Yeah." The teacher-researcher saw an opportunity to commend Cecelia on her performance, "You did it very well. Did it do something for your, like how you feel about yourself?" Cecelia responded with, "Yeah, like since I did the Science club, I've been more into plants and animals than I had ever been." This acknowledgment, i.e., about how the Science club impacted Cecelia's interest in plants and animals was also reinforced by Cecelia's parents during the parent post interview. Cecelia's mother (Maria) stated that Cecelia is now more interested in plants (this will be discussed further in RQ3). This provides some evidence of motivation to possibly extend her learning of plants, i.e., one of the reasons why the teacher-researcher mentioned botany and ethnobotany as potential, future careers during Cecelia's post interview.

Finally, Cecelia states that she can be an active voice for educating others about wetlands. Although she did not elaborate her answer (she's very tired), she asserted that she could speak to others, such as her friends, family, cousins, about wetlands.

***Presentation.*** Cecelia was visibly nervous before starting her presentation. She giggled at first, and then started. Cecelia read each section of her Scientific Inquiry Book (cut and pasted into sections on a three-winged poster board) first in English, and then made an attempt to translate into Spanish as the teacher-researcher requested all students to do for parents who only understood Spanish. Interestingly, at times, Cecelia would look to her parents for help with translating, but her mother,

who only speaks Spanish, would shrug her shoulders as if to say, "Don't look at me. I don't know."

Although Cecelia read from her poster during the presentation, she appeared to understand the logical sequence of each step in the inquiry process, i.e., pausing and emphasizing key points and findings. For example, when discussing why she chose the blue-eyed grass as one of her plants of interest, Cecelia emphasized how she was interested in the medicinal properties of this plant: "blue-eyed grass was used to make tea to treat such conditions as heart burn, ulcers, asthma, and indigestion."

She also emphasized how surprised she was not to find any blue-eyed grass in the Struve slough, especially after reading that it was found in this region of the Watsonville wetlands. As Cecelia continued with her presentation, she started to get visibly tired, often taking deep breaths as if she was running out of air. However, Cecelia pressed on and continued, finishing her presentation with laudatory applause. The teacher-researcher asked the audience members if they had any questions. One audience member (male) did (*see below*):

**Male:** Yes, I have one, you mentioned that mosquito fern was used by the Native Americans, is it still used for medicine? For a, I think you mentioned grass?

**Me:** Oh

**Cecelia:** The blue-eyed grass?

**Me:** The blue-eyed grass is used for what Cecelia?

**Cecelia:** Heartburn, ulcers, asthma, and indigestion (says without looking at her poster board).

**Male:** Is it still used for that?

**Cecelia:** I don't know.

**Me:** But the Ohlone Indians were the first ones

**Male:** First ones to

**Me:** Native people used plants for medicinal purposes

**Male:** What did they do, brew it?

**Cecelia:** Yeah, to make tea.

**Male:** Oh, they made tea out of the plant, okay. They probably still do.

**Me:** Same with the um, the willow tree, they used umm for aspirin…

**Margarita's father:** (inaudible…sounds like peach rub or peach rum)

This dialogue demonstrates how Cecelia was able to answer an audience member's question without referring to her poster board. She appeared confident and matter of fact in her responses, even when she did not know if Native Americans still use blue-eyed grass for medicinal purposes. This audience member (male) appeared genuinely intrigued with what Cecelia presented and latched onto Cecelia's interest of plants (medicinal qualities). Likewise, an audience member (Margarita's father) added his own knowledge of another remedy (peaches for either rubbing or rum). This generated some laughter amongst audience members (shared camaraderie).

***Template book at Elkhorn slough.***

Template: What I found most interesting at the Elkhorn slough was _____

Cecelia: I found interesting the polychaete larvae.

Template: If I were to research what I found interesting, I would research the following:

Cecelia: It's habitat, what they eat, do they stay with their birth parents, and are they always going to be that small?

Template: After learning about these facts, (researching whether these have already been answered), I still have some questions:

Cecelia: Why do polychaetes only like being in marsh water? What do they eat?

Template: I asked myself, "Are these testable questions?"

Cecelia: (Maybe): Why do polychaetes only like being in marsh water?

(Yes): What do they eat?

Template: My research question is _____

Cecelia: "What do they eat?"

Template: For my research question, I need to collect _____

Cecelia: I need to collect the food in their stomach

Template: Since I will _____ in order to answer my research question, of the three types of inquiry: observations, investigation, and experiments, my type of inquiry will be _____

Cecelia: Observations and investigations

Template: I realize that the tools I will need to answer my research question are

_____

Cecelia: Microscope (high-powered)

Template: I designed my own datasheet to write down (record) my observations. My datasheet looks like this _____

Cecelia: (see what she wrote below for her datasheet)

**Date** **Location**

*Polychaete 1*

*It is important to note that students did not have data, as this was an imaginative inquiry in order to assess whether they understood the logical sequential steps of scientific inquiry.*

Template: My interpretation of the data is _____

Cecelia: That the polychaete larvae eat duckweed

Template: Possible explanation as to why?

Cecelia: Because they are too small and they can't eat big things

Template: An alternative explanation _____

Cecelia: That the polychaete larvae participates in cannibalism.

Template: Based on the data, it appears that _____ although more data points are needed in order to strengthen this conclusion.

Cecelia: Polychaete larvae could eat each other as well as other things

Cecelia demonstrates that she had a working knowledge of the steps of inquiry, even without data to analyze. Her research question, "What do polychaetes eat?" was a testable question (**3**). Her understanding that she will need a high-powered microscope (tool) (**3**) to examine the stomach contents (data collection) in order to assess what they eat is also accurate (**3**). Cecelia's assessment of the type of inquiry she will use (observation and investigation) is also accurate (**3**), although her datasheet did not contain a third column for stomach contents (**2**).

When asked what her interpretation of the data would be (even though there is no data, i.e., students are imagining what they would find), her response, "the polychaete larvae eat duckweed," is somewhat accurate (**2**), since duckweed is a freshwater green flower and the Elkhorn slough is a mixture of fresh and saltwater. It is understandable why Cecelia would say duckweed, considering it is a predominant food source for aquatic invertebrates. Perhaps another reason why Cecelia said duckweed had to do with students' observations in the microscope laboratory with Kenton, i.e., students noticed that the transparent polychaete larvae had green material inside of them. When they asked Kenton what the green stuff was, he said it was plant food that the larvae eat (not distinguishing what kind of plant food).

When asked for a possible explanation as to why polychaete larvae eat duckweed, Cecelia states, "Because they are too small and they can't eat big things." This is a reasonable explanation (**3**) as to why polychaete larvae would eat duckweed, a very small, microscopic green flower. When asked for an alternative explanation,

Cecelia remembers Charlena and Margarita's findings from their scientific inquiry project on the polychaete worm (not the larvae, but rather the worm). She states, "The polychaete larvae participate in cannibalism." This is a reasonable alternative explanation (**3**), since the larvae are younger versions of the polychaete worm, and the polychaete worm practices cannibalism.

Finally, Cecelia concludes that the, "Polychaete larvae could eat each other as well as other things." Based on Cecelia's explanation and alternative explanation, this conclusion is reasonable, although vague (**3**), understandably so, i.e., no hard data to refer to.

Overall, Cecelia's template assessment was impressive because she was able to imagine undergoing a scientific inquiry investigation of the polychaete larvae in another context (Elkhorn slough). Cecelia was able to successfully follow the logical sequential steps of the inquiry process with reasonably accurate responses, scoring 25 out of 27 on the rubric scale.

***Field-notes (middle and end).*** Throughout the study, Cecelia demonstrated not only an interest in plants, but also a curiosity about animals. This was discussed in RQ1, and will briefly be mentioned here. One day in the field, she shared that she heard the bird that makes (she imitated what sounded like a goose) sound at school and wondered what bird it was. This showed the teacher-researcher that Cecelia was extending her learning from the context of our Science club project out into her everyday life (school).

On another day in the field, the students noticed what looked to be a little brown mammal with ears swimming in the water. Not knowing what it was, they asked the science educator, Crysti. When Crysti said it was a muskrat, Cecelia took the initiative to seek more information on this mammal, i.e., searching through her Earth Cards for a muskrat, walking through The Nature Center in search of an exhibit panel, and then, when finding one, carefully reading every word and closely examining the picture. This showed the teacher-researcher that Cecelia had grown as a learner by taking the lead in her learning through self-motivation to satisfy her curiosity to know more about the muskrat.

In addition, on this same day, Cecelia shared her scientific inquiry project with Crysti, explaining how she was interested in the medicinal properties of plants. Both she and the other students appreciated Crysti and felt comfortable opening up to her because she took a genuine interest in getting to know them as 'whole persons' rather than just participants in a doctoral study.

Lastly, Cecelia demonstrated her inquiry skills in a completely different context, i.e., the aftermath of a plane crash. For example, a plane crashed into the side of the Watsonville Community Hospital (Thursday) where the Science club periodically worked (Saturday). When the teacher-researcher and students took a break, they went to visit the memorial site. Cecelia carefully examined the blackboard covering the wall where the plane crashed into the hospital.

She made an interpretation that the pilot's body (which would have been the father) died to the right (pointing to the right) and the rest of the family to the left. The teacher-researcher asked Cecelia what evidence she used to arrive at this interpretation. She described how each wing of the plane hit the building and how the body of the plane went right down the middle. As she was providing her explanation, the teacher-researcher looked at the blackboard covering the damaged wall and she could see that Cecelia's explanation was reasonable. The teacher-researcher was very impressed with her ability to reconstruct the scene of the crash.

**Results** (**case study 1**).

***Triangulation of data sources***. All four data sources triangulated, as each provided evidence of an increase in Cecelia's understanding of scientific inquiry and her motivation to learn. For example, when asked what she learned from her inquiry project, Cecelia stated that she learned blue-eyed grass was used for medicine and that the California Poppy was used to assist children with going to sleep. In addition, when asked how she felt about her experiences in the field, she said she enjoyed measuring plants and surveying the amount of mosquito fern on the water's surface. Although Cecelia's research questions were geared toward biological aspects of blue-eyed grass and California Poppies, Cecelia focused more on the medicinal properties during the gathering information stage of the inquiry process.

During Cecelia's presentation, she read from her poster board, however, when an audience member asked her a question about how the blue-eyed grass was ingested

by the Ohlone Indians, Cecelia responded confidently and without the aid of her poster board, "They made tea from the leaves." She also emphasized how surprised she was not to find any blue-eyed grass in the Struve slough, especially after reading that it was found in this region of the wetlands.

Cecelia's template inquiry assessment revealed a strong knowing of inquiry, scoring 25 out of 27 on the rubric scale. This demonstrates that she had a working knowing of inquiry on a different animal (polychaete larvae), in a different context.

Lastly, Cecelia's field-notes demonstrate how she shared her knowledge of the medicinal properties of her plants with a science educator, Crysti. Crysti responded favorably stating, "I didn't know that; that's really interesting.

**Discussion** (**case study 1**).

From the beginning of the study, Cecelia demonstrated an interest in plants. On our first day in the field, she was drawn to the mosquito fern which covered the surface of the water. Curious to know what it was, she sought information from the science educator, Cindy. At that moment, the teacher-researcher surmised that Cecelia was interested in plants and encouraged her to explore them at the slough. During this exploration, she was drawn to those with medicinal properities. Perhaps one reason why is due to the fact that Cecelia suffers from chronic illnesses; asthma being one of them. Thus, it was understandable why Cecelia chose this flower to investigate.

Although Cecelia did not demonstrate understandings of the biological aspects of her plants in her post-assessments, this is not to say that she did not understand the inquiry process. On the contrary, Wells' describes his first principle of inquiry as, "not simply a method of discovery, but rather a position toward experiences and ideas." This includes, "a willingness to wonder, to ask question, and to seek to understand by colloborating with others in an attempt to make answers to them (Wells, 1999, p. 121). Thus, Cecelia was indeed engaged in the inquiry process. She often worked with the research assistant (Roxanne) to find more information on her interests. Both Roxanne and the teacher-researcher provided books, access to the Internet, and numerous hours in the field in order for Cecelia to make empirical observations of her plants.

In summary, Cecelia demonstrated an interest in plants; particularly the medicinal properties. Her template inquiry assessment demonstrated a strong understanding of the inquiry process; scoring 25 out of 27 possible points. Field-notes demonstrated Cecelia sharing her interests about plants with a science educator.

**Jacquelina** (**Case study 2**). The following section contains an analysis of Pre-assessments and Post: assessments. The pre-assessments include: pre-assessment interview and field-notes. The post-assessments include: post-assessment interview, presentation, template book at Elkorn slough, and field-notes.

***Pre-assessment interview***. Jacquelina's pre-assessment interview reveals two curiosities: (a) the fur (burlap bag material) on the logs; and (b) why the roads are

under water. On our first day, we visited three sloughs and at two of the sloughs (Struve and Harkins), the road was partially under water. This puzzled Jacquelina and the other students. During the interview, to assess her scientific inquiry skill of researching information, the teacher-researcher asked Jacquelina, "If you wanted to find an answer to that question about why the roads are under water, what do you think we could do to find an answer to that question?" Her response, "Um, Google it or find it on the computer." This is a reasonable answer as many scientists (researchers) begin their initial inquiry researching historical records to reconstruct a more accurate assessment of current conditions and events.

The researcher-teacher and Cindy explained that the Struve slough was a dairy farm back in the early 1900's, and the road underwater lead to and from the farm to export milk and other dairy products to both local and distant residents. Even with this information, for some students, the submerged roads still did not make sense to them.

**Example 1:**

**Me:** Did you see anything that interested you or made you wonder at the Watsonville slough?

**Jacquelina:** Yes

**Me:** Tell me what.

**Jacquelina:** Um, the fur that we saw on the logs.

**Me:** Yeah, we were wondering about what that was, huh?

**Jacquelina:** (nods yes)

**Me:** Anything else?

**Jacquelina:** No

**Example 2:**

**Me:** Is there anything that interests you now about the wetlands? We've gone to three. Is there anything that you find interesting so far?

**Jacquelina:** Uh, yes

**Me:** Can you tell me please?

**Jacquelina:** About the roads under the water

**Me:** That is interesting huh? We need to find more about that. Okay

**Example 3:**

**Me:** Do you have any question or concerns about the wetlands we went to?

**Jacquelina:** No

**Me:** No questions?

**Jacquelina:** No

**Me:** Well, you just asked a question about, you wondered about the roads, right? If you wanted to find an answer to that question about why the roads are under the water, what do you think we could do to find an answer to that question?

Jacquelina: Um, Google it or find it on the computer

**Me:** Anything else?

**Jacquelina:** No

**Me:** Okay, thank you.

***Field-notes (beginning).*** Throughout the study, Jacquelina demonstrated strong observational skills. From noticing a narrow opening of the mouth of the Pajaro River to the ocean (on a topography map), to red tail hawks, seagulls, and a black bird with white tipped wings. All of these observations were made on our first day of the Science club project.

With regard to beginning the research phase of the inquiry process, Jacquelina was slightly lost with the very broad questions asked in the research report. When the teacher-researcher asked why she had not written anything down, Jacquelina said, "I don't know what to write." At that moment, the teacher-researcher realized that the research report was not specific enough and redesigned the questions. After doing so, Jacquelina successfully gathered information for her research report.

This was a very important realization for the teacher-researcher to be clear, specific, and even explicit with questions. Interestingly, the same thing occurred during the inquiry template book assessment at the Elkhorn slough (as will become apparent in the post-assessment section). Jacquelina did not know how to start. Perhaps the reason why was because she had no information to draw from in order to complete the task. Thus, the teacher-researcher provided some scaffolding in order to facilitate Jacquelina with the assessment. In hindsight, this is a reflection of the assessment, i.e., perhaps not being contextualized enough, rather than Jacquelina's ability to perform.

***Post-assessment interview***. Jacquelina's post-assessment interview reveals four things: (a) an understanding of her inquiry project; (b) what 'doing science' entails; (c) her enjoyment of being out in the field; and (d) her dislike for Cindy (science educator).

First, when asked what she learned from her inquiry project on the ruddy duck, Jacquelina responds, "It, I was trying to like observe its behavior but it mostly, it was mostly foraging." Here, Jacquelina uses three scientific concepts (observe, behavior, and foraging) on her own. When the teacher-researcher presses for what she was trying to find out about the ruddy duck, Jacquelina responds, "How it interacts with the female ruddy ducks?" When the teacher-researcher says, "We didn't see a whole of that, huh? Kind of ignoring each other, huh," Jacquelina smiled in acknowledgement of this fact.

Second, when asked if she thought the inquiry project was 'doing science,' Jacquelina says, "Yes." When the teacher researcher asks how, she responds, "*Because* we like learned words from like scientific words." The teacher-researcher presses for more, "What else?" She responds, "Like we learned like the water temperature and the pH and that's what some scientists do." Nudging Jacquelina a bit further along her zone of proximal development, the teacher-researcher asks, "What else were you doing out there when you were learning about the ruddy duck, scientists always do something when they're out there in the field and you were doing it whenever you were out there?" Jacquelina responds, "Observations." When the

teacher-researcher asks what she was writing her observations on, Jacquelina says, "On a datasheet."

This conversation reveals an awareness and knowing of: (a) part of 'doing science' is learning scientific language; (b) doing science can include water quality and also observations of an animal (ruddy duck); and (c) scientists make observations and record them on a datasheet. This knowing is impressive considering Jacquelina did not have this knowledge prior to the study. This provides some evidence that the experiences Jacquelina participated in during the Science club increased her understanding of the scientific inquiry process.

Third, Jacquelina enjoyed all of the outdoor activities in the field. For example, when asked if she liked being in the water collecting water samples for water quality, she says, "Yeah." When asked if she liked being in the field to collect data on the ruddy duck, she responds, "Yes." Finally, when asked if she liked the Elkhorn slough, she nods yes. Even though the other students complained about the long trail walk (at Elkhorn) and how tired they felt afterward, Jacquelina states that she did not feel tired.

Finally, Jacquelina confides with the teacher-researcher about how she enjoyed her time in The Nature Center, but did not like Cindy (science educator). When asked why, she responds, "*Cuz* she was like, when we were talking to her, she was like talking to us, like, like mad." The teacher-researcher affirms Jacquelina and asks another question, "Okay, not very friendly?" Jacquelina, "Mm hm." This verbal

statement sums up other students' feelings toward Cindy. Interestingly, every student (except Charlena) felt that Cindy was not a nice person and did not demonstrate a genuine interest in getting to know them as 'whole persons.' The teacher-researcher sensed this as well.

***Presentation.*** Jacquelina was the first student to present. She was very quiet and shy. When the teacher-researcher prompted Jacquelina to begin, "Okay ready," Jacquelina shyly smiled and shook her head no. This is understandable as there were 20 people in the room, many of whom Jacquelina did not know. On top of this, Jacquelina's parents were not present. The teacher-researcher sensed that Jacquelina needed to feel supported, so she said, "It's okay, you know it. Go head." Jacquelina cleared her throat, but she was mute. The teacher-researcher went up front with Jacquelina and said, "She did her presentation on the ruddy duck. Just take it step by step." Jacquelina finally began.

Nervous, she had her back to the audience as she read from her poster. The teacher-researcher moved the poster board at an angle so Jacquelina was facing the audience. This improved the volume of her voice somewhat, however members in the audience still could not hear her, "a little bit louder," from one audience member, and "hija, could you please speak a little bit louder," from another. Jacquelina made an effort to project her soft voice, and her volume did increase somewhat. When she finished, an audience member said, "Good job," and everyone in the audience

applauded. Jacquelina smiled shyly. The teacher-researcher asked the audience if they had any questions. One audience member did (see below)

**Male:** Hijas to your, did you go early in the morning to observe the duck? Where did you go? I didn't catch that.

**Jacquelina:** To the Watsonville slough

**Me:** Anymore questions for Jacquelina?

*Note: The audience member sensed that Jacquelina was very uncomfortable and did not press for more detail or follow up with another question.*

Jacquelina's presentation ended with her peers applauding for her once again (showing support for Jacquelina). This was a pleasant surprise, i.e., as they knew her parents could not make the event and see Jacquelina's presentation. The teacher-researcher also praised Jacquelina for her performance.

It is important to note that Jacquelina's parents were home with their younger daughter (3 years old). It was her birthday and they had family and friends at the house. When Jacquelina explained this to the teacher-researcher, the teacher-researcher asked Jacquelina, "Why didn't you tell me that the day of the presentation was the same day as your sister's birthday. If I had known that, I would have chosen another day so your parents could have come?" Jacquelina shook her head and said, "It's okay." It was very apparent to the teacher-researcher that it wasn't okay. She was visibly upset that her parents weren't there to see her presentation. However, after Jacquelina presented and she was watching her peers, she appeared to relax and

brighten up a bit, i.e., perhaps relieved that she was finished and could sit back and relax.

During the post-assessment interview, the teacher-researcher asked Jacquelina if she told her parents how her presentation went. Jacquelina responded with, "I haven't told them yet." When the teacher-researcher heard this she could not help but to feel a sense of sadness and disappointment. She responded and said, "Ohhhh (tone of disappointment), okay, well when I interview your mom again, we'll talk about it, okay? Jacquelina nodded yes.

***Template book at Elkhorn slough.***

Template: What I found most interesting at the Elkhorn slough was _____

Jacquelina: That the Elkhorn slough is a mixture of salt and fresh water.

Template: If I were to research what I found interesting, I would research the following: Jaquelina: (1) In what year is the water saltier, (2) How much is salt and freshwater, (3) What type of ecosystem, and (4) Type of habitat.

Template: After learning about these facts (researching if they have been answered), I still have some questions:

Jacquelina: Why is there a mixture of fresh and salt water?

Template: I asked myself, "Is this a testable question?"

Jacquelina: Can I test the % of fresh and salt water?

Template: My research question is _____

Jacquelina: How does the water change over the seasons?

Template: For my research question, I need to collect _____

Jacquelina: I will need to collect a sample of water for 4 seasons.

Template: Since I will need to _____ in order to answer my research question, of the three types of inquiry (observations, investigation, and experiments), my type of inquiry will be _____

Jacquelina: Experiments

Template: I realize that the tools I will need to answer my research question are:

Jacquelina: Beakers (4), gloves (2), and binoculars

Template: My datasheet looks like this _____

Jacquelina: (see below)

**Elkhorn slough**

**Seasons** **% of salt water** **Day/Time**

Template: My interpretation of the data is _____

Jacquelina: The water could be not as salty in the winter because of the rain

Template: Possible explanation as to why _____

Jacquelina: The % of salt water will be higher in the summer because it doesn't rain much at all.

Template: An alternative explanation is _____

Jacquelina: That the % of salt water will be higher in the summer than in the winter.

Template: Based on the data, it appears that _____ although more data points are needed in order to strengthen this conclusion.

Jacquelina: My research is testable

It is important to note that Jacquelina experienced some difficulty with this task. When the teacher-researcher noticed that she had not written anything down, she asked Jacquelina, "Do you understand what you're doing?" Jacquelina nodded no. The teacher-researcher decided to work with Jacquelina within her zone of proximal development, rather than not assist her at all.

She asked Jacquelina, "What did you notice here? Is there something you're wondering about and would like to find an answer to?" Jacquelina thought for a while and said she wondered why there was a mixture of salt and fresh water. The teacher-researcher affirmed her interest and asked her to look at the template booklet and follow the steps of inquiry like she did for her ruddy duck inquiry project. Jacquelina began writing, and the teacher-researcher stepped back giving her room to take the initiative, but at the same time, checking in on her to see how far she had gone. The following step-by-step analysis will discuss when the teacher-researcher provided prompting, i.e., with leading questions, and when she did not.

Jacquelina demonstrated that she needed guided facilitation with getting started on this task. Her research question was prompted through leading questions about what she found interesting at the Elkhorn slough. Jacquelina had expressed that she was interested in the mixture of fresh and salt water and wanted to learn more about it, however, she had difficulty formulating a testable research question. The

teacher-researcher suggested she could examine the salinity of the water throughout the year, for example during each season.

From here, Jacquelina formulated her research question, "How does the water change over the seasons?" Since the teacher-researcher provided some guided facilitation for Jacquelina, an appropriate score from the rubric would be **(2)** (somewhat). Her understanding that she will need four beakers, two gloves, and binoculars (tools) is accurate, although the use of binoculars is not necessary for her inquiry (**2**). Jacquelina states that she will need to collect a sample of water for four seasons (**3**). This is accurate, however, more samples per season would be more accurate. Jacquelina's assessment of the type of inquiry she will use (experiment) is not accurate. Rather, her type of inquiry is an investigation in order to determine how the salinity of the water changes over the four seasons (**1**). On a positive note, Jacquelina's datasheet is impressive. She has three columns with proper headings in order to answer her research question: Seasons, % of salt water, and day/time (**3**).

When asked what her interpretation of the data would be (even though there is no data, i.e., students are imaging what they would find), her response, "The water could be not as salty in the winter because of the rain," is a reasonable interpretation (**3**). The fact that it rains in the winter, and rain is indeed fresh water supports her interpretation. When asked for an explanation for her interpretation, Jacquelina states, "The % of salt water will be higher in the summer because it doesn't rain much at all." This explanation for her interpretation is somewhat accurate (**2**), because it is

more of an alternative explanation rather than an explanation of her interpretation. If she had re-stated her interpretation with an explanation, for example, "Because it rains more in the winter and rain water is fresh water, the water in the slough would not be as salty," her explanation would have been more reasonable. When asked for an alternative explanation, Jacquelina restates what she said for her explanation, "That the % of salt water will be higher in the summer than in the winter." This is a reasonable alternative explanation (**3**).

Finally, Jacquelina concludes that, "My research is testable." Although this is true, it is not a reasonable conclusion for her research question (**1**). Overall, Jacquelina's performance on this assessment was not as strong as expected. She initially needed a 'jump start' to start thinking about an area she would like to inquire about. Once she discovered this, she needed assistance with formulating a testable question. From this point, Jacquelina determined what kind of tools she would need, but included binoculars (not necessary for her data collection). She accurately designed a datasheet for recording her data. Her interpretation of the data was reasonable, however her explanation for her interpretation was more of an alternative explanation. When asked for an alternative explanation, Jacquelina restated her explanation. Finally, her conclusion was not reasonable. Jacquelina's final score, 20 out of 29 is lower than expected, i.e., considering, Jacquelina appeared to understand the scientific inquiry process so well in her ruddy duck project. Perhaps this low score is a reflection of the assessment (see below).

When reflecting on Jacquelina's performance of this task, the teacher-researcher realizes this was a challenging task. It would have been more beneficial for the students to choose from a set of four established areas of inquiry with data, for example: frogs, birds, aquatic invertebrates, and vegetation. This would have provided students with something to work with, rather than imagining an invisible scenario. As stated throughout this analysis, many students need contextualization in order to construct meaning. Although the environment (Elkhorn slough) was a highly contextualized experience, the assessment was not. Even though there were framed sentences to scaffold students with the sequential steps of the scientific inquiry process, a concrete example of data was not provided for students to work with. Instead, students had to imagine an inquiry project, data, and provide an interpretation, explanation, alternative explanation, and conclusion based on non-existent data. In hindsight, this assessment may have been to high of a cognitive leap, but interestingly, Cecelia did well (scoring 25 out of 27)?

***Field-notes (middle and end).*** With regard to formulating her research question, Jacquelina moved from a one-sided perspective of the relationship between the male and female ruddy duck, i.e., her first attempt for her research question was, "How does the male attract the female to him," a testable question which evolved to, "How do the male and female attract each other," to lastly, "How do the male and female ruddy ducks interact with each other?" This took very little scaffolding, thus

it appeared that Jacquelina 'had an edge' with understanding how to formulate well thought out testable questions.

When out in the field, Jacquelina demonstrated strong scientific inquiry skills. For example, her datasheet was always out with a pencil ready in hand. Her recording technique of using male and female symbols in addition to arrows to represent directional movement were accurately recorded and interpreted (out in the field when the teacher-researcher would ask for an interpretation). Her strong observatory skills heightened as the study progressed. For example, accurately recounting a line of ducklings that the teacher-researcher and students thought would contain one less (due to a bull frog lunging at the last duckling in the line). In addition, on our last day (at the Elkhorn slough), Jacquelina was the only student who noticed black cormorants perched in eucalyptus trees while conducting a plantkton tow, and observing a very small tree fro on the ground as we were walking back to the visitor center.

When designing her Scientific Inquiry Book, Jacquelina needed very little scaffolding with completing it. Her datasheets were in order for organizing into tables and she knew how to edit her everyday language, such as eating, to foraging instead (a more scientific word). With one suggestion from the teacher-researcher, Jacquelina went through her book and changed everyday words to scientific concepts and/or specific terms.

Overall Jacquelina demonstrated not only interest, curiosity, and wonder while engaged in her scientific inquiry project, but also joy. She loved being out in the field, whether looking for the ruddy duck to record observations or taking water quality samples, Jacquelina appeared to be in her element anytime we were outdoors.

**Results (case study 2).**

***Triangulation of data sources.*** Three of the four data sources (post-assessment interview, presentation, and field-notes) triangulated with the scientific inquiry template book at the Elkhorn slough showing weak results. This may be a reflection of the assessment itself.

Jacquelina's post-assessment interview revealed an understanding that: (a) part of 'doing science' is learning scientific language; (b) doing science can include water quality and also observational field work of an animal (ruddy duck) and; (c) scientists make observations and record them on a datasheet. This knowing was impressive considering Jacquelina did not have this knowledge prior to the study.

Jacquelina's performance on her presentation needed encouragement because she was quiet, shy, nervous, and the first student to present. Overall, Jacquelina appeared to understand the logical sequence of her inquiry project, even though she read from her poster. When an audience member asked her a question, she was able to successfully answer.

There was one data source- template book at the Elkhorn slough- that did not triangulate as strongly as the other data sources. For example, Jacquelina initially

needed a 'jump start' to begin thinking about an area she would like to inquire about. Once she discovered this, she needed assistance with formulating most aspects of the inquiry process. Thus, her score on this assessment was 20 out of 29; lower that expected considering Jacquelina appeared to understand the scientific inquiry process so well in her ruddy duck project.

Finally, Jacquelina's field-notes demonstrated two things. First, when formulating her research question, Jacquelina moved from a one-sided perspective of the relationship between the male and female ruddy duck, i.e., her first attempt was, "How does the male attract the female to him," to, "How do the male and female attract each other," to lastly, "How do the male and female ruddy ducks interact with each other?" This took very little scaffolding, thus it appeared that Jacquelina 'had an edge' with understanding how to formulate testable questions.

Second, when out in the field, Jacquelina demonstrated strong scientific inquiry skills. For example, her datasheet was always out with a pencil ready in hand. Her recording technique of using male and female symbols in addition to arrows to represent directional movement was accurately recorded and interpreted out in the field when the teacher-reasearcher would ask for an interpretation.

**Discussion (case study 2).** The fact that Jacquelina demonstrated a knowing and awareness that part of doing science is learning scientific language; doing water quality; and making observations and recording them on a datasheet, reflects the experiences she had in the field. This includes the semiotic tables which contained

scientific language, in addition to the scientific inquiry book students used to scaffold the inquiry process. In additon to these semiotic tools, instructional conversations provided demonstrations, asked leading questions, and pushed for more detailed explanations of what students were experiencing. Thus, the combination of instructional conversations with semiotic tools proved to be an effective means for Jacquelina's understanding of the inquiry process.

Although Jacquelina performed well on her presentation, she had a difficult time getting started. For this reason, the teacher-researcher stood next to her and introduced the animal she had investigated. Once Jacquelina heard the name of her animal, she began her presentation. One reason why Jacquelina was so reticent could be due to the fact that her family was not there to share the moment with her. The Science club members sensed this and provided needed support.

The one assessment where Jacquelina had difficulty was the decontextualized inquiry template book. Students were asked to use the same books they had used in the field, however, in a different context. In addition to this, students had to generate their own testable questions and imagine: (a) what type of inquiry they would use to answer their research question; (b) what tools they would need to carry out their data collection; (c) what kind of datasheet they would need in order to record their data, etc. This proved to be a difficult task for Jacquelina as she appeared not to understand what to do on the assessment. The teacher-reasearcher realized the cognitive dissonance Jacquelina was experiencing, and rather than just let her sit

there, the teacher-rearcher decided to extend her from her actual level of development to her potential level. When reflecting on Jacquelina's performance of this task, the teacher-researcher realized it was challenging. It would have been more beneficial for the students to choose from a set of four established areas with data, for example: frogs, birds, aquatic invertebrates, and vegation. This would have provided students with something to work with, rather than imaging an invisible scenario.

As stated previously, many students, particularly ELL and other students without access to quality science learning, need contextualization in order to construct meaning. Although the environment (Elkhorn slough) was a higher contextualized experience, the assessment was not. Even though the assessment contained framed sentences to scaffold students with the sequentail steps of the scientific inquiry process, a concrete example of data was not provided for students to work with.

Lastly, of all the participants in the study, Jacquelina had the keenest observational skills. She often saw things no one in the Science club even noticed; including the teacher-researcher. On many occasions, while observing the ruddy duck, Jacquelina correctly recorded preening, diving, and foraging behaviors. She also noticed other animals and environmental featurs on a topography map that other student participants missed.

Jacquelina's post-assessments demonstated that if her experiences were saturated in the concrete, she performed well. However, if they were abstract and decontextualized, Jacquelina did not perform as well.

In summary, of all the student participants, Jacquelina demonstrated the strongest obversational skills. She also understood how to refine her research down to a more specific focus. Jacquelina did however experience some difficulty with the inquiry template assessment; stalling and not knowing what to do. This required guided facilitation from the teacher-researcher. The teacher-researcher realize that this needed more contextualization in order to better scaffold Jacquelina's demonstration of her understandings. Toward the end of the study, Jacquelina expressed an interest to continue exploring at the Elkhorn slough.

***Charlena (case study 3).*** The following section contains an analysis of Pre-assessments and Post: assessments. The pre-assessments include: pre-assessment interview and field-notes. The post-assessments include: post-assessment interview, presentation, template book at Elkorn slough, and field-notes.

***Pre-assessment interview.*** Charlena's pre-assessment interview reveals an interest and wonder about three things: (a) green backed heron; (b) polychaete worm; and (3) if banana slugs are denizens of the Watsonville slough. Charlena also provides a response to how she would investigate her question in Example 4. Lastly, she discusses her view about science in Example 5.

When the teacher-researcher asked Charlena if she noticed anything on our nature walk that interested her or made her wonder, Charlena said the green backed heron. When the teacher-researcher asked what interested her about the green backed heron, she responded, "It's because, um, you, at first you said that, you thought it was

a cinnamon teal duck and you said they were suppose to be in Mexico and it made me wonder."

This statement appears to reflect an interest with an incongruent statement by the teacher-researcher about having seen a cinnamon teal, when in fact, she saw a green backed heron. The likelihood of observing a cinnamon teal duck in the Watsonville slough during the winter (this was January) is very low, since many migratory birds, particularly ducks, reside in southern regions (such as Mexico) during this time of year.

Charlena noticed the incongruity of the teacher-researcher's initial observation because she remembered from the pilot study that cinnamon teal ducks are in Mexico during the winter months.

**Example 1.**

**Me:** Did you see anything on our walk that interested you or made you wonder?

**Charlena:** That bird that you saw that we saw at the very end.

**Me:** Do you remember the name of it?

**Charlena:** No

**Me:** The green backed heron.

**Charlena:** Oh yeah.

**Me:** What interested you about that?

**Charlena:** It's because, um, you, at first you said that, you thought it was the cinnamon teal duck and you said they were suppose to be in Mexico and it made me wonder.

Second, when asked if anything else interested her about the wetlands, Charlena expressed an interest (on our first day) for the polychaete worm. Both Charlena and Margarita chose the polychaete after looking through a stack of Earth Cards. When asked what interested them about the polychaete worm, they both said it was cute and wanted to learn more about it.

**Example 2.**

**Me:** Is there anything that interests you about the wetlands?

**Charlena:** The polykite…

**Me:** The polychaete worm?

**Charlena:** Yeah

**Me:** Okay, okay.

Third, when the teacher-researcher asked Charlena if she had any questions or concerns about the wetlands, her initial response was no. However, when the teacher-researcher prodded Charlena to ask a question, she eventually did, "How come there is a picture of a banana slug from this wetlands?" The teacher-researcher tried to understand her question by asking, "But there are no banana slugs here? Is that what you're wondering?" Charlena responded, "Yeah."

**Example 3.**

**Me:** Do you have any questions or concerns about the wetlands?

**Charlena:** Mmmm, no.

**Me:** You've got to have something; some kind of question.

**Charlena:** Mmmm (silence).

**Me:** A question or a concern; anything that you wonder about, why does this, what is this, how come…something?

**Charlena:** Mmmm, (silence)…how come there was a picture of a banana slug from this wetlands?

**Me:** But there are no banana slugs here? (*Note: I'm not asking her this, but rather trying to see if this is her question*). Is that what you're wondering?

**Charlena:** Yeah

**Me:** Okay

From this point, the teacher-researcher asked, "How do you think we might find an answer to that question?" At first, Charlena stalled but after the teacher said, "They could be here and we just don't know it. How could we find out?" she said, "We could look into the bushes, but in a safe way." This is a reasonable answer as many scientists and researchers begin their initial inquiries in the field making preliminary observations, whether crouched in the bushes or surveying the skies, making observations is often the first step in the inquiry process, particularly with regard to field studies.

**Example 4.**

**Me:** How do you think we might find an answer to that question, that, how come there's no banana slugs here at the Watsonville slough?

**Charlena:** Ahhh

**Me:** They could be here and we just don't know it. How could we find out?

**Charlena:** We could look into the bushes, but a safe way, but not like, like falling into the and probably hitting something, like in a safe way to do it.

**Me:** Okay, anything else?

**Charlena:** No

**Me:** Okay, can you go get Margarita for me?

This last example demonstrates Charlena's view of science, i.e., stating how the study of life- biology, can be fun because you get to go outside, but cautious about another type of science, that which occurs in a laboratory because of "all the chemicals". Interesting, in her post-assessment interview, her view of science broadens and becomes more inclusive for laboratory sciences, such as chemistry.

**Example 5.**

**Me:** What do you think about science?

**Charlena:** Um, it depends what kind.

**Me:** How about biology?

**Charlena:** The study of life?

**Me:** (nods yes)

**Charlena:** Oh, it's kind of fun *cuz* you get to go outside and not stay in and you get to walk around and look at the plants.

**Me:** Okay, what about a science that's more indoors, like in a laboratory. What do you think of that kind of science?

**Charlena:** It's kind of fun but I think it's also a little bit dangerous *because* all the chemicals that are in the lab.

***Field-notes (beginning)***. Charlena was inquisitive throughout the study. For example, she noticed a moose in a book the teacher-researcher was reading and asked if there are moose in the Watsonville slough region. The teacher-researcher said no, but said elk used to exist in the Elkhorn slough region, hence the name of the slough. Charlena found this interesting and when the teacher-researcher said the Science club would go for a day to the Elkhorn slough, she became very intrigued.

She expressed an interest in the polychaete worm early on in the study. Even though the teacher-researcher had said that finding them in the Watsonville slough (freshwater) was low because they are predominantly found in marine (saltwater) environment, she was still interested in seeing one.

In addition, when the students received their research reports and were asked to start gathering information about their plant and/or animal of interest, Charlena was the only student to complete her report at home (even though the other students also had computers at home). This demonstrates motivation, i.e., a willingness to learn on her own.

***Post-assessment interview.*** Charlena's post-assessment interview reveals six things: (a) what she enjoyed and found interesting; (b) what she learned; (c) her thoughts about whether her inquiry project was 'doing science', (d) whether she thinks she can be an active voice for educating others; (e) her feelings/thoughts about her family (mother) watching her presentation; and (f) her thoughts about science after participating in the Science club.

Charlena enjoyed using the net and doing water quality at the Watsonville slough and using the net at the Elkhorn slough, i.e., trying to find animals. When the teacher-researcher asked, "Okay, so you like the 'hands on' actually seeing and doing?" Charlena nodded yes.

Second, Charlena said, "There's more that meets the eye in the water," referring to the non-native cone snails from Japan. Charlena said, "In the water, there's like more snails and you can't really see but when you actually put your hand in there you can actually see what's actually there."

When asked what she learned from her polychaete inquiry project, Charlena came to the realization that polychaetes are "easier to find in the Elkhorn slough than in the Watsonville slough." She also admitted that she found only one polychaete at the Watsonville slough and surmised that their habitat was basically saltwater rather than freshwater. Charlena also admitted that perhaps she should have chosen another animal for her inquiry project at the Watsonville slough. The teacher-researcher also recognized that perhaps the Science club should have done their study at the Elkhorn

slough rather than the Watsonville slough. Charlena agreed and said, "Yeah, then it would be easier."

Third, when asked if she felt she could do science now, after experiencing the Science club, Charlena hesitated and said maybe, i.e., explaining her reluctance, "Maybe cuz, I can do it, but (sighs), if I get out there alone and I see these squiggly things I'll freak out and probably fall." The teacher-researcher, amused with Charlena asked, "Okay, but what if like a bird or um you wanted to just study the population of the red legged frogs which are an endangered species, what if you wanted to study that? Do you think you could?" Charlena responds, "Yes."

When asked if she felt her inquiry project was doing science, Charlena responded, "I think it was doing science *because* we had to answer questions and make observations." This statement revealed her understanding that science involves making observations and seeking answers to questions, two key steps of the scientific inquiry process.

Fourth, when asked if she could potentially be an active voice for educating others about the importance of the wetlands, Charlena expressed that she did not feel she could because of her shyness. At this moment, the teacher-researcher saw an opportunity to help Charlena with a personal reference of her own life, i.e., that the teacher-researcher was also quite shy during her youth, but eventually grew out of it. The teacher-researcher also commended Charlena for her intelligence and how much

she has to offer. Charlena smiled shyly, appearing to appreciate what the teacher-researcher had said.

Fifth, with regard to her feelings/thoughts about her family (mother) watching her presentation, Charlena said that her mother was proud of her, however, she also mentioned how relieved she was that her mother did not make fun of her. This shocked the teacher-researcher, as her observations of Charlena with her mother appeared to be reserved and not playful and/or joking.

Finally, the following example below demonstrates Charlena's thoughts about science after participating in the Science club for six months:

**Example 6.**

**Me:** What are your thoughts about science now? Like what do you think about science?

**Charlena:** Now I know that science isn't like the mad scientist with the crazy hair now, it's like both, the the chemical and with plants and life.

**Me:** Mmm hmm. That it's not so hard, it's not so like a mad scientist only can do it. What do you think about that?

**Charlena:** Anybody can do it, yeah...

**Me:** Umm, do you think science is important?

Charlena: It's important *cuz* we can get smarter and also learn how to maintain the Earth.

**Me:** Okay

When juxtaposing Example 5 (pre-assessment interview), with her response in Example 6, it appears Charlena realized that science can pertain to chemicals and plants (and life in general). She also stated that science is important *because* it makes you smarter and you can learn *how* to maintain the Earth, i.e., a reference to the scientific concept- conservation.

This example demonstrates a broader and more encompassing view of what science can be. Charlena understood that science is not reserved to mad hair scientists mixing dangerous chemicals in a laboratory, but rather, science includes both, i.e., chemical and plants, and life in general. She also makes an important claim that science isn't only for the select few, but that, "anyone can do it." This is an important insight, particularly for a female ELL. Lastly, Charlena stated the reason why science is important, "*cuz* we can get smarter and also learn *how* to maintain the Earth." This causal statement reveals how Charlena perceives science as more than a subject domain in school, but rather as a vehicle for developing intelligence. Perhaps through this development, one can "learn how to maintain the Earth," a very noble statement from a 12 year student.

***Presentation.*** Charlena's presentation was impressive. First, she had memorized her poster. As a result, instead of having her back to the audience, she spoke directly to them. This made a difference in how the audience related to Charlena's information. The audience appeared more attentive to Charlena than the other student presentations.

Charlena also appeared to understand the logical sequence of her inquiry, stressing key words and putting an emphasis on particular areas. For example, when discussing why she initially became interested in the polychaete worm, she stressed the fact that, "they can bite people," and that "they can eat each other," and finally, that "they are hermaphrodites and can release sperm and eggs in the water."

When Charlena finished, the audience roared with applause. The teacher-researcher asked if anyone had any questions. Two audience members did (see below):

**Female:** Do they only live in the water?

**Charlena:** Yes

**Male:** Are they part of the leech family?

**Charlena:** Yes, they're related to the leech.

**Male:** So they just live in freshwater?

**Charlena:** Yeah

**Male:** How big was the one you caught? You mentioned only during the flood?

**Charlena:** Yeah, we didn't get to measure it so we really don't know.

**Me:** But when we saw it, it was probably about, about that big (showing a distance of 3-4 inches).

**Male:** Wow! Yeah

**Me:** 3-4 inches, very fast. Tell him what it looked like.

**Charlena:** It had some orange and red and white

**Male:** Since they have teeth, do they eat other insects or do they stay on greens?

**Charlena:** They eat each other

**Male:** Oh! Cannibalism. (Laughs) Okay, wow! That's good.

**Me:** And what else do they eat? Do they eat anything else?

**Charlena:** I don't quite remember.

**Me:** How about you Margarita?

**Margarita:** Um, no. I don't remember either.

**Audience:** Good job (applause again).

This dialogue demonstrates that Charlena successfully handled the questions from the two audience members. However, she did not add that not only does the polychaete live in fresh water, but that it is predominantly found in marine habitats. She also did not know the full range of their diet, as their main source of food must include something else (fish, coral, algae, etc.) other than each other (cannibalism). Aside from this, Charlena's responses were accurate.

***Template book at Elkhorn slough:***

Template: What I found most interesting at the Elkhorn slough was _____

Charlena: Pickleweed

Template: If I were to research what I found interesting, I would research the following:

Charlena: Native or non-native, what eats it, how the salt gets on it, if non-native how did it get here, endangered or not

Template: After learning about these facts (whether they have already been researched) I still have some questions:

Charlena: What animal(s) eat it? And, why does it have salt on it?

Template: I asked myself, "Are these testable questions?"

Charlena: What animal(s) eat it? [Yes] Why does it have salt on it? [No]

Template: My research question is _____

Charlena: What animal eats the pickleweed?

Template: For my research question, I need to collect _____

Charlena: Pickleweed and the animal that eats it.

Template: Since I will need to _____ in order to answer my research question, of the three types of inquiry (observation, investigation, experiment), my type of inquiry will be _____

Charlena: observations

Template: I realize that the tools I will need to answer my research question are:

Charlena: Notebook to record data, pickleweed, and the animal that eats it.

Template: My datasheet looks like this:

Charlena:

**Animal Eat it? Yes? No?**

Template: My interpretation of the data is _____

Charlena: That the brown pelicans eat the pickleweed (guess)

Template: Possible explanation as to why _____

Charlena: The pelican is an omnivore and thus needs to eat plants.

Template: An alternative explanation is _____

Charlena: An alternative explanation would be that the pelican needs some salt in its diet.

Template: Based on the data, it appears that _____ although more data points are needed in order to strengthen this conclusion.

Charlena: brown pelicans and people eat pickleweed.

Charlena demonstrated working knowledge of the steps of inquiry. Her research question, "What animal eats the pickleweed?" is a testable question (**3**). Her understanding that she will need a notebook to record her data is correct, however, she includes pickleweed and the animal that consumes pickleweed as tools. This is somewhat accurate (**2**) as, of course, the notebook is a tool used to record data. The inclusion of pickleweed and the animal that consumes it are not tools. Charlena states that in order to answer her research question, she will need to collect pickleweed and the animal that eats it. This is accurate (**3**), although collecting pickleweed is probably not necessary. Charlena's assessment of the type of inquiry she will use (observation) is accurate (**3**), in addition to her datasheet which contains two columns: **Animal** and **Eats it? Yes or No**. (**3**).

When asked what her interpretation of the data would be her response, "That the brown pelican eats the pickleweed." She wrote the word *guess* above her answer and stated during her post interview (when the teacher-researcher went over the

template book with her), "I'm *guessing* because you say I have to think about it, so, and I didn't really study the pickleweed over there in the place, so I just had to guess." The teacher-researcher responds, "Okay, and also we saw a pelican by the pickleweed there, huh?" Charlena, "Yeah."

This dialogic exchange between Charlena and the teacher-researcher puts Charlena's interpretation of her imagined data into context. On the day of the field trip we all noticed a pelican nestled in the pickleweed just off from the water line. We wondered what the pelican was doing there. Perhaps Charlena thought the pelican was consuming the pickleweed.

Charlena's interpretation is somewhat reasonable (**2**) based on her observation of the pelican sitting in the pickleweed. However, since Charlena did not actually see the pelican eating the pickleweed, she doesn't know for sure that pelicans eat pickleweed. Perhaps the pelican was just resting, sleeping, or even ill. She has no way of knowing for sure that the pelican consumes pickleweed unless she sees this action or collects a fecal sample and examines it.

Later in the day, we mentioned this to a staff member in the visitor center. She commented that during the summer months, sometimes the pelicans, especially the yearlings, do not seem to find enough food and starve. We were all very concerned for the pelican and she reassured us that she would call a bird rescue group to assess the pelican.

When asked for a possible explanation as to why pelicans eat pickleweed, Charlena states, "The pelican is an omnivore and thus eats plants." This is not accurate, as pelicans eat only fish, but Charlena wouldn't know this since she didn't study the pelican. Her logic, though, is important. She understood that the pelican eats animals (fish) simply by using the scientific concept omnivore. Her explanation is aligned with her interpretation that the pelican eats pickleweed. Based on this interpretation, her explanation is somewhat reasonable (**2**). In most circumstances this would of course be considered inaccurate as pelicans are clearly carnivores. Because the students are basing their interpretations, explanations, and alternative explanations on imagined data, her explanation is somewhat reasonable.

When asked for an alternative explanation, Charlena states, "An alternative explanation would be that the pelican needs some salt in its diet." This is also a reasonable alternative explanation (**3**) She suggests that, perhaps they consume it for salt intake, rather than as a main source of food.

Finally, Charlena concludes that, "Brown pelicans and people eat pickleweed," is reasonable (**3**), but again, setting the context is important in order to understand why Charlena includes people. Before we encountered the pelican sitting in the pickleweed, the teacher-researcher introduced the plant to the students, explaining its unique adaptation to survive in saltwater, i.e., excreting salt out of its leaves.

As the teacher-researcher showed the students the salt crystals on the outside of the succulent leaves, she asked the students if they wanted to taste the plant. She mentioned that the plant is edible and perhaps the Ohlone Indians consumed it as part of their diet. At first, the students were reluctant, but once they saw the teacher-researcher tasting it, they did as well. Most students liked it, stating, "It's good, salty, but good."

Overall, Charlena's template assessment is impressive because she was able to imagine a scientific inquiry observation of potential animals (pelicans), which may consume pickleweed at the Elkhorn slough. Charlena was able to successfully follow the logical sequential steps of the inquiry process with reasonably accurate responses, scoring 24 out of 27 total possible points.

***Field-notes (middle and end)***. Charlena demonstrated a strong inclination for the development of scientific inquiry skills throughout the study. Charlena had no difficulty, for example, when the students first began to formulate testable research questions. In fact, Margarita decided to use Charlena's research questions since she had difficulty formulating her own and they were interested in the same animal.

In the field, i.e., when Charlena and Margarita finally found a polychaete at the Watsonville slough, Charlena said that polychaetes are burrowers and that is the reason why it disappeared so quickly into a crevice in a log. The teacher-researcher was impressed with Charlena's '*in the moment*' teaching, not only for the students,

but also for the teacher-researcher and assistant researcher. It was clear to everyone that Charlena was the expert.

Aside from her own inquiry, Charlena also demonstrated her inquiry skills in the field with the teacher-researcher. For example, Charlena challenged the teacher-researcher's initial assessment that a group of ducklings we had observed in April was the same group we had observed in June. Charlena said, "Well, we don't know if it's the same one we saw in April." The teacher-researcher acknowledged Charlena and said, "You're right, that's true. The only way to know for sure is if we had tagged her (the female mallard duck, mother), huh?"

This dialogic interaction between Charlena and the teacher-researcher demonstrated that Charlena is a critical thinker and not shy to challenge the teacher-researcher. It also demonstrated a power shift as Charlena appeared to challenge the teacher-researcher's initial observation. The teacher-researcher recognized this as a '*teachable moment*' as Charlena expressed and defended an alternative explanation. Leveling the playing field of teaching and learning between teachers and students fosters a learning environment where all participants work collaboratively to negotiate new meanings and reach mutual understandings. This has also been demonstrated in Wells' studies (1999), and Duran et al., (1998).

**Results (case study 3).**

***Triangulation of data sources*** . Taken together, Charlena's data sources provide evidence that participation in an out-of-school contextualized inquiry science

project helped to increase her understanding of scientific inquiry and enhanced her motivation to learn.

Charlena's post-assessment interview revealed four significant findings: (a) the things she enjoyed and found interesting; (b) what she learned; (c) whether she thought her inquiry project was 'doing science' and (d) her thoughts about science in the Science club.

First, Charlena expressed that she enjoyed 'hands on' activities such as using the net to try and find animals and also taking water quality measurements. Second, Charlena revealed that it was easier to find a polychaete at the Elkhorn slough than at the Watsonville slough. She admitted that perhaps she should have chosen another animal to study at the Watsonville slough.

Third, when asked if she felt the inquiry project was 'doing science' Charlena responded, "I think it was doing science because we had to answer questions and make observations." And finally, Charlena came to the realization that science is not just something a mad hair scientist does in a laboratory with dangerous chemicals, but includes the study of plants and life in general.

Charlena was the only student who memorized her presentation poster. She demonstrated an understanding of the logical sequence of her inquiry, stressing key words and putting an emphasis on particular areas. In addition, when two audience members asked Charlena questions, she successfully answered them, but did not extend her answers.

Charlena demonstrated a good working knowledge of the inquiry steps in her template book. She successfully followed the logical sequential steps of inquiry with reasonably accurate responses, scoring 24 out of 27 possible points.

Finally, Charlena's field-notes demonstrated that she: (a) was very inquistive; (b) demonstrated a very strong interest in the polychaete worm; (c) demonstrated an understanding of formulating testable research questions; and (d) felt confident challenging the teacher-researcher's initial prediction of the 'missing' mallard duckling.

**Discussion (case study 3).** In Charlena'a post-assessment interview, she mentioned that she enjoyed 'hands on' activities. This was apparent throughout the study both at the Watsonville slough and Elkhorn slough. For example, Charlena often volunteered to collect a water sample for our weekly water quality measurements. She enjoyed using the equipment and getting in the water. At the Elkhorn slough, she enjoyed her time both observing marine invertebrates at Whistle Lagoon, in addition to using the high-powered microscopes in the laboratory. These examples demonstrate how saturated concrete experiences contextualize the learning process.

Charlena also came to the realization that she should have studied another animal at the Watsonville slough. This related to the fact that polychaete worms are predominantly found in marine environments rather than fresh water. The teacher-researcher tried to caution both Charlena and Margarita with pursuing this animal for

their inquiry project, but they insisted on this animal. Ultimately in the end, Charlena realized that perhaps she should have either chosen another animal or had the Science club experience at the Elhorn slough.

Charlena's response about how doing science involves answering questions and making observations is aligned with the inquiry steps. This signified that Charlena had developed a better understanding of the scientific inquiry steps. Perphaps having gone through the experience herself, provided an understanding of the process.

Finally, Charlena came to the realization that science is not just for 'mad hair scientists' using dangerous chemicals in a laboratory, but rather broader and more inclusive, stating science also included studying life in general and that anyone could do it. These insights are significant, particularly for ELL who tend to perceive science as too difficult or boring.

During her presentation, Charlena spoke directly to the audience. She appeared confident and expressed why she became interested in the polychaete worm, stating, "because they can bite people; they can eat each other; and finally because they are hermaphrodites and can release sperm and eggs in the water." These demonstrate that Charlena initially chose her animal based on these interests. When an audience member asked about the polychaete diet, she did not know the answer other than the fact that they are cannibalistic. Aside from this, Charlena's responses to questions were all accurate.

On Charlena's inquiry template assessment, most of her responses were reasonable, while three were somewhat reasonable. When asked for the tools needed for her inquiry, she stated that she would need a notebook to record her data, but also included pickleweed and animals as tools. This part of her answer was not accurate, thus her total score for this inquiry step (Tool needed) was considered somewhat accurate. On the whole, Charlena demonstrated a firm understanding of the inquiry process on this assessment.

Finally, Charlena demonstrated throughout the study that she was inquisitive, often asking questions about content in a book, i.e., whether moose reside at the Watsonville wetlands like they do in other wetland ecosytems, or from observations in the field, for example why the teacher-researcher thought she saw a cinnamon teal duck in the winter when they are residing in southern regions at this time of the year. Overall, Cecelia demonstrated a strong understanding of nearly all aspects of the inquiry process.

In sum, Charlena demonstrated a strong understanding of the inquiry process. In addition, she was very inquisitive and able to formulate testable research questions from the beginning of the study.

**Margarita (case study 4).** The following section contains an analysis of Pre-assessments and Post: assessments. The pre-assessments include: pre-assessment interview and field-notes. The post-assessments include: post-assessment interview, presentation, template book at Elkorn slough, and field-notes.

***Pre-assessment interview***. From the beginning, Margarita expressed an interest in studying the polychaete worm. During the pre-assessment interview (on our first day), the teacher-researcher asked Margarita, "Is there anything that interests you about the wetlands, like in general, anything that you are interested in studying?" Margarita replied, "The the animal, the that looks like an earthworm and has a head of like, between a crab and a shrimp."

When asked if she had any questions or concerns about the wetlands, Margarita wondered if the polychaete worm lives here (in the Watsonville slough region). When asked how she could find out, she responded, "We could test that out getting um to know by Cindy or we could go into the water and make water samples and find out um what kind of water there is and what kind of water they like."

This response is very impressive as the scientific inquiry project has not yet begun, yet Margarita demonstrates an understanding of conducting inquiry. She states three reasonable inquiry steps to finding an anwer to her testable question, "Does the polychaete worm live here?" (1) ask an expert (Cindy) in order to gather information, (2) gather a water sample to determine what kind of water the Watsonville slough has, and (3) find out (research) what kind of water polychaetes prefer. These inquiry suggestions provide evidence that Margarita was already thinking scientifically even before the doctoral study. Perhaps discussing inquiry informally during the pilot study or her experiences in school or at home prefaced her scientific thinking.

**Example 1.**

**Me:** Did you see anything that interested you or made you wonder on our walk to the Watsonville slough?

**Margarita:** Um, the animal where we had to find out with the um microscope.

**Me:** On what we just saw on our walk?

**Margarita:** Um (pause), the blue jay.

**Me:** The blue jay? The bluebird?

**Margarita:** Yeah

**Example 2.**

**Me:** Is there anything that interests you about the wetlands, like in general, anything that you are interested in studying?

**Margarita:** The, the animal, the that looks like an earthworm and has a head of like, between a crab and a shrimp.

**Me:** Okay so the polychaete worm?

**Margarita:** Yeah

**Me:** You're really interested in that aren't you? (Laugh)

**Margarita:** (Nods shyly with a smile)

**Me:** Okay

**Example 3:**

**Me:** Do you have any questions or concerns about the wetlands?

**Margarita:** No

**Me:** You have to have something that you're wondering about, something that you're concerned about?

**Margarita:** Uhhh, if the polychaete worm lives here?

**Me:** Okay

**Example 4:**

**Me:** And how could we find out if it lives here? What would we do to find out?

**Margarita:** We could test that out getting um to know by Cindy or we could go into the water and make water samples and find out um what kind of water there is and what kind of water they like.

**Me:** Right. And then use the microscope to see, huh?

**Margarita:** Yeah

**Me:** Uhhh, okay, thank you

***Field-notes (beginning).*** With regard to her scientific inquiry project, Margarita, Charlena, and the teacher-researcher co-constructed that since the polychaete is predominantly found in marine environments, and the Watsonville slough is a freshwater environment, the likelihood of finding a polychaete worm at the Watsonville slough would be quite low. Even though they both understood this, they still wanted to do their inquiry project on the polychaete worm. There was no dissuading them otherwise. In fact, they both expressed that perhaps the Elkhorn slough would be a better place for their inquiry. The teacher-researcher considered this, but do to the distance, decided to stay local (in Watsonville).

When Margarita was beginning to formulate potential research questions, they appeared not to be testable due to the Science club's limited budget. For example, her first research question was: (1) "How do polychaetes engage in cannabalism."

Although this is a testable research question, the teacher-researcher tried to explain to Margarita that in order to observe cannibalistic behavior, we would need cameras set up 24 hours a day, seven days a week. Since the Science club did not have the money to spend on a camera, her research question was not considered feasible due to our limited financial means.

Thus, she tried again, (2) "Why are polychaetes hermaphrodites?" This too was not a testable question, but rather a question that could potentially be answered by reading the literature on polychaetes. Although both of Margarita's attempted research questions demonstrate higher order thinking, i.e., by using *how* and *why*, they are not realistically testable research questions (Ballenger, 1997). Thus, since Charlena was also interested in studying the polychaete worm, Margarita decided to use Charlena's research questions: (1) Do polychaetes have teeth, and (2) What kind of polychaetes live in the Watsonville slough?

Interestingly, Margarita was able to formulate a perfectly reasonable inquiry question in her pre-assessment interview, "Does the polychaete worm live here in the Watsonville slough?" on her first day of the study. In fact, this very same question is Charlena's second research question.

***Post-assessment interview.*** When asked if she felt studying the wetlands was important, Margarita expresses a social concern (pollution) and sets up a hypothetical situation with the following statement, "Let's consider if like your family from like, let's say they come from Nevada and over there it's like, snowy there, then they want to see like something that's cool, we can take them to the wetlands and show them *how*, like we have nature here that's that's pretty and stuff." This hypothetical statement is a form of scientific thinking, i.e., *if* your family comes from Neveda, *then* they can come here and see something cool (different) like the wetlands. Hypothetical statements are clearly a form of scientific thinking, thus, this provides some evidence that Margarita is thinking in a scientific way.

When asked about her thoughts about science now, after experiencing the Science club, Margarita states, "Well at first I thought it was boring, but after doing the Science club, I learned that science is not just um like seeing you read out of textbooks it's actually collecting data, making observations looking at small aquatic invertebrates and high powered microscopes and stuff, and using binoculars and other fun stuff that you never actually get to do in your science classes."

This statement reveals an understanding of what real science entails, i.e., making observations, using tools (high powered-microscopes and binoculars), and collecting data. Margarita contrasts her experiences in school (boring textbook work without an opportunity to do real science and use tools) with her experiences in the

Science club (fun real science experiences making observations, using tools, and collecting data).

Margarita also states that science is important because "science can help you learn something that other people don't know, like if you want to know something, you go to a science web-site and they'll show you what has been discovered and stuff." This statement reveals one of the initial steps in the inquiry process (researching information).

She expands the importance of science by stating, "And then you can help other people by doing science and like, science issues is like if you want to find out something, it's science…to make observations…and to find an answer that you found." This statement includes more of the investigative process of: (1) finding something out (seeking information), and (2) making observations to find an answer (making observations as a type of inquiry in order to answer a research question).

When asked what she learned from her inquiry project, Margarita states that it is rare to find a polychaete at the Watsonville slough because it prefers saltwater rather than freshwater. She also states that she thinks her inquiry project was 'doing science' because she was collecting data and recording when she found a polychaete and when she didn't. When asked if she thought she could do science after the Science club experience, she responded, "Yes, I do think, after this experience I can do science."

Finally, when asked if she thought/felt she could be an active voice for educating others about the importance of wetlands, Margarita said, "Yeah."

With regard to presenting, Margarita shared that at first she was very nervous, but after she did it, she got over her embarrassment and wasn't nervous anymore.

When asked about her thoughts and feelings about her experiences at The Nature Center, Margarita said, "I, well, I thought it was pretty good *because* it kind of helped me a little bit, but not as much as like when we were actually doing it all by ourselves so like, not having people around us or disturb us and stuff." The teacher-researcher, verifying what Margarita had just said asked the following question, "So when we were outside and seeing it for ourselves, that helped you more?" Margarita responded, "Yeah." This demonstrates that perhaps our experiences as a club in the field were more beneficial to her learning than receiving non-experiential information from the exhibits and science educator (Cindy) in The Nature Center.

***Presentation.*** Margarita was the only student who translated her presentation in Spanish. Although she read from her poster (English version), when Margarita translated, she faced the audience. This appeared to be appreciated by audience members who only understood Spanish.

Throughout the presentation, Margarita's voice was strong and clear. She also had a very good pace. When she finished, the audience applauded. The teacher-researcher asked if anyone had a question and one audience member smiled and said, "I think you covered all." Another added, "Covered it all."

Overall, Margarita demonstrated a knowing of the logical sequential steps of the inquiry process. She appeared somewhat nervous at the beginning, but toward the middle and end, she appeared confident and took command of her presentation. Her father also used his cell phone to either videotape or take pictures of her presentation. He appeared to be beaming with pride as he and his wife (her mother) watched and listened.

***Template book at Elkhorn slough.***

Template: What I found most interesting at the Elkhorn slough was _____

Margarita: When I found the Green European crab.

Template: If I were to research what I found interesting, I would research the following: Margarita: The polychaete larvae, the brittle starfish, the European crab

Template: After learning about these facts (whether they have already been answered), I still have some questions:

Margarita: I would want to know what the polychaete larvae eat? How does the brittle star move? Does it swim? Can the European crab go back to Europe?

Template: I asked myself, "Are these testable questions?"

Margarita: What does the polychaete eat? Does the brittle star swim? Can the European green crab go back to Europe?

Template: My research question is _____

Margarita: Why do brittle stars have 6 little legs?

Template: For my research question, I need to collect _____

Margarita: How the brittle star moves around. When it is a newborn brittle star. How it comes out.

Template: Since I will need to _____ in order to anwer my research question, of the three types of inquiry (observations, investigations, and experiments), my type of inquiry will be _____

Margarita: observations

Template: I realize that the tools I will need to answer my research question are:

Margarita: I will need to use a microscope and a jar to collect a brittle star.

Template: My datasheet looks like this _____

Margarita: (Two columns)

**Did I see a brittle star? Yes? No? How many legs?**

Template: My interpretation of the data is _____

Margarita: I collected 9 brittle stars. Also they had different legs.

Template: Possible explanation as to why?

Margarita: Maybe it could be a different species or maybe a predator ate some of its legs.

Template: An alternative explanation _____

Margarita: Maybe it was born like that.

Template: Based on the data, it appears that _____ although more data points are needed in order to strengthen this conclusion.

Margarita: Brittle stars can be a different kind of species.

Margarita demonstrates that she has a working knowledge of the steps of inquiry, even without data to analyze. Her research question, "Why do brittle stars have 6 legs?" is somewhat of a testable question (**2**) as most brittle starfish have five arms. Note: While examining aquatic invertebrates in the microscope laboratory, Margarita found brittle starfish with five arms, in additon to four and six arms. This puzzled her and she asked Kenton why brittle starfish have different numbers of legs. Interestingly, he did not know why and appeared just as curious as Margarita.

Margarita's understanding that she will need a jar to collect brittle starfish in additon to a microscope (tools) is accurate (**3**). Her understanding that she will need to collect data on the number of legs she sees is also accurate (**3**). Margarita's assessment of the type of inquiry she will use (observation) to answer her research question is also correct (**3**). Her datasheet also demonstrates two columns for recording data: the first column determines whether she sees a brittle starfish (yes or no), and the second column determines how many legs are present. This is somewhat accurate (**2**), as she will be collecting a sample of brittle starfish and of course will see starfish, hence column one is unnecessary.

When asked what her interpretation of the data would be (even though there is no data, i.e., students are imagining what they would find), her response, "I collected 9 brittle stars. Also they had different legs." This is more of a statement of findings rather than an interpretation, thus this is considered somewhat reasonable (**2**). When asked for a possible explanation of her interpretation, Margarita states, "Maybe it

could be a different species or maybe a predator ate some of its legs." This is a reasonable explanation (**3**) as Margarita observed at least 6-8 brittle starfish with varying numbers of arms. When asked for an alternative explanation, Margarita states, "Maybe it was born like that." This is also reasonable (**3**), however, how would a scientist assess this? How would a scientist be able to dicipher if the quantity of legs (less than the normal five) is a congenital deformation or the effects of predation? These questions are open for interpretation.

Finally, Margarita concludes that, "Brittle stars can be a different kind of species." This is a reasonable conclusion (**3**) because Margarita can refer to the literature on brittle stars to see if the ones she has are different species from one another. Overall, Margarita's template assessment is impressive because she was able to imagine the scientific inquiry process on another animal (brittle starfish) in a different context (Elkhorn slough). Margarita was able to successfully follow the logical sequential steps of the inquiry process with reasonably accurate responses, scoring 24 out of 27 possible points.

***Field-notes (middle and end).*** Throughout the study, both Margarita and Charlena found only one polychaete at the Watsonville slough. During the remaining field outings, they found only worms. This disappointed them, particularly Margarita who appeared quite despondent after a day in the field.

Consequently, the teacher-researcher noticed very few data entries when working with them on their scientific inquiry books. She asked, "You only have one

data entry? What about all of the other times you were out in the field? What did you find?" They said, "Worms, so we didn't right anything." This was surprising to the teacher-researcher because they should have recorded their findings for each day, whether they found a polychaete or not.

**Results (case study 4).**

***Triangulation of data sources.*** Taken together, Margarita's data sources provide evidence that participation in an out-of-school contextulized inquiry science project helped to increase her understanding of scientific inquiry and enhanced her motivation to learn. Margarita's post-assessment interview revealed five significant findings: (a) her use of a hypothetical statement about pollution; (b) her new perception about science; (c) what she learned from her inquiry project; and (d) her confidence that she could do science.

First, when asked if she felt studying the wetlands was important, Margarita formulated a hypothetical statement to express a social concern about pollution. Hypothetical statements are clearly a form of scientific thinking, thus this provides support that she was thinking in a scientific way.

Second, when asked about her thoughts about science now after experiencing the Science club, Margarita expressed that she learned science is more than just reading textbooks, but actually involves collecting data, making observations, using tools such as microscopes, and other fun stuff she never gets to do in her class.

Third, when asked what she learned from her inquiry project, Margarita stated that it is rare to find a polychaete at the Watsonville slough because it prefers saltwater rather than freshwater. This statement meets the grammatical construction, "X is found in Y locations/contexts" thus, demonstrating accurate science discourse.

Fourth, when asked if she felt she could do science after the Science club, she reponded, "Yes, I do think, after this experience I can do science." This statement reveals both confidence and volition.

Margarita's presentation demonstrated a knowing of the logical sequential steps of the inquiry process. Although she appeared somewhat nervous at the beginning, she quickly rebounded, appearing confident and taking command of her presentation.

Margarita's performance on her inquiry template assessment revealed that she was accurate on all inquiry steps. Overall, Margarita's performance on this assessment was impressive because she was able to imagine the scientific inquiry process on another animal (brittle starfish) in a different context (Elkhorn slough).

Lastly, Margarita's field-notes demonstrate her determinism to follow her interests. The field-notes also provide support that Margarita's initial research questions were all testable, demonstrating higher levels of thinking, however, due to lack of funds, the project could not buy the equipment she needed to carry out her investigation.

**Discussion (case study 4).** During Margarita's post-assessment interview, she set up a hypothetical statement about pollution using everyday language and a personal experience. This demonstrates that students can formulate scientific ways of thinking through their everyday language and personal experiences.

Margarita also demonstrated a shift in her thinking about science. She initially said that she had thought science was boring because in school she just reads textbooks, but having participated in the science inquiry project, her view changed. This provides support for how real life experiential experiences can change a student's perception about science.

Margarita came to the realization that it is rare to find a polychaete at the Watsonville slough because it prefers saltwater over freshwater. Even though this knowing was co-constructed with the teacher-researcher at the beginning of the project, Margarita had to experience this for herself to come to the realization.

Finally, at the end of the science inquiry project, Margarita felt that she could do science after her experience. This provides support for how the instructional process as well as the tools used to facilitate learning, had a positive effect in her belief about doing science.

Margarita's presentation demonstrated not only a strong knowing of the inquiry process, but also confidence. Although she read her poster board in English, when she translated it into Spanish, she looked at the audience. Members in the

audience who spoke only Spanish said at the end of the presentation how much they appreciated that.

Margarita's performance on her inquiry template assessment showed that she could successfully follow each step of the inquiry process. She was able to formulate a testable research question, identify the mode of inquiry to answer her question, determine the type of tools she would need to collect her data, design a data sheet, analyze her data, and interpret the result. Although some of her interpretations were not fully accurate, her performance on this decontextualized assessment was very strong.

Finally, Margarita's field-notes demonstrate that throughout the study she had a strong conviction to follow her interest no matter what the outcome. This was apparent at the beginning of the study when the teacher-researcher said that the probability of finding a polychaete would be low since they are predominately found in marine environments. Knowing this, she still wanted to study the polychaete.

Overall, Margarita demonstrated a knowing and understanding of all aspects of the inquiry process. She also showed a strong conviction to follow her interests no matter what the outcome may be. As the study progressed, she was able to successfully formulate hypothetical statements and higher level thinking- asking how and why questions.

**Cross Case Analysis**

There are many ways a cross case analysis can occur. For this study, I will first cross analyze Charlena and Margarita (old timers) who participated in the pilot study. I will then cross analyze Cecelia and Jacquelina (new comers), and then compare all students with each other.

When comparing Charlena and Margarita's pre-assessment interviews, both students revealed an interest in studying the polychaete worm. They also demonstrated a knowing of how to conduct inquiry, especially Margarita. For example, when the teacher-researcher asked Margarita if there was anything at the wetlands she would be interested in studying, she replied, "Does the polychaete worm live here (in the Watsonville slough region)?" When the teacher-researcher asked Margarita how she could find out, Margarita offered three steps of inquiry: (a) ask Cindy (science educator); (b) find out what kind of water the Watsonville slough has (freshwater or saltwater); and (3) find out what kind of water polychaetes prefer. All three of these suggestions are in alignment with reasonable inquiry steps to answer her testable research question.

The fact that Margarita could formulate a testable research question with reasonable inquiry steps to answer her research question is very impressive, considering it was the first day of the Science club and the teacher-researcher had not yet discussed inquiry in a systematic way. However, the teacher-researcher

informally discussed how to engage in an inquiry study during the pilot study, which Margarita and Charlena participated in six months prior to the doctoral study.

Like Margarita, Charlena also demonstrated a knowing of how to conduct inquiry when she asked a testable research question, "Do banana slugs live at the Watsonville slough?" When the teacher-researcher asked how she could find out, Charlena said, "We could look into the bushes, but in a safe way." This is a reasonable answer as many scientists and researchers begin their initial investigations in the field making preliminary observations.

With regard to their post-assessment interviews, both students demonstrated a firmer understanding of what inquiry entails. For example, in reference to Margarita's science inquiry project on the polychaete worm, she states that it is rare to find a polychaete at the Watonville slough because it prefers saltwater rather than freshwater. When asked if she thought/felt her inquiry project was 'doing science' Margarita states that she believes her inquiry project was 'doing science' because she was collecting data and recording when she found a polychaete and when she did not. Lastly, when asked if she thought/felt she could do science after experiencing the Science club, Margarita responds, "Yes, I do think, after this experience I can do science."

Like Margarita, Charlena also states that it was easier to find a polychaete (larvae) at the Elkhorn slough than at the Watsonville slough. She even admits that perhaps she should have chosen another animal to study at the Watsonville slough.

When asked if she thought/felt her science inquiry project was 'doing science' Charlena states, "I think it was doing science because we had to answer questions and make observations." This statement reveals her understanding that science involves making observations and seeking answers to questions, two key steps of the scientific inquiry process.

Interestingly, Margarita and Charlena touch upon different aspects of the inquiry process. For example, Margarita emphasizes collecting data and recording observations, while Charlena focuses on answering a question and making observations. Their answers combined form a more complete picture of the inquiry process. It is important to note that Margarita and Charlena were partners in their inquiry project and worked very well with each other, i.e., balancing each other out. This is reflected in their answers to whether they thought/felt their inquiry project was 'doing science'.

With regard to their presentations, both students presented on the same animal, the polychaete worm. Charlena's presentation was second, and Margarita followed (third). Both students demonstrated an understanding of the logical sequence of their inquiry projects, however, Charlena memorized her poster and looked directly at the audience, while Margarita read from her poster (English version) but when translating in Spanish, she looked directly at the audience. Although shy and 'embarrassed' at the beginning, they both appeared to relax toward the middle of their presentations. Charlena received two questions from audience

members, whereas Margarita received none. Perhaps since Margarita followed Charlena and the content was the same, the audience did not have questions for her.

On their scientific inquiry template book assessments, both students scored 24 out of 27 possible points. They demonstrated reasonable accurate responses for 6 inquiry steps, receiving 3 points for each, and somewhat reasonable responses for 3 inquiry steps, receiving 2 points for each, for a total of 24 out of 27 possible points.

Lastly, when comparing their field notes, both students demonstrated a very strong interest in studying the polychaete worm. Even when Margarita, Charlena, and the teacher-researcher co-constructed together that the likelihood of observing a polychaete in the Watsonville was low, both Margarita and Charlena were determined to do their inquiry projects on the polychaete worm. This demonstrates both conviction and motivation to stick with what interests them.

With regard to formulating research questions, Margarita's questions demonstrated higher order thinking, in that she asked *how* and *why* questions, yet, due to financial reasons (camera), her first research question, "How do polychaetes engage in cannibalism," could not be realistically investigated. Her second research question, "Why are polychaetes hermaphrodites," was also not considered testable as this question could potentially be answered by reading the literature on polychaetes.

The fact that Margarita had somewhat of a difficult time formulating a testable research question surprised the teacher-researcher, as Margarita was able to do so on our very first day by asking, "Does the polychaete worm live here in the Watsonville

slough." She was also able to provide three feasible means of exploring her testable research questions: (a) ask an expert (Cindy); (b) take a water sample to find out what kind of water the Watsonville slough has and; (c) find out (research) what kind of water the polychaete prefers.

Charlena, on the other hand, had no problem formulating a testable research question for her animal of interest. In fact, she formulated two: (1) What kind of polychaete lives in the Watsonville slough, and (2) Do they have teeth? Since Margarita was also studying the polychaete worm, she decided to use Charlena's research questions as well (pairing up together).

All four of the data sources triangulated for both Margarita and Charlena. Even their pre-assessment interviews demonstrated an increased understanding of the scientific inquiry process and also motivation to learn. Perhaps their participation in the pilot study contributed to this as the teacher-researcher informally discussed how to conduct inquiry in two different contexts, i.e., Natural Bridges tidepools and Watsonville slough. As the study progressed, each student demonstrated a very good knowing of the inquiry steps and both thought/felt that their inquiry project was indeed 'doing science'.

When comparing the newcomers (Cecelia and Jacquelina), their pre-assessments revealed an interest, curiosity and wonder about both biological and social observations. For example, when the teacher-researcher asked Cecelia what she noticed on our nature walk, she mentioned red specks (mosquito fern), memorial

crosses, and wanted to understand why people throw garbage. Jacquelina expressed an interest and curiosity about what looked like fur on a log (which may have been an old, worn-out burlap bag), in addition to a social concern (why are the roads under water). These intial observations reflect both a biological and social perspective which is different from Charlena and Margarita who just made biological observations.

This difference between the newcomers and old timers is reminiscent of the Moje & Carrillo (2001) study where the students were just learning about a unit on water quality. Their questions were much more aligned with social concerns about pollution, for example, "Why do people keep polluting?" rather than biological concerns, which the unit was geared toward, "What is the quality of water in our river?"

This provides some evidence about how teachers need to consider all perspectives students have at the beginning of a unit, both social and biological. These perspectives and others (historical, economical, technological, and political) should be fully explored and discussed if students have questions, interests, and concerns from these perspectives (Lemke, 2001, p. 300). This learning and teaching platform provides students with an opportunity to examine an area of interest or concern to them from multiple angles. This kind of learning and teaching is a balanced approach to understanding information from multiple perspectives.

There is another difference between the newcomers and oldtimers in reference to how they would find an answer to a question they have posed. For example, Cecelia asks, "What is that red stuff in the water?" When the teacher-researcher asks her how she would go about finding an answer to her question, Cecelia says, "By asking other people."

Although Cecelia's answer does not reflect a traditional inquiry step, such as making observations, researching the literature, asking an expert, etc., it still conveys consulting with others (who may be experts).

Jacquelina, the other newcomer, provides more of an acceptable response with regard to traditional inquiry steps for answering a question. For example, she asks, "Why are the roads under water?" When asked how she would go about finding an answer to her question, she says, "Um, Google it or find it on the computer." This is a reasonable answer as many scientists' (researchers') first step in the inquiry process is to research literature via the Internet.

When examining the questions posed by the old times and their suggestions for how they would go about finding an answer to their posed questions, their responses are much more aligned with traditional inquiry steps. For example, Margarita asks, "Do polychaete worms live here in the Watsonville slough?" When asked how she would go about finding an answer to her question, she states, "We could test that out getting um to know by Cindy or we could go into the water and

make water samples and find out um what kind of water there is and what kind of water they like."

This answer demonstrates a stronger understanding of the inquiry steps in that Margarita suggests: (a) consulting an expert to obtain information; (b) taking a water sample to test the kind of water the Watsonville slough has; and (c) researching the type of water (salt or fresh water) polychaetes prefer.

Similarly, Charlena provides an inquiry step which is aligned with the traditional means of engaging in the scientific inquiry process. For example, she asks, "Do banana slugs live in the Watsonville slough region." When the teacher-researcher asks how she would go about finding an answer to her question, she says, "We could look into the bushes, but in a safe way." Looking in the bushes is indicative of making observations. This is a reasonable answer as many scientists and researchers begin their initial inquires in the field making observations.

Returning back to the new comers, with regard to their post-assessment interviews, both students demonstrated a deeper understanding and interest in their awareness and knowing of 'doing science'. For example, Jacquelina expressed that part of 'doing science' was learning scientific language, taking water quality samples, making observations (ruddy duck), and recording observations on a datasheet. This demonstrates a deeper and well-rounded perspective of what 'doing science' entails. It is not just a series of steps, but includes using scientific language while engaged in the practice of science.

Like Jacquelina, Cecelia also demonstrated a deeper understanding and interest in some of the plants she chose for her inquiry project. For example, Cecelia was fascinated with the medicinal properties of the California poppy and blue-eyed grass. For instance, when asked what she learned from her inquiry project, Cecelia states she learned that the California poppy was used in the past to help children go to sleep (by placing a poppy underneath a child's bed), and that blue-eyed grass was used to treat asthma and other illnesses.

Even though her inquiry project included understanding potential biological factors which may contribute to different colors (bright orange and yellow) and heights (short and tall) of the California poppy in two regions (Watsonville slough and Struve slough), Cecelia did not mention these in her post-assessment interview. What Cecelia latched onto were the medicinal properties of her plants of interest. One potential reason as to why Cecelia placed such an emphasis on the medicinal properties of her plants of interest may have to do with the fact that throughout the study, Cecelia was ill most of the time. She also has asthma and anemia. Perhaps, in her own way, she was looking for a remedy to ameliorate her illnesses?

On the day of the presentations, both students presented well. Even though they read from their poster boards, they both appeared to understand the logical sequence of their scientific inquiry projects. When audience members asked them questions, they were both able to answer successfully. Cecelia stated that the day of the presentations was her favorite activity of all of the Science club activities.

Jacquelina also enjoyed the day, but her parents were not present to support her. This appeared to bother her somewhat, but her peers and the teacher-researcher stepped up and provided additional support for Jacquelina, i.e., the teacher-researcher stood next to her at the beginning of her presentation and helped her get started, while her peers applauded for her twice.

Perhaps the most telling data source, as far as revealing various levels of performance, was the template book assessment. For example, of all of the participants, Cecelia (newcomer) scored the highest, 25 out of 27 possible points. She missed two points on: (a) not providing a third column of her datasheet to record the stomach contents of the polychaete larvae; and (b) providing somewhat of an accurate interpretation that polychaete larvae consume duckweed (a freshwater plant, however, the Elkhorn slough is a mixture of fresh and saltwater).

When comparing Jacquelina with Cecelia, there is a difference in their performance on this assessment. For example, Jacquelina scored 20 out of 27 possible points. This was very surprising for the teacher-researcher as Jacquelina appeared to understand the scientific inquiry process so well in her ruddy duck project. Perhaps this low score is a reflection of the assessment itself. However, before considering this, it is important to mention that the two old timers scored the same on this assessment, 24 out of 27 possible points.

With regard to the template assessment, the teacher-researcher realizes this was a challenging task for the students. It would have been more beneficial for them

to choose from a set of four established areas of inquiry with data, for example: frogs, birds, aquatic invertebrates, and vegetation. This would have provided students with something to work with, rather than imagining an invisible scenario.

As stated throughout this analysis, many students, particularly ELL and other students without access to quality science learning, need contextualization in order to construct meaning. Although the environment (Elkhorn slough) was a highly contextualized experience, the assessment was not. Even though the assessment contained framed sentences to scaffold students with the sequential steps of the scientific inquiry process, a concrete example of data was not provided for students to work with. Instead, students had to imagine an inquiry project, data, and provide an interpretation, explanation, alternative explanation, and conclusion based on non-existent data. In hindsight, this assessment may have been too high of a cognitive leap, but interestingly, Cecelia (25 out of 27), a newcomer, and Margarita and Charlena (24 out of 27), two old timers, scored well on this assessment.

Another explanation to consider is that Cecelia's experiences in her science learning at school often intersected with what she was learning in the Science club. The same can be said for Margarita, as they both had the same science teacher (Mr. Murphy). However, Jacquelina was not doing well at her charter school and had to transfer mid-year to a public middle school. Perhaps Jacquelina experienced a lack of continuity with course content and this may be a factor in how and why she did not perform as well as her peers on this assessment?

With regard to field notes, both new comers demonstrate strengths and weaknesses. With regard to strengths, Cecelia demonstrated three key principles of inquiry (interest, curiosity, and wonder) (Wells, 1999, p. 121) throughout the study. For example, on our very first day, she was curious as to what the red specks were in the water. After asking the science educator and finding out (mosquito fern), we visited another slough (Watsonville slough) where we observed the same red floating specks on the water's surface. When the teacher-researcher asked the students if they remembered what Cindy (science educator) had told them, Cecelia was the only student who remembered, "mosquito fern!"

In addition to plants, Cecelia also demonstrated a sense of wonder about animals. For example, she shared with the Science club that while at school, she heard what sounded like geese flying overhead and wondered what kind of birds they were. Cecelia's sense of wonder here demonstrates how she is integrating her experiences in the Science club with her experiences at school.

On another occasion in the field, the teacher-researcher and students noticed a brown, furry animal with ears swimming in the water. Not knowing what it was, they decided to ask Crysti (science educator). After revealing that the animal was a muskrat, Cecelia took the initiative to search through her Earth Cards to learn more about this animal. Not finding a card, she walked through the exhibits and found an information panel and picture on the muskrat. She carefully read the information and closely examined the picture.

An area where Cecelia demonstrated a weakness was with water quality correlations, particularly with regard to nitrates and dissolved oxygen. When ever the teacher-researcher asked the students what the dissolved oxygen level would be if the nitrate level were high, Cecelia always answered high rather than low. It wasn't until the very last day of the Science club experience when the teacher-researcher contextualized the question using the apple warehouse fire as an example that Cecelia finally understood the negative correlation of these two water quality factors.

Jacquelina also demonstrated strengths and weaknesses. For example, from the start, Jacquelina demonstrated very keen observational skills. From noticing a narrow opening of the mouth of the Pajaro River to the ocean (on a topography map), to red tail hawks, seagulls, and a black bird with white tipped wings. As the study progressed, Jacquelina's skills improved even more, particularly with regard to her inquiry project. For example, Jacquelina appeared to intuitively understand how to formulate a testable research question. During a very short period of time, she had progressed from a one side question, "How does the male ruddy duck attract a female," to a two-sided interaction, "How do the male and female ruddy ducks interact with each other?"

When out in the field, Jacquelina correctly recorded preening, diving, and foraging behaviors of the ruddy duck. For instance, her datasheet was always out with a pencil ready in hand. Her recording technique of using male and female symbols in addition to arrows to represent directional movement were accurately

recorded and interpreted (out in the field when the teacher-researcher would ask for an interpretation).

Jacquelina also demonstrated weaknesses as well. For example, when she was given a research report to start gathering information on the ruddy duck, she appeared lost and confused. When the teacher-researcher asked why she had not written anything down, Jacquelina said, "I don't know what to write." Thus, the teacher-researcher amended the report and asked specific and explicit questions. Once this was done, Jacquelina had no problems seeking information on her animal of interest.

Overall, both Cecelia and Jacquelina demonstrated aspects of scientific inquiry in all four data sources, with Jacquelina slightly weak in one data source (template book assessment). Both students demonstrated very strong levels of interest, curiosity and wonder, i.e., three aspects of inquiry that many would argue are not part of scientific inquiry. I would argue that they are for they create the initial spark which often motivates students (and scientists) to seek information, collaborate with others, and reach mutual understandings.

**Interactive Instructional Group Conversation Analysis on Modes of Inquiry**

There are 5 excerpts worthy of analysis. These excerpts will be presented in sequence of time, in other words, in order of when they occurred, i.e., excerpt 1 occurred at the beginning of the instructional conversation, while excerpt 9 occurred at the end.

**Excerpt 1:**

**Me:** But to inquire means to wonder and there's different kinds of inquiry, there's observational, investigations, and experiments, okay.

**Me:** Now, I'm going to give you an example of each one. An observation is someone who just goes into their natural environment (pulling out a book on Jane Goodall)

**Margarita:** Oh! Isn't Jane Goodall the one who studies the chimpanzees?

**Me:** Yeah, yeah if you're observing something, it means that you're just going into the natural environment and you're making observations on natural behavior, okay.

**Me:** Do you guys know about Jane Goodall?

**Student:** Yeah (I think Jacquelina said yeah)

**Me:** She studies chimpanzees in Africa?

**Jacquelina:** Yeah

**Me:** A woman, mmm hmmm. And she's been doing it ever since she was very young, in her 20's; see how young she is here (*pointing to a picture of her*). And she became fascinated with the chimpanzees, so this man, is very well known, his name is Louise Leakey, he hired her. He said I want you to go to Tanzania, Africa and observe the chimpanzees' behavior. So she says, okay, notice what's she's doing here? What is she using?

**Cecelia:** Binoculars

**Me:** Mmmm hmmm.

**Me:** And what she found was that chimpanzees are very, very much like us. That they're very human like, they have strong family bonds, that they use tools, sticks to pick up termites out of termite holes, that they're very smart, um, that they are very curious, see that (*laughing, showing them a picture in the book*), anyways, she's she's, if it weren't for her, we would not have known that the chimpanzees are 98% similar to human beings in their DNA and in how they interact with each other; they're like humans. One came up to her, they shared a banana (*showing picture in the book*).

**Cecelia:** (laughs)

**Me:** There she is, she's really, really amazing like the one's that get captured (*emphasis on capture*), you know, to sell in the pet-trade, you guys know about that in Africa?

**Student:** No

**Me:** The parents are killed, the parents meat is sold as bush meat, people eat, they'll eat it, and then the babies are sold as pets for zoos and peoples homes and stuff like that, and what she does is she rescues the babies, gets them out of there and puts them in a sanctuary in Tanzania which is a safe place for them to live. This is cute; this is, okay (*showing a picture in book*).

**Me:** So she's a scientist and the type of inquiry she's doing is called, what?

**Students:** Observations

This excerpt demonstrates how the teacher-researcher uses a contextualized example (Jane Goodall) to demonstrate the meaning of one mode of inquiry

(observations). As soon as she pulls out a book on Jane Goodall, Margarita instantly recognizes Jane Goodall and says, "Oh! Isn't Jane Goodall the one who studies the chimpanzees?" This question from Margarita provides an entry point for all participants to enter. For example, the teacher-researcher acknowledges Margarita and says, "Yeah, yeah if you're observing something, it means that you're just going into the natural environment and you're making observations on natural behavior, okay. Do you guys know about Jane Goodall?" A student responds and says, "Yeah."

The teacher-researcher contextualizes the example further, emphasizing that Jane Goodall is a woman, "A woman, mmm hmmm." The purpose in doing so was to build awareness that scientists are not just men, but also include women. The teacher-researcher discusses how young she was when she first started (20's), who hired her (Louise Leakey), where she did her research (Tanzania), and what she did (observe chimpanzee behavior).

When she asks the students what Jane Goodall is using to make her observations (showing a picture of her using binoculars), Cecelia answers, "Binoculars." The teacher-researcher affirms Cecelia's response and continues with more contexutalization. She summarizes some of Jane Goodall's key findings: (1) chimpanzees are similar to human beings because they have strong family bonds, (2) they use tools such as sticks to retrieve termites from holes, (3) they are very curious, and (4) their DNA is 98% similar to human DNA. Finally, the teacher-researcher

asks, “So she’s a scientist and the type of inquiry she’s doing is called what?” The students respond in unison, “Observations.”

This excerpt demonstrates that students can come to their own realizations if examples are contextualized with meaningful information. It is important to note that the students listened very intently to the information and appeared interested in learning more about Jane Goodall’s work. The fact that the teacher-researcher contextualized this mode of inquiry by sharing a book about her work and talking about her research perhaps provided a more palpable means of understanding.

*Note: Excerpts 2 & 3 contextualize the second mode of inquiry (investigations)*

**Excerpt 2:**

**Me:** So the second one is investigation. How many of you have read, you guys know what this means, right? (*writing the word investigation on the board*)

**Cecelia:** Investigation

**Me:** Yeah, so that’s a type of science inquiry. Who can tell me, who can give me an example of an investigation?

**Cecelia:** Ah when they, in movies when they investigate who killed the person?

**Me:** Okay, so with murders, when you have detectives and they’re investigating what happened?

**Students:** Yeah

**Me:** Usually investigations involve trying to figure out what happened, right? Or, trying to figure out, why something happened, right? So let's write this down.

This excerpt demonstrates how the teacher-researcher provides an opportunity for students to contextualize the next mode of inquiry (investigations). Cecelia is correct with her reference to movies and how investigations are carried out to find out who killed a person. Interestingly, throughout the study the students, particularly Cecelia, made reference to movies when constructing knowledge. This is one example here.

The teacher-researcher follows up and adds (extends) to what Cecelia has said, "Okay, so with murders, when you have detectives and they're investigating what happened?" She even uses the word (investigating), hoping to solidify this example as a point of reference for students to refer to when they determine their own type of inquiry for their research projects.

**Excerpt 3:**

**Me:** Another example of an investigation would be ummm, do you remember how we found that dead cormorant, that day, Charlena, remember?

**Cecelia:** Yeah

**Me:** And you guys kept saying to me, "I wonder what happened?" That would be an investigation, if we took that dead cormorant and took it to the lab and took tissue samples to see if it ate something toxic, if we opened up it's stomach to see if it ate a

piece of plastic, if we ran tests on it, if we ran an x-ray on it to see if there's any broken bones, that would be an investigation, okay? So is that clear?

**Students:** Yeah

This excerpt demonstrates how the teacher-researcher is providing another example of investigations by using a shared experience. For instance, she asks the students if they remember finding a dead cormorant. Cecelia says, "Yeah," while the other students nod yes. The teacher-researcher proceeds by stating what the students had asked her on the day the cormorant was discovered, "I wonder what happened?" The teacher-researcher, having tapped into their memory, provides numerous scenarios of how one would investigate what happened in the following statement, "If we took that dead cormorant and took it to the lab and took tissue samples to see if it ate something toxic, if we opened up it's stomach to see if it ate a piece of plastic, if we ran tests on it, if we ran an x-ray on it to see if there's any broken bones, that would be an investigation, okay?" These specific, concrete scenarios not only contextualize how one would investigate the death of a cormorant, but they also provide a mental picture of what a scientist or lab technician would actually do. Contextualizing content through the use of imagry is an effective strategy in teaching and learning with ELL.

**Excerpt 4 :**

**Me:** Now you guys think about your own projects. Look at the last question down below. What kind of inquiry are you doing? Now think about it, are you looking at

natural behavior, Jacquelina, I think we're going to take a break after this because I see you guys are tired, are we looking at natural behavior, like Jane Goodall looking at chimpanzees?

**Cecelia:** Yes

**Me:** Are you doing an investigation? Are you trying to figure out what is going on or why something is?

**Student:** Yes

**Me:** Or are you doing an experiment? Experiment means you're manipulating your environment, okay.

**Margarita:** We're making the species of why.

**Me:** An experiment means, that, here's another example of an experiment, there are these kids, that were interested in trying to figure out if ants preferred dark or light environments, so they got two tubes and they covered one tube with foil and the other tube they just left without foil, and they gave it water and water (*meaning both sides of the experiment both got water*), and then they watched the ants to see if they went into the tube that had the foil that looked like dark inside the tube, or the one that didn't have the foil. So you see how they created an exp

**Cecelia:** Experiment

**Me:** Right?

**Margarita:** But we're not really doing an experiment.

**Me:** No one is doing an experiment. So, Margarita caught on that. Think about which one you're

**Cecelia:** Observation

**Margarita:** We're doing like observation and (*inaudible*)

**Me:** You're kind of doing a little bit of both of these (*pointing to the board with observation and investigation written down*)

**Students:** Uh huh (*agreeing with me*)

**Me:** Especially you guys (*referring to Charlena and Margarita*) cuz you're trying to figure out what kind of polychaetes are at the Watsonville slough and if they have teeth. So you're doing, you're doing both.

**Student:** Both

**Me:** Um Cecelia, you're kind of doing both too, huh? You're trying to figure out

**Cecelia:** Why are they different colors? (r*eferring to the California poppies*)

**Me:** Yeah, so that's an investigation, and then you're looking at percentage cover of mosquito fern and what else? And then how many blue-eyed grass are there, so you're kind of doing both too. Jacquelina is doing, what do you think Jacquelina?

**Jacquelina:** What?

**Me:** You're doing which one?

**Jacquelina:** How they, how they are attracted to each other.

**Me:** Yeah, but is it observation

**Jacquelina:** Oh!

**Me:** Investigation, or experiment?

**Jacquelina:** Observation.

**Me:** Very good! Because you're just observing natural behavior, huh? Okay, so write that down. I am doing an observation.

Having contextualized all three modes of inquiry, the teacher-researcher asks the students what kind of inquiry they are doing for their research projects. The teacher-researcher realizes she needs to provide another example of the third mode of inquiry (experiments). She uses an example from a study conducted by Warren et al., 2002, where students designed an experiment in order to find out if ants prefer dark or light environments. The teacher-researcher contextualizes the example by using words which evoke visual imagry. For instance, "They were interested in trying to figure out if ants preferred dark or light environments, so they got two tubes and they covered one tube with foil and the other tube they just left without foil, and they gave it water and water (meaning both the treatment and control received water), and then they watched the ants to see if they went into the tube that had the foil that looked like dark inside the tube, or the one that didn't have the foil."

After the teacher-researcher provided this contextualization, Margarita raises her hand and says, "But we're not really doing an experiment." This statement indicates that Margarita understands her inquiry project and her peers' inquiry project do not meet the 'experiment' category. The teacher-researcher acknowledges Margarita's insight and says, "No one is doing an experiment. So, Margarita caught

on that. Think about which one you're." Just as the teacher-researcher was about to say 'doing', Cecelia states the type of inquiry she is doing, "Observation." Margarita joins in and says, "We're doing like observation and (inaudible)." The teacher-researcher follows her statement with, "You're kind of doing a little bit of both of these (pointing to the board with observation and investigation written down)." The students respond with, "Uh huh," as if they are agreeing with what the teacher-researcher has suggested. Cecelia also comes to the realization that she too is doing both inquiries (observations and investigations) as well.

When the teacher-researcher asks Jacquelina what type of inquiry she thinks she is using to answer her research question, she says, "What," as if she's not paying attention. It is important to note that throughout this instructional conversation, Jacquelina was 'out of it'. She appeared to be very tired, yawning a lot and saying how tired she felt. Even after eating breakfast (the teacher-researcher brought bagels, cheese, fruit, and juice), she was still hungry and asked mid-way through the teaching/learning session if she could get more food. The teacher-researcher of course said yes as she could tell Jacqulina was still hungry.

When Jacquelina returned and appeared ready to engage, the teacher-researcher asked Jacquelina again, "What type of inquiry do you think you're doing for your research project, observations, investigations, or experiments?" Jacquelina said, "Observations." The teacher-researcher responded with praise, "Very good! Because you're just observing natural behavior, huh? Okay, so write that down. I am

doing an observation." The teacher-researcher was sensitive not to push Jacquelina too much, as she sensed she was having an 'off' day.

**Excerpt 5:**

**Me:** Now, the tools that Andrea needed, she says, "I realize that the tools I will need to make my observations are binoculars, right, or a telescope, and a datasheet to record my data. Now you think of the tools that you need (*emphasis on need*) for your observations or investigation, what do you need?

***Note:*** *The teacher-researcher is showing the students a model of what a complete book looks like. She uses the name Andrea as a mock name for a student and her inquiry is focused on two research questions: (1) What do mallard ducks use to make their nest, and (2) How many ducklings are born for each pair of parents?*

**Margarita:** We need a microscope.

**Me:** Okay, so Charlena and Margarita are going to write microscope.

**Me:** You need a lot of tools, huh? (*speaking to Cecelia*). You need a ruler for the square feet, write down ruler. Think of all of the tools that you need to make your measurements. Jacquelina needs (*pause*)…

**Jacquelina:** Binoculars and a datasheet

**Me:** Okay, you're right on. Jacquelina, she knows what's going on. (*I think I said this to get students up and going! Wake up! Plus, I wanted to acknowledge and affirm her correct response*).

**Cecelia:** Ruler (coughs)

**Me:** You need a ruler for the um, blue-eyes grass. What do you need for this? (*pointing to poppies*), ruler

**Cecelia:** A ruler

**Me:** Do you need anything for that? (*pointing to mosquito fern question*), no, you're just looking with your eyes, right?

**Cecelia:** So I just need a ruler and

**Me:** You need a ruler, a datasheet to write, and don't you need something else, Cecelia? (*Pause*) I guess that's it.

**Margarita:** Poppy and the flowers.

**Me:** She's just using her eyes to make observations. You might need binoculars for this (*pointing to mosquito fern*), no, cuz, we can see it without binoculars, huh? Cecelia, do we need binocular for that?

**Cecelia:** No

**Me:** No, okay, so Cecelia's done. You guys need what? Margarita and Charlena?

**Margarita:** I realize that the tools I wanted to use are a microscope, I realize that the tools I wanted to use are

**Me:** that you need to use

**Margarita:** that I need to use a microscope also a polychaete worm?

**Me:** Well that's not a tool. A tool is like something that you use to measure or, you know, collect data

**Margarita:** Oh

**Me:** So a tool is like an instrument.

**Charlena:** I need an identification key.

**Me:** You need a microscope, Charlena said it. An identification key, which helps you figure out what kind a, what kind a what?

**Charlena:** Polychaete we have.

This excerpt demonstrates many things: (1) the use of a model inquiry book to scaffold students' understanding of an inquiry step (tool use), (2) students' imitation of the tools needed for their inquiry, i.e., with some students needing more scaffolding (Cecelia) than others, (3) Margarita realizing that a polychaete is not a tool, and (4) Charlena including an identification key as a tool to answer one of her research questions, "What kind of polychaete worms live here in the Watsonville slough?"

First, the teacher-researcher uses a model inquiry book to scaffold students' learning of the inquiry steps. In this particular instance, she is showing the page where Andrea (a mock student) is determining the tools she will need to conduct her inquiry. The teacher-researcher reads aloud what Andrea is thinking, "I realize I will need binoculars to make observations of the kind of materials the mallards use to build their nests." The students listened intently. This modeling of an inquiry book provides students with an opportunity to imitate (Vygotsky, 1987, p. 209-210).

Second, when the teacher-researcher asks the students what kind of tools they will need for their inquiry projects, one by one they begin to answer. For example, Margarita says, "We need a microscope." This is correct, but she also needs an

identification key to determine what kind of polychaete they found at the Watsonville slough, and also a notebook to record her data.

The teacher-researcher senses that Cecelia is slightly stuck, as she has three research questions to think about. She says to Cecelia, "You need a lot of tools, huh? You need a ruler for the square feet, write down ruler. Think of all of the tools that you need to make your measurements. Jacquelina needs (pause)?" While Cecelia is thinking, Jacquelina says, "Binoculars and a datasheet." This was impressive as prior to this, she appeared quite tired, hungry, and 'out of it'. Perhaps eating more food and resting provided enough time for Jacquelina's energy to rebound. The teacher-researcher follows Jacquelina's correct response with, "Okay, you're right on. Jacquelina, she knows what's going on." The teacher-researcher says this because she wants to acknowledge that Jacquelina is back on track.

Third, as the students continue naming the tools they need for their inquiries, Margarita includes a polychaete worm. The teacher-researcher follows with, "Well that's not a tool. A tool is like something that you use to measure or, you know, collect data." Margarita says, "Oh," realizing that a polychaete is not a tool. Charlena adds, "I need an identification key." This response from Charlena demonstrates that she is referring to her research question, "What type of polychaetes live here in the Watsonville slough." In the end, Charlena and Margarita realize they will need a microscope, an identification key, and a notebook to record their data. Jacquelina realizes she will need binoculars and a notebook, and finally, Cecelia

realizes she will need a ruler to measure the square footage of the blue-eyed grass and the height of the California poppies. She also needs a notebook to record her data. Note: The teacher-researcher initially thought Cecelia might need binoculars to assess the percentage cover of mosquito fern on the water's surface, but after consulting with Cecelia, she states she can determine this without binoculars.

## Chapter 7: Research Question 3: Funds of Knowledge

### Research Methods

**Data sources.** Data sources for determining whether parents' funds of knowledge informed students' experiences in the science project included: pre/post interviews, parent letters (written by students), and a parent homework assignment.

**Data collection.** Parent interviews were conducted both before and after the study by the teacher-researcher and research assistant (Lupe). A written copy of the questions (in both English and Spanish) was offered to the parents (see Appendix A). Interviews were face-to-face, semi-structured, and translated into Spanish. Parents' responses were translated into English for the teacher-researcher. The teacher-researcher and research assistant took notes. They were transcribed for analysis.

The purpose of the parent interviews was to access parents' funds of knowledge about the local ecology and to have this knowledge inform the learning and teaching practices throughout the study. The hope was that by tapping into parents' funds of knowledge, parents would feel more welcomed to participate as active members and/or cognitive resources in an area of expertise. It is important to note that these parental interviews also shed light on the following: (1) family background, (2) parents' attitudes and beliefs, (3) personality and behavior traits of their child, (4) financial hardships, and (5) circumstances which can affect a student's

performance, i.e., chronic illness, parents not proficient in English, parents absence from the home due to long working hours, etc.

Parent letters (written by students) were written for the following purposes: (1) for students to express their experiences, knowledge, and questions, (2) to create a medium for exchanging both knowledge and personal information, thus fostering congruency between home and the Science club, and (3) to assess how students used language based on the context in which the letters were written. For example, when students wrote letters to their parents, which language did they use: everyday or scientific? The expectation was that students would use everyday language when constructing letters to their parents, and scientific language when writing letters to scientists. Students referred to their semiotic tables (see Appendix B) when formulating all letters (whether to parents or science educators/scientists).

Parent homework assignment was used to extend a particular interest, area of knowledge, attitude, belief, or expertise which was discussed during the pre study interview (see Appendix A). The purpose of this homework assignment was: (1) to access a particular fund of knowledge at a deeper level, (2) to observe a different mode of communication (written text and illustration), (3) to integrate parents' funds of knowledge into the learning/teaching activities and discussions, and (4) to provide an entry point for parent participation by welcoming and valuing their contributions to the Science club.

**Data Analysis**

Parent interviews were member checked in order to ensure accurate statements and information for the pre/post interviews. Correlations between parents' responses and their child's inquiry projects were coded. For example, Cecelia's parents work at an organic farm, i.e., cultivating, harvesting, and packaging produce. Cecelia's scientific inquiry project focused on plants.

Parent letters (written by students) were assessed for students' language pre and post study using the 5 point-scale rubric (see Appendix B). If students used scientific concepts, reference to grammatical constructions was used to determine accurate usage of scientific concepts.

Parent homework assignment was assessed for: (1) a deeper and/or more detailed elaboration of an interest, concern, or fund of knowledge discussed during the pre interview, (2) whether this information correlated to their child's scienific inquiry project, and (3) how parents used a different mode of communication (written text and illustrations).

Single case analytic induction (Patton, 1990) was used to analyze these data sources for emerging themes, similar patterns, and trends (p. 44). Triangulation was sought through the use of multiple data sources and through the use of multiple methods of data collection (Denzin, 1978).

*Note: Parent letters (written by students) will be assessed using the same rubric used for students' science letters*

## Analysis of Parents' Funds of Knowledge

**Cecelia's Parents (Case study 1).** The following section contains an analysis of pre/post parental interviews, parent letters (written by students), and parent homework. Overall, all parents influenced students' experiences in the inquiry science project.

***Pre-assessment interview.*** The pre-assessment questions were trying to access three things: (1) parents' experiences of the wetlands with their family, particularly the student in the study, (2) their knowledge of agriculture fields next to the sloughs and the potential consequences of this, and (3) their views about experiencing nature.

During the interview, the mother held the questions (translated in Spanish), while the father showed up late (mid-way through the interview). When he arrived, he stood behind his wife. Cecelia stood with her parents to help translate. The teacher-researcher, research assistant (Lupe), and Cecelia's mother all sat at a table. The parents had company over (in the livingroom), so there was a lot of talking in the house.

First, when asked about their experiences at the wetlands, Cecelia's mother said she had never been to the wetlands before. When asked if she would like to go, she said yes, but there was no time because she works too late. When asked if she and her husband would like to join the Science club on a nature walk, she said she

would like to join us, but she works. She then added that she works at an organic farm and there is a reservoir nearby where she once saw the duck with a blue beak, but it was a while ago. The teacher-researcher said that was a ruddy duck and described how one of the students in the Science club has chosen the ruddy duck for her inquiry project (Jacquelina).

Second, when asked if she sees agriculture fields surrounding the wetlands, she says, "Yes, I see them." When asked about her thoughts, Cecelia's father arrives during this question and answers. He talks about how chemicals are dangerous because they kill plants, insects, and animals. When asked if they felt it was important to learn about the wetlands, the father responded again, "It's important to know what's going into the water. Plants and stuff are interesting."

The teacher-researcher turned to Cecelia and asked her if she had shared the water quality activity with her parents. Cecelia said, "Oh, no, not yet." Then, Cecelia shared how the mentors from Pajaro Valley High School showed the students how to identify aquatic invertebrates and based on the type of aquatic invertebrates identified, they could determine the water quality. For example, finding a leech would indicate that the water is polluted since it has a high tolerance for dirty, turbid, polluted water. The parents listened and appeared interested with what Cecelia had shared. The teacher-researcher was surprised that Cecelia had not shared this with her parents after the event which took place a couple of weeks prior to the parent interview.

Third, when asked about their thoughts with regard to nature, the father mentioned the importance of recycling. When asked if they felt connected with nature, the father responded first, "Yes, the plants, flowers, and gardening," and the mother added, "I like flowers." This is very interesting as Cecelia's inquiry project focused on plants, two of which were flowers: the California poppy and blue-eyed grass.

When asked about their thoughts experiencing nature with their children and how Cecelia was going to give a presenation on her plants of interest toward the end of the study, the father answered in a surprising way, "It's going to be very emotional. We don't get to see our kids very much, only in the evening for a short time." The teacher-researcher smiled and looked at Cecelia. Cecelia said, "My parents don't get to see us so much because they are always at work."

The teacher-researcher asked if the parents made an effort to experience nature with their children and the parents said yes. When asked how, the mother said not the beach because she's afraid of the water. Cecelia said, "The mall, my mom likes the mall." Cecelia's father added, "We walk in the park sometimes, go to Pinto Lake and feed the birds."

Lastly, when asked if the parents had any questions for us, the father asked if a body of water near Cecelia's middle school was a wetland because he sees ducks and other birds there. The teacher-researcher, knowing the location, said it was a temporary wetland because the water is only present during the winter and spring, but

then dries up in the summer and fall. This demonstrates that even though the parents are very busy with work, they still notice their environment and make connections with what Cecelia is experiencing in the Science club.

***Parent letters.*** Cecelia wrote two letters to her parents. The first letter describes her experiences at the Watsonville slough. She states seeing animals she has never seen before, such as the **ruddy duck**. She also states that she is studying plants and some of her favorite ones are: **California poppy**, **blue-eyed grass**, **pennywort**, and **mosquito fern**. It is important to note that this parent letter, compared to Cecelia's letters to science educators and scientists, is different because she uses her native language. It is also similar to her first two science letters because she uses everyday language and specific terms to write about her experiences and share her interests.

Writing her letter in Spanish is appropriate as Cecelia's parents speak Spanish to their children. Since Cecelia's audience is her parents, it makes sense that she would use her native language to construct her letter. Cecelia also uses everyday language rather than scientific language when writing about her experiences at the wetlands. This is also appropriate as everyday concepts tend to be saturated with concrete experiences (Vygotsky, 1987, p. 178). Finally, Cecelia shares her interests with her parents, i.e., naming her favorite plants, three of which became part of her inquiry project (California poppy, blue-eyed grass, and mosquito fern). She also illustrated a beautiful pink, yellow, and green flower on the cover of her letter.

Cecelia's first letter meets a rubric score of 2 (everyday concepts and specific terms), using her native language, Spanish). Cecelia's second letter was written about her experiences at the Elkhorn slough. Interestingly, this letter was written in English instead of Spanish. Cecelia shares what she saw at the Elkhorn slough. She states that first she saw a crab from Europe called the **European green crab**. She also states that she saw a **skeleton shrimp** and a **brittle starfish**. She states that of all the **aquatic invertebrates** she saw, the **polychaete larvae** fascinated her the most. She says that it looked like it had mascara on. Cecelia ends her letter with the saddest moment of her life, i.e., seeing a hurt **pelican**. She adds one final note about a trail where trains pass by. She also illustrated a beautiful picture with birds (ducks) in the water, a green crab, and a pelican sitting in pickleweed.

This letter demonstrates three things: (1) she uses English instead of Spanish, (2) she uses everyday concepts and specific terms, and (3) her fascination with animals, particularly the polychaete larvae, and a deep concern for the pelican. Cecelia's second letter meets a rubric score of 2 (everyday concepts and specific terms), using English.

First, it is interesting how Cecelia uses English instead of Spanish in her second letter to her parents. She knows her parents have limited proficiency in English, yet she writes her letter in English. Perhaps one reason in doing so was that the teacher-researcher held onto all letters in order to photocopy them for analysis. Cecelia may have thought that since her first letter did not go to her parents, her

second letter wouldn't either, so it didn't matter which language she used to construct her second letter. Note: The parents received the letters toward the end of the study.

Second, Cecelia uses six specific terms: aquatic invertebrates, European green crab, skeleton shrimp, brittle starfish, polychaete larvae, and pelican). She uses these specific terms accurately, providing specific, vivid examples based on her observations at the Elkhorn slough.

Third, perhaps most interesting was Cecelia's fascination with the aquatic invertebrates, particularly the polychaete larvae since it looked like it was wearing make up. Cecelia may have shared this experience with her mother, as during the post-assessment interview, Cecelia's mother said she learned about aquatic invertebrates with Cecelia.

Finally, Cecelia talks about how grief stricken she was to see a hurt pelican. During the Elkhorn slough field-trip, the Science club came across a pelican sitting in pickleweed as we were walking to meet Kenton at ***Whistle Lagoon***. We didn't think it was injured until later on in the day when we saw the pelican in the visitor center waiting to be picked up by an animal rescue foundation. The pelican was quietly sitting in a sink. Although the teacher-researcher did not see this, the students did and were very concerned about the welfare of the pelican. The teacher-researcher said she would call next week to find out about the status of the pelican. She did and found out that an International bird rescue group retrieved the pelican from the Elkhorn slough visitor center and were currently rehabilitating it. The pelican was

malnourished due to lack of food. When the teacher-researcher updated the students on the pelican's condition, they were relieved that it was being taken care of.

***Parent homework.*** Parent homework was generated from the pre-assessment interviews. For instance, the teacher-researcher used something the parents had mentioned in the interview and asked them to provide more elaboration. For example, Cecelia's father had the following homework question, "You mentioned during the parent interview that you enjoy gardening. What kind of plants, flowers, vegetables or fruits do you plant? You can also draw a picture. Please give to Cecelia and she'll give it back to me. Thank you." This was translated into Spanish for parents who only understand Spanish (see Appendix A).

Cecelia's father's response (in Spanish) was, "We plant lots of plants and vegetables like red potatoes, lettuce, carrots, kale, onions, cilantro, tomatoes, chillies, zuchinni, lemons, cabbage, plums, cheeries, strawberries, pears, apples, nectarines, radishes and herbs." He also drew a picture of an apple tree, a flower, and a vegetable garden plot. This homework demonstrates that Cecelia's father and mother are immersed with plants, particularly vegetables and fruits, at work. Thus, it comes as no surprise that Cecelia would also be interested in plants, as this was her focus on her scientific inquiry project. Perhaps the parents' funds of knowledge influenced Cecelia's interest in plants.

***Post-assessment interview.*** The post-assessment interview took place in the home. The parents were 20-30 minutes late, returning home from work. They

appeared tired. The teacher-researcher asked what their thoughts/feelings were about participating in the Science club. Both parents said, "Bueno (good)". When asked how they felt/thought the experience was for Cecelia, they said, "Muy bueno," and added (in Spanish), "She learned a lot about plants, is more interested in plants than ever before. She also learned about ecosystems, picking up trash, and is more aware." The teacher-researcher asked if Cecelia shared her experiences in the Science club with them. The parents said in Spanish, "Yes, that she liked it a lot, especially flowers." Cecelia's mother also shared that she learned with Cecelia about aquatic invertebrates and from the students' presentations.

When asked about the day of the presentations, the parents said they were nervous because they had never seen Cecelia present. It was a new experience for them and a big deal. The father said that the poster needed to be more bilingual. Specifically, he said in Spanish, "Just having the headings translated into Spanish wasn't enough, everything should have been in Spanish." Note: This was a goal the teacher-researcher had, but most of the students, except Margarita, were unable to translate their posters into Spanish.

Finally, when asked if they would be interested in allowing Cecelia to participate with the Science club but exploring another ecosysytem, both parents said yes, but that she would be starting catechism soon on Saturdays. Both the teacher-researcher and research assistant ended the interview with a member check of what the parents plant (garden) at the organic farm where they both work. The father said,

"We plant apples, strawberries, blueberries, kiwi, broccoli, carrots, cauliflower, lettuce, chard, kale, mustard greens, tomatoes, chillies, we have a web-site, we grow these at work." Sensing that the parents were tired, we thanked them and ended the interview.

**Results (case study 1).**

***Triangulation of data sources.*** This triangulation will only discuss aspects of parents' funds of knowledge which informed Cecelia's experiences in the Science club project, particularly her scientific inquiry project on plants. With regard to the pre and post-assessment interviews, although the parents have not been to the wetlands, Cecelia's mom shared during the pre-assessment interview that there is a reservoir near her work and she observed a ruddy duck a while ago. This observation ties nicely with Cecelia's first letter to her parents, describing all of new animals she saw and specifically mentioning the ruddy duck.

When asked about the agriculture fields near the wetlands, both parents were aware of this fact, but only the father addressed a concern about "how chemicals are dangerous because they kill plants, insects, and animals," and also, "it's important to know what's going into the water." When the teacher-researcher asked if they felt connected to nature, the father expressed his interest in plants, flowers, and gardening, likewise, the mother said she likes flowers. This is interesting as Cecelia's inquiry project focused on plants, two of which were flowers: the California poppy and blue-eyed grass.

Lastly, during the pre-assessment interview, the teacher-researcher asked if the parents had any questions. The father had one. He asked if a body of water near Cecelia's middle school was a wetland because he sees ducks and other birds there. The teacher-researcher, knowing the location, said it was a temporary wetland because the water is only present during certain seasons (winter and spring), but then absent during others when the water dries up (summer and fall). This demonstrates that even though the parents are very busy with work, they still notice their environment and make connections with what Cecelia is experiencing in the Science club.

The post-assessment interview revealed how they felt about participating in the Science club experience. Both parents said it was a good experience, particularly for Cecelia because "she learned a lot about plants and is now more interested in plants than ever before. She also learned about ecosystems, picking up trash, and is more aware." When asked if Cecelia would share what she was learning, both parents said, "Yes, that she liked it a lot, especially the flowers."

Cecelia's mother also shared that she learned with Cecelia about aquatic invertebrates and from the students' presentations. The teacher-researcher asked how they felt about the day of the presentations. Both parents expressed how they felt nervous because they had never seen Cecelia present before. To them, it was a 'big deal'. Both parents enjoyed the presentations and were proud of their daughter,

however, the father was dissatisfied with the lack of Spanish translation on the poster board. He said, "more than just the titles should have been translated into Spanish."

Lastly, during a member check question, the teacher-researcher asked the parents what they garden. The father answered with a variety of vegetables, fruits, and herbs. Since both parents work at an organic farm, like flowers, and enjoy gardening, it comes to no surprise why Cecelia would also show an interest (on the very first day of the Science club project) for plants. Perhaps her parents' funds of knowledge influenced her interests, thus the reason why Cecelia's inquiry project focused on: the California poppy, blue-eyed grass, and mosquito fern.

With regard to Cecelia's letters to her parents, her first letter was in Spanish. She shared her experience of seeing new animals, particularly the ruddy duck (which the mother mentioned seeing a while ago in a reservoir near her work-site). Cecelia also shared her favorite plants: the California poppy, blue-eyed grass, pennywort, and mosquito fern.

Cecelia's second letter was written in English and discussed her observations on the Elkhorn slough field trip. She talked about seeing the European green crab and many different kinds of aquatic invertebrates, such as the skeleton shrimp and brittle starfish. She expressed her fascination with the polychaete larvae because it looked like it was wearing makeup (mascara). This sharing about aquatic invertebrates ties nicely with the post-assessment parent interview when the mother said she learned

about aquatic invertebrates from Cecelia. Finally, Cecelia ends her letter with her concern about the 'hurt' pelican and how this was the 'saddest moment of her life'.

Cecelia's letters demonstrate that what she wrote was read by her parents, shared and discussed, and in fact, the parents, particularly the mother, learned from Cecelia's experiences. Likewise, Cecelia shared the ruddy duck experience because she was present during the pre-assessment parent interview when her mother shared her experience of seeing a ruddy duck in the reservoir near her work. Thus, both Cecelia and her parents are sharing their experiences and information with each other via verbal conversation and written text (letters). Since the parents' time is so limited due to long working hours, perhaps the letters provided a means of sharing that may have been missed otherwise.

The parent homework solidifies that both parents are immersed with plants: vegetables, fruits, and herbs. They both work at an organic farm where the mother inspects and packs produce and the father drives the tractor and assists with harvesting the food. Cecelia shared early in the study that sometimes she helps her mom pack produce. It is likely that with both parents working with plants and also having an interest in flowers and gardening, that Cecelia would have more experiences and access to information in this area of knowledge (funds of knowledge). In addition to this, the father mentioned how dangerous chemicals are to plants, animals, and also the water source. Working at an organic farm, both he and

his wife did not have to worry about chemical use, but nevertheless, they were both aware of its harmful environmental effects.

Lastly, with regard to rating writing parent letters, Cecelia rated this activity 5 (Wow) for helping her learn and 5 (Wow) for level of enjoyement. She also stated in her post-assessment interview that of all the Science club activities, having her parents see her present was her favorite activity. The parents also shared the same sentiment in that they both stated how they were nervous on the day of the presentations because they had never seen Cecelia give a presentation. They expressed how it was a 'big deal' for them and how proud they were of Cecelia. Perhaps since Cecelia rarely sees her parents, only for a short time in the evening when they return home from work, that the Science club activities may have provided an entry point for sharing experiences and information, learning from each other, and celebrating key moments, such as the day of the student presentations.

**Discussion (case study 1).** The results support how Cecelia's parents' funds of knowledge informed Cecelia's scientific inquiry project. Since both parents work at an organic farm and Cecelia often assists her mother pack produce, Cecelia has first hand experience with plants. In addition to this, both parents expressed an interest in gardening and flowers.

Cecelia's first letter demonstrated that she used her native language and that she shared her experiences in the science project. She drew a picture of a ruddy duck.

This linked to the pre parent interview when the mother said she saw a ruddy duck at the reservoir. This demonstrates making a connection with a common experience.

Just as Cecelia's parents influenced Cecelia, it is important to note that Cecelia's experiences in the science project also informed her parents. For example, Cecelia's mother said that she learned about aquatic invertebrates from Cecelia. This mutual reciprocation of teaching and learning is how knowledge is constructed. Both sharing, informing, and influencing each other's experience.

Overall, it is apparent that Cecelia's parents' funds of knowledge informed Cecelia's choice of what she wanted to inquire about. Having met Cecelia's parents, the teaching-researcher could make connections and understand Cecelia as a 'whole person'.

**Jacquelina's Parents (Case study 2)**. The pre-assessment questions were trying to access three things: (a) parents' experiences of the wetlands with their family, particularly the student in the study; (b) their knowledge of agriculture fields next to the sloughs and the potential consequences of this; and (c) their views about experiencing nature.

***Pre-assessment interview.*** First, Jacquelina's mother participated as a chaperone on a fourth grade field trip with her daughter's class. When asked about her experience and what she observed, she said, "I saw black birds and black and orange worms." The teacher-researcher asked if they were caterpillars. Jacquelina

translated for the teacher-researcher and the mother answered, “Yes.” The mother also said the wetlands were pretty and that she enjoyed the tour because the guide spoke in both English and Spanish. When asked if she had any interests concerning the wetlands, the mother said that she wanted to learn more about them. Finally, when asked if she would be interested in joining us on a field outing, she said, “Yes.”

Second, when asked if she was aware of the agriculture fields surrounding the wetlands, she said, “No.” When asked about her thoughts of insecticides and pesticides, she quickly responded and said it was bad for the animals and how they could die. She also mentioned how people can get sick. She described how her son gets ill from mosquitoes by stating a cause-effect relationship. For instance, insecticides infect the mosquitoes which bite (cause) my son and make him sick (effect). The teacher-researcher, trying to verify her causal statement asked, “Oh yes, like a vector?” When the research assistant translated the question to the mother, she said, “Si (yes)”.

Third, when asked about her thoughts with regard to nature, she expressed how she thinks the environment should be more natural. She also stated, “If we all got together, if we ourselves did more.” The teacher-researcher then asked if she felt connected to nature. Her initial response was, “Very little. I don’t go to the beach or go camping, but I do walk the levee and I am interested in nature, especially flowers and hummingbirds.” The teacher-researcher wanted to be sure that she understood the question, so she added, “When you look at a tree, do you see the beauty in it?

That to me is feeling connected with nature." She responded, "Oh yes. The trees across the street get filled with flowers in the spring and I enjoy seeing the hummingbirds." The mother became very animated with her description, pointing out the window and describing how the hummingbirds hover over a tree across the street when the flowers bloom during the spring.

When asked about her thoughts experiencing nature with her children, particularly Jacquelina, she said she thought the Science club was a good experience for Jacquelina. She also said that she enjoys walking with Jacquelina and her younger daughter to the levee where they see animals. When asked if she made an effort to experience nature with her children, she said that she gardens and loves flowers. She also talked about the hummingbirds again and how raccoons come to the house at night.

Finally, the teacher-researcher asked if she had any questions for her. She said yes and said Jacquelina had told her about how the teacher-researcher was upset with the students' behavior one Saturday morning. The teacher-researcher said, "Yes, the students were not listening and being disrespectful." The mother said, "I talked to Jacquelina about being respectful and to listen." The teacher-researcher appreciated the mother's follow through with Jacquelina's behavior. The mother added, "Each child has their own personality." The teacher-researcher said, "Yes, that's true." Although the teacher-researcher wanted to say more such as, "But being disrespectful is not a personality trait," she decided to keep this thought to herself. At the end of

the interview, the teacher-researcher consulted with the research assistant about her thoughts on the mother's comment. The research assistant said that the mother was upset with Jacquelina's behavior on that day, not with the teacher-researcher's response to her daughter's behavior.

***Parent letters.*** Both of Jacquelina's letters to her parents were written in Spanish in addition to using everyday language. Her first letter describes her experiences. She focuses on what she had learned about the ruddy duck (so far). For example, Jacquelina states that she has not seen the male and female **ruddy duck** interact with each other. What she has seen is the male ruddy duck diving to look for food. Since Jacquelina uses mostly everyday language, in addition to one specific term, ruddy duck, her first letter meets a rubric score of 2 (everyday concepts and specific terms), using Spanish.

Although this is a short letter, it is very specific and precise with what Jacquelina has observed in the field thus far. The predominant behavior observed with the male and female ruddy ducks was bathing, preening, and foraging. Unfortunately courtship behavior, which tied to Jacquelina's research question, "How do the male and female ruddy ducks interact with each other," was never observed during our time in the field. Jacquelina also drew a picture of a ruddy duck in the water with two clouds and a sun in the sky.

Jacquelina's second letter focuses on her experiences at the Elkhorn slough. She describes her observations using everyday language, "Like how it has a lot of

animals, like small animals and big animals." She also states, "There's like a lot, like different types of animals, some of them swim and some of them eat, like the **polychaete** eats other polychaetes." These general descriptions and use of everyday language when writing to her parents are very different from Jacquelina's specific descriptions and use of scientific concepts when writing science letters to science educators and scientists. Since everyday language is satarated with concrete experiences and general descriptions tend to be used to convey experiences, it comes as no surprise that Jacquelina would use both in her parent letters (Vygosky, 1987, p. 178; Halliday, 1993, p. 99). Thus, her second letter also meets a rubric score of 2 (everyday concepts and specific terms), using Spanish).

Jacquelina ends her letter with a discussion about how the Elkhorn slough is a mixture of both fresh and salt water and how this slough has lots of animals. She also wishes that both of her parents could have shared the experience with her. She closes her letter with, "I love you," and a drawing of a heart and a happy face (winking). [Reminds me of Halliday's position of language...construed for shared experiences]

***Parent homework.*** The parent homework question for Jacquelina's mother was derived from the pre-assessment interview. She had mentioned an interest in watching the hummingbirds hover over a tree across the street from her home during the spring. Thus, her homework question was, "You mentioned during the parent interview that you enjoy seeing the hummingbirds in the tree across the street. Can you describe what you see and why you enjoy seeing it? You can also draw a

picture." In addition to the homework question, an Anna's hummingbird Earth Card was attached to the homework. Although the text was in English (on the back), Jacquelina's mother had a visual image of the animal she was describing during her interview.

Jacquelina's mother writes, "I Maria like to sit on my sofa and open the curtains because I like to see the variety of birds that land on the flowers. I like to see because they are different sizes and colors of birds on the tree. From my house I see lots of birds that go inside the tree and fly from branch to branch." She also illustrated a picture of a tree with flowers and a hummingbird drinking nectar from a flower.

This homework assignment demonstrates that Jacquelina's mother has an interest in birds and flowers and makes observations in her environment. It is interesting that Jacquelina chose a bird, although a ruddy duck, for her scientific inquiry project. Perhaps her mother's interest in birds may have influenced Jacquelina's interest in the ruddy duck. Also, Jacquelina's mother had mentioned during the pre-assessment interview that both she and Jacquelina sometimes walk to the levee to see animals. When the levee is full, ducks and other waterfowl inhabit the area. Perhaps this experience with her mother planted a seed of interest to learn more about ducks.

***Post-assessment interview.*** The post-assessement interview revealed five things: (1) the mother's thoughts and feelings about the Science club in addition to

Jacquelina's experience, (2) whether her funds of knowledge influenced Jacquelina's learning, (3) if Jacquelina shared what she was learning in the Science club with her family, (4) her thoughts and feelings about the day of the presentations, and (5) whether she would participate with the Science club again.

First, when asked about her thoughts and feelings about participating in the Science club, she said, "It was great." When asked about how she thought/felt the experience was for Jacquelina, she said, "Different things, different activities. I'm happy Jacquelina was experiencing the wetlands." When asked if she has noticed any changes in Jacquelina since the project started, she said, "She's telling me more about wetlands." Finally, when asked about her thoughts/feelings about the wetlands now, she expressed her concern about how the pesticides contaminate the water. She also mentioned how when her son comes home after visiting Pinto lake, his arms are covered with welts from mosquito bites.

Second, when asked if she thought/felt her knowledge influenced Jacquelina's learning experience, she said, "Yes, different animals, butterflies, hummingbirds." When asked about her thoughts and feelings about parental participation in Jacquelina' learning, she did not understand the question. The research assistant reworded the question several times, but the question remained unclear to her.

Third, when asked whether Jacquelina would share her experiences in the Science club with her family, the mother responded, "Yes, she would come home and talk about what she was learning about the ruddy duck. She would talk about her

research question and how she was investigating it to answer her research question." This response is impressive as it demonstrates that Jacquelina shared exactly what she was doing in the Science club and how the mother remembered and fully articulated what Jacquelina was doing. Finally, when asked if she asked Jacquelina about her learning experiences in the Science club, the mother said, "Yes, I would ask her questions. For example, when she would walk in, I would ask, "What did you do today?" This demonstrates a mutual reciprocation of sharing information and asking questions on a common theme, i.e., Jacquelina's learning experiences, particularly with regard to her scientific inquiry project on the ruddy duck.

Fourth, with regard to the day of the presentations, Jacquelina's parents could not attend because it was her younger daughter's birthday and they had family visiting. The mother was aware that Jacquelina was sad about her parents not being there on the day of the presentations. The teacher-researcher asked about her thoughts/feelings about Jacquelina's poster and ruddy duck sculpture. She said she was proud of Jacquelina and thought the poster was very nice. She was also happy with Jacquelina's sculpture, but mentioned how one of the wings came off. However, what she appeared most impressed with was Jacquelina's scientific inquiry book because she said she would often see Jacquelina reading it, sometimes studying her book.

Fifth, when asked if she would like to participate with the Science club again if we decided to explore another ecosystem, she said, "Yes, I would love to." The

teacher-researcher ended the interview with member checking. For example, she asked the mother about her level of education, but was sensitive to the fact that if she did not feel comfortable answering, she did not have to. The mother appeared relaxed and willing to answer the question. She said, "Fourth grade in Mexico. I regret dropping out, but I had to work to help my family. Also, in Mexico, you have to pay to go to school. My family did not have the money. We are very lucky here in the USA. School is paid for and so is lunch." The teacher-researcher shared a personal story about how her grandmother also had to drop out of school at a young age to work and help support the family.

Another question that needed further understanding was Jacquelina transferring schools. The teacher-researcher asked the mother to explain what happened. She said, "Jacquelina felt uncomfortable at the charter school. It was too difficult for sixth grade. Instead of doing sixth grade work, she was doing seventh-eighth grade level work. Now Jacquelina's at a public middle school and she's happier there. She goes to the after-school program to get help with her homework."

Lastly, the teacher-researcher expressed how Jacquelina was a very keen observer throughout the study. Of all the students, she was the most observant. The teacher-researcher also said that Jacquelina would do very well in life science courses, such as biology in middle school and high school because she has a talent with keen observational skills. The mother listened and smiled with pride.

Both the pre and post-assessment interviews reveal that although Jacquelina's mother did not have a deep conceptual understanding of the wetlands, she did have interests, such as flowers, gardening, and hummingbirds, and she was aware of the harmful effects of insecticides and pesticides on animals, people, and the environment (water contamination). She also made a cause-effect statement about how mosquitoes inject insecticides into her son when they bite him and how this makes him ill. Although this may not be accurate, her statement demonstrates a form of scientific thinking (causal relationships).

She also provided experiences in nature with her daughters by walking to the local levee to see animals. Lastly, she asked Jacquelina questions about what she did each time she met with the Science club. Jacquelina would, in turn, respond with what she was learning and the mother remembered what her daughter shared with her. This is apparent in the post-assessment interview. Based on this data source, it appears that both Jacquelina and her mother shared experiences and information which supported Jacquelina's learning in the Science club.

**Results (case study 2).**

***Triangulation of data sources*** . All data sources triangulated for parents' funds of knowledge informing Jacquelina's experienes in the inquiry project. The pre-assessment revealed how Jacquelina's mother attended field-trips with Jacquelina's class to the wetlands. This experience provided prior knowledge and experiences about the wetlands with regard to the study.

When asked about whether she felt connected to nature, Jacquelina's mother expressed an interest in watching the hummingbirds gather around a tree across the street. She also enjoys walking around the levee with her daughters to see the animals; some of which are ducks. These experiences with birds may have informed Jacquelina choosing the ruddy duck for her inquiry project.

The post-assessment interview revealed Jacquelina sharing her experiences with her mother. The interaction was reciprocate with her mother asking Jacquelina what she learned each time the Science club met. This mutual reciprocation was also apparent in Jacquelina's letter which were written in Spanish (two out of three).

The parent homework assignment demonstrated that Jacquelina's mother is keenly aware of her environment and makes observations on things that interest her such as hummingbirds and flowers. This ties with Jacquelina's keen observation skills and interest in birds (ruddy duck). Jacquelina rated writing letters to her family 5 (Wow) for helping her learn and for level of enjoyment.

**Discussion (case study 2).** This triangulation will discuss aspects of parents' funds of knowledge which informed Jacquelina's experiences in the Science club project. With regard to the pre and post-assessment interviews, Jacquelina's mother demonstrated a willingness to participate in her child's learning about the wetlands two years prior to the doctoral study on a fourth grade field trip. She said that she observed black and orange worms (caterpillars), enjoyed the tour because it was in both English and Spanish, and expressed an interest in learning more about the

wetlands. The fact that she attended Jacquelina's field trip demonstrates parental support. In addition, this experience provided both prior knowledge and experiences about wetlands with regard to the doctoral study.

In addition to having some prior knowledge and experiences about the wetlands, Jacquelina's mother expressed a concern about the effects of insecticides and pesticides on animals and people. For example, she stated a cause-effect relationship between how insecticides infect mosquitoes which then bite people (cause), specifically her son, and make them sick (effect). Although this may not be accurate, her statement demonstrates a form of scientific thinking (causal relationships), an important aspect of the scientific inquiry process. Interestingly, Jacquelina showed this skill throughout the study. Perhaps her mother may have 'informally' demonstrated this way of thinking with Jacquelina.

When asked about whether she felt connected to nature, Jacquelina's mother expressed an interest in watching the hummingbirds gather around a tree across the street. She also said that she enjoys walking around the levee with her daughters to see the animals. The levee, particulary when it is full (winter and spring) often has ducks and other waterfowl. Perhaps these experiences with birds (hummingbirds and ducks) influenced Jacquelina's interest in studying the ruddy duck for her inquiry project.

Lastly, the post-assessment interview reveals Jacquelina sharing her experiences with her mother. For instance, when asked whether Jacquelina shared

about her learning experiences in the Science club, the mother said, "Yes, she would come home and talk about what she was learning about the ruddy duck. She would talk about her research question and how she was investigating it to answer her research question." This response demonstrates that Jacquelina shared exactly what she was doing, but even more, it also demonstrates that Jacquelina's mother remembered and fully articulated what her daughter was doing. This shows that the mother took the time to listen and remember what her daughter had shared with her.

Finally, the interaction between Jacquelina and her mother was mutual in that the mother would often ask Jacquelina what she was learning each time the Science club met. For instance, when the teacher-researcher asked if the mother asked Jacquelina about her learning experiences, she said, "Yes, I would ask her questions. For example, when she would walk in, I would ask what did you do today?" This demonstrates a mutual reciprocation of sharing information and asking questions on a common theme, i.e., Jacquelina's learning experiences, particularly with regard to her scientific inquiry project on the ruddy duck.

With regard to Jacquelina's letters to her parents, these letters demonstrate that Jacquelina is sharing her experiences and using her native language (Spanish) and everyday language rather than English and scientific language to communicate with her parents. For example, in her first letter, she describes her observations of the ruddy duck thus far, i.e., how she has not yet seen the male and female ruddy ducks interact, and how she mostly sees the ducks diving down looking for food. This letter

is very different from her science letters to science educators and scientists where Jacquelina uses scientific language to describe her observations of the ruddy duck.

Her second letter focuses on her experiences at the Elkhorn slough. Again, she uses Spanish and everyday language to describe her observations. In this letter, her descriptions are broad and general. For example, "Like how it has a lot of animals, like small animals and big animals." She also states, "There's like a lot, like different types of animals, some of them swim and some of them eat, like the polychate eats other polychaetes."

This last sentence does contain a specific term, polychaete, but the majority of her words are everyday concepts. This is understandable as she is describing her experiences and everyday language is saturated with concrete experiences and general descriptions (Vygotsky, 1987, p. 178; Halliday, 1993, p. 99). In addition, her audience is her parents who may not understand scientific language. Thus, Jacquelina is considering her audience and using appropriate language when constructing her letters.

With regard to parent homework, the mother responds to a question derived from the pre-assessment interview. The mother described how she enjoyed watching the hummingbirds hover over a tree across the street. Thus, her homework question asked for further elaboration of this event. She wrote, "I Maria like to sit on my sofa and open the curtains because I like to see the variety of birds that land on the flowers. I like to see because they are different sizes and colors of birds on the tree.

From my house I see lots of birds that go inside the tree and fly from branch to branch."

This homework assignment demonstrates that Jacquelina's mother is keenly aware of her environment and makes observations on things that interest her such as hummingbirds and flowers. Like Jacquelina who exhibited very keen observational skills throughout the study, her mother also demonstrates this capability in her homework assignment, i.e., describing how she sees a variety of birds of different sizes and colors flying from branch to branch. Perphaps Jacquelina developed these skills through everyday interaction with her mother, thus informing her scientific inquiry skills.

Lastly, Jacquelina rates writing letters to her parents 5 (Wow) for helping her learn and also for level of enjoyment. With regard to helping her learn, she states, "Because it helped me communicate with them and tell them what's going on." This shows that writing about her experiences in the Science club helped her learn and also created a connection with her parents about what she was doing. With regard to level of enjoyement, Jacquelina states, "We got ot share fun things with them." This demonstrates how she felt that the letters provided another means of sharing information (through text), rather than just talk. Overall, these high ratings demonstrate that parent participation in a child's learning is powerful, meaningful, and relevant to the student.

**Charlena's Parents (Case Study 3)** . The pre-assessment questions were trying to access three things: (1) parents' experiences of the wetlands with their family, particularly the student in the study, (2) their knowledge of agriculture fields next to the sloughs and the potential consequences of this, and (3) their views about experiencing nature.

***Pre-assessment interview.*** The pre-assessment questions were trying to access three things: (1) parents' experiences of the wetlands with their family, particularly the student in the study, (2) their knowledge of agriculture fields next to the sloughs and the potential consequences of this, and (3) their views about experiencing nature.

When asked if Charlena's mother had been to the wetlands before, she said, "No, but I have been to the park to pass time with the kids (Charlena and her other daughter). They played on the play structure and fed the ducks." When asked if she had any interests concerning the wetlands she said, "I want to know more about what's there, the animals, the whole experience." The teacher-researcher asked if Charlena had shared her Earth Cards with her and she said, "No." When asked if she would be interested in joining us on a field outing she said yes, but it would have to be the last Saturday of the month because she works every Saturday except the last Saturday.

With regard to her knowledge and thoughts about the agriculture fields near the wetlands, she said, "No, but I see some strawberry and lettuce fields from the

freeway." When asked about what she thinks/feels about the use of insecticides and pesticides, she said, "It's bad, causes cancer and children are born with defects, but I guess it can also be good because it kills the insects too and we eat fruits and vegetables, but it's killing us too. Maybe it's bad for the animals…fish." This is a very balanced answer as she is looking at the pros and cons of chemical use on produce in addition to the harmful effects on humans and animals.

With regard to her thoughts about nature, she states, "Little by little it's disappearing, cutting trees, unless we do something about it, cut trees, no rain, no food, we die." Although this is somewhat of an extreme statement, it is not far off from current environmental trends, i.e., global deforestation which decreases transpiration which can have an affect on the amount of rainfall which can cause drought and lack of food.

When asked if she felt connected to nature, she said, "Sometimes, protecting the plants, the trees, no littering. I tell my kids not to throw any garbage because it kills us; water gets contaminated and we get sick." When asked about her thoughts experiencing nature with her children, she said, "Take care of nature, don't throw garbage. I don't like the beach because of the beach fleas. I also don't like camping because of the mosquitoes and there are no showers. We need to take care of the environment. God gives this to us; don't throw garbage."

When asked if she makes an effort to experience nature with her children, she said, "No, not really." When the teacher-researcher asked why, she said, "I don't

really think about it." The teacher-researcher then said the following statement under her breath, "Trying to survive." She immediately responded and said, "Yes! I have to work, my husband and I work, pay the bills, take care of the house and the girls. I love to be inside my house experiencing nature on t.v. by watching Discovery or Animal Planet."

Finally, when asked if she had any questions for the teacher-researcher, she said, "Yes, why are you doing this?" The teacher-researcher responded, "Kids in school don't really get an opportunity to explore nature, to get out there and really learn about it. I've been teaching in this district for many years and I know what happens in the classroom during the elementary years- the focus is on language arts and math; not much science. Also, the science field is dominated by white men and I feel that every ethnic group and women should have opportunities to pursue science as a career if they choose to, but they need learning opportunities when they are younger in school, that's why. Plus, I love animals and nature and I want today's youth to care about the environment and all of the wonderful animals which inhabit it." The mother listened and said, "Oh, that's good."

***Parent letters.*** Both of Charlena's letters to her parents are written in English, even though her father is not proficient in English. She uses everyday language to discuss her experiences in the Science club. She states that she enjoys going to the park with her teacher and friends and likes to see the animals, even the dead ones. However, she states, "It's kind of hard because it takes a long time for all of us to

learn about science and nature, even though I still really like it." Her salutation says, "From: Charlena (along with her last name). This is rather formal for a letter to parents.

Charlena also does not talk about her research project on the polychaete worm, rather, her letter is very broad, general, and lacks affect with regard to sharing her thoughts and feelings about her experiences in the Science club thus far. *Note: Charlena drew a picture of three students with the words, "Eeekk," and "Dead things," above two students looking at a bird that appears dead in the drawing. This may be in reference to the dead cormorant (yearly) we found in the parking lot one Saturday morning.* Charlena's first parent letter meets a rubric score of 1 (everyday concepts, using English).

Charlena's second letter demonstrates more interest and affect than her first letter. She discusses her experiences at the Elkhorn slough, again writing her letter in English and using everyday language. She states that what she liked most about the Elkhorn slough was seeing all of the big crabs. She also says that she became very excited when she got to touch a jellyfish. She also liked using the net to catch animals. Charlena also expresses how she had difficulty keeping up with everyone on our long trail walk. She confides with her parents that no one knew how much she was struggling to keep up. She says that along the walk, she touched a snake's skin. She ends her letter with, "I really, really, REALLY enjoyed going to the Elkhorn slough." Again, her saluation states, From: Charlena (along with her last name). She

includes an illustration of a fish tank which contain jellyfish, and also a picture of Charlena lagging behind three stick figures ahead of her (demonstrating the trail walk). Charlena's second parent letter also meets a rubric score of 1 (everyday concepts).

***Parent homework.*** Charlena's mother's homework question was derived from the pre-assessment interview. Her question was as follows, "You mentioned during the parent interview how important it is that people pick up their trash in nature. How do you think picking up trash will help the environment and animals in the wetlands? You can also draw a picture." She responded in English, "Yes I think it can help our rivers, lagoons, beaches and clean air for people and animals. If everyone of us do a litter be of cleaning, our planet by picking up trash." She also drew a picture of two green hills, two trees, a red flower, and a yellow sun.

Although her last sentence is not fluid in it's meaning, her overall message is that cleaning up litter helps the environment, animals, and people. This same message was also conveyed during the pre and post-assessment interviews, although she added a specific concern such as water contamination and how people can get sick in her pre-assessment interview. Basically, the funds of knowledge Charlena's mother contributed to this study was her keen awareness of the harmful effects litter has on the environment and how these effects can contaminate the water and make people sick. She was also willing to join the Science club on a field day cleaning the

wetlands. Unfortunately, when the day arrived, only one parent (Margarita's father) could attend, thus the event was cancelled.

***Post-assessment interview.*** The post-assessment interview revealed four things: (1) her thoughts/feelings about participating with the Science club and her perception of how the experience was for her daughter Charlena, (2) her thoughts, feelings, and concerns about wetlands now (after six months), (3) her thoughts and feelings about how her knowledge influenced her child's learning experiences (funds of knowledge), and (4) whether she and Charlena would like to participate with the Science club again if we explored another ecosystem, such as tidepools or estuaries.

First, when asked about her experiences participating in the Science club, she said, "Wonderful, getting the parents involved like on the day of the presentation. Every girl did a wonderful job, especially the girl who did the bilingual presentation. A lot of work for you and the students." The teacher-researcher nodded as if to thank her for her compliment. The mother added, "Everyone was friendly, nice, caring, and the tamales and sandwiches were very good."

The teacher-researcher then asked how she felt the experience was for Charlena. She said, "Positive, good experience; she's missing it." The teacher-researcher then said, "Of all the students, Charlena was the only one who memorized her presentation; that was very impressive. However, the mother did not see this as noteworthy, rather, she commended the student who gave the bilingual presentation instead. She said, "Yes, but the girl who did the bilingual presentation was better. I

try and get Charlena to speak in Spanish but she's not interested. She says she was born here."

The teacher-researcher and research assistant discussed how Charlena would most likely transition very quickly to speaking Spanish when and if she takes a language course in school since her parents speak to her in Spanish, yet she answers in English. The research assistant shared how her daughter was the same way at home, but when she took a year of Spanish in high school, she quickly learned how to speak Spanish. Charlena's mother listened intently and said, "Yes, well I'm hoping she does; it's important."

Second, when asked about her feelings, thoughts, and concerns about wetlands now, after six months of her daughter's participation in the Science club, she said, "I think we need to study more, protect more, more animals endangered. The city council needs to get more involved; put more signs up." The teacher-researcher, research assistant, and mother discussed putting more doggy bag dispensers in the park, especially along the wetland trails.

Third, when asked whether she thought or felt her knowledge influenced her daughter's learning experiences, she said, "I don't really share with Charlena." When asked about her thoughts with regard to parental participation, she said, "Yes, that way because she knows I like it and she'll work on it harder. Parents need to provide support with what they do, i.e., go to meetings, games, etc." This is an interesting statement as she says in the sentence just prior to this one that she doesn't share with

Charlena. The two statements seem contradictory? Support involves not only attending meetings and games, but also sharing information, asking questions, listening, and encouraging one's growth and development.

When asked if Charlena shared what she was experiencing in the Science club with her, she said, "Sometimes she does, not a lot. I work pm's so sometimes no." Just as the teacher-researcher was about to ask the next question, "Would you ask Charlena about what she was doing or learning in the Science club," Charlena came down stairs. Her mother started to answer, "Yes," but Charlena interjected and said, "No, she would rarely ask." This was a slightly uncomfortable moment for everyone, but it did shed light on the relationship dynamic between Charlena and her mother. Although Charlena's mother said parent participation is important, she would not share her knowledge with Charlena nor ask her questions about what she was doing or learning in the Science club. However, Charlena's mother does indeed demonstrate both financial (works) and physical support (attended the presentation day and also both pre and post parental interviews).

Lastly, when asked if they would like to participate with the Science club again, both Charlena and her mother said yes. The teacher-researcher said that if we continued with the Science club, it would only be on the last Saturday of the month. The mother said, "Good, that's my day off." This last statement can be interpreted three ways: (1) she is happy to join us on one of our field outing days, (2) she has one less daughter in the house to look after, or (3) Charlena gets to have more

experiences and learning opportunities in the Science club. This is open for interpretation.

Although Charlena's mother spoke of parental support, and she clearly provided financial support and physical support, there is some evidence of a lack of sharing between Charlena and her parents. As stated previously, it is important to note that parental support includes intellectual and emotional support just as much as financial and physical support. It is understandable that since Charlena's mother works so much that she may feel exhausted, thus not sharing her knowledge or asking Charlena questions, but at the same time, parents need to take the time to interact and connect with their children.

**Results (case study 3).**

***Triangulation of data sources.*** This triangulation will only discuss aspects of parents' funds of knowledge which informed Charlena's experiences in the Science club project. Not all data sources triangulated in this case study. Charlena's mother demonstrated that she had not been to the wetlands before. Although Charlena's mother has an appreciation of nature, she stated that she would rather be indoors. This runs counter to what Charlena prefers; being outside.

Charlena's mother was aware of the harmful effects of litter and said that she tells her children to never litter because it contaminates the water and can make people sick. During the post-assessment interview, she suggested that the City

Council needed to become more involved with protecting the land and endangered animals.

With regard to sharing her knowledge with her daughter, Charlena's mother expressed that she does not share with her daughter. Charlena expressed the same about her mother not asking questions about what she is learning. In addition to a lack of sharing, there also appeared to be a lack of praise for Charlena's presentation which was impressive, considering she was the only one who did not have to refer to her poster board during her presentation. Instead, the mother praised the student who provided a bilingual presentation for parents who only understood Spanish. Interestingly, Charlena did not feel the need to use Spanish, since she lives in the USA.

Charlena's letters to her parents were in English, even though her father speaks predominately Spanish. Her first letter was very broad and general, however her second and third letters were more specific and contextualized. What's most intriguing about these letters to her parents is the fact that she does not include love in her salutations, but indeed says from.

Finally Charlena's mother's homework assignment contained one sentence about not littering. It also had an illustration on the cover. Charlena rated writing letters to her parent 1 (not helpful) to her learning and also, not enjoyable.

**Discussion (case study 3).** Charlena's mother demonstrated that she had not been to the wetlands before, however, she and her daughters have spent time at Ramsey park which is adjacent to the Watsonville wetlands playing on the play structure in addition to feeding the ducks. When asked if she had any interests or concerns about the wetlands she said she wanted to learn more about them and the animals which inhabit them.

Although Charlena's mother was not aware of agriculture fields near the sloughs, she said she sees strawberry and lettuce fields from the freeway. When asked about her thoughts and feelings with regard to insecticide and pesticide use, she provided a very balanced answer of the pros and cons. For example, she stated the harmful effect on children (birth defects), but at the same time said that the chemicals kill insects. She also said that the chemicals are bad for animals, such as fish.

Charlena's mother was particularly aware of the harmful effects of litter and said that she tells her children to never litter because it contaminates the water and can make people sick. During the post-assessment interview, she suggested that the City Council needed to become more involved with protecting the land and endangered animals in addition to putting more signs along the trails.

Although Charlena's mother has an appreciation for nature, she does not like the beach (beach fleas), nor does she like camping (mosquitoes and no showers). Her ideal connection with nature is to be inside her house watching the Discovery channel or Animal Planet.

With regard to sharing her knowledge with her daughter, Charlena's mother said she does not share with Charlena. Likewise, when asked if Charlena shared her Earth Cards or her learning experiences with her, she said, "Sometimes she does, not a lot. I work pm's so sometimes no." When asked if she would ask Charlena questions, Charlena's mother was about to answer yes, but Charlena interjected and said, "No, she would rarely ask." Although this was somewhat of an awkward moment, particularly for Charlena's mother, it shed light on the relationship between Charlena and her mother.

In addition to a lack of sharing, there also appeared to be a lack of praise for Charlena's presentation, i.e., memorizing her poster board. Rather than acknowledge her daughter's stellar performance, she down played it by stating that the bilingual presentation (from Margarita) was better. This was somewhat difficult for the teacher-researcher to hear as she had hoped that some kind of recognition for Charlena would have been given.

It is understandable that perhaps Charlena's mother is tired and when she is home with her family she wants to relax and have 'down time' but it is also important to consider the significant impact families have on their childrens' learning. For example, according to Gandara (1989) parents are a child's first educators. Half of children's mature intellect is formed at home before they even reach school.

In addition, most of the Mexican American students Gandara studied attributed their desire to succeed from supportive mothers who encouraged them

unwaveringly. Although Charlena's mother touted the importance of parental support by stating, "Parents need to provide support with what they do, i.e., go to meetings, games, etc," one can argue that intellectual and emotional support is just as important as physical and financial support.

With regard to Charlena's letters to her parents, she did not share specific learning experiences in her first letter, but rather broad generalizations of having fun and enjoying the animals (both dead and alive). Her second letter was much more demonstrative of enjoying her experiences at the Elkhorn slough, i.e., seeing the big crabs, using the net to catch animals, and touching jellyfish and a snake's skin. She also confided with her parents about the long trail walk and how she had trouble keeping up with everyone.

What's most intriguing about these parent letters is the fact that Charlena does not include love in her saluations, but rather, uses the word from. This was somewhat surprising as her peers all used love in their parent letters.

Charlena's mother's homework demonstrates her awareness of how picking up litter can help the environment, animals, and people. This is in alignment with her pre and post-assessment interviews. Charlena's mother does not elaborate in her letter as it is only two sentences long with an illustration on the cover (two green hills, two trees, one red flower, and a sun).

Finally, Charlena rated writing letters to her parents 1 (not helpful) with regard to helping her learn, and 1 (not enjoyable) with regard to level of enjoyment. This is somewhat consistent with Charlena's post interview in addition to the pre and post parent interviews which revealed a lack of sharing knowledge, experiences, and materials (Earth Cards).

Thus, it appears that the data sources did not triangulate with regard to Charlena's parents' funds of knowledge informing Charlena's experiences in the Science club. Charlena's mother did however provide financial (work) and physical (attended presentation and parent interviews) support, but there is some evidence of a lack of intellectual and emotional support from her mother.

**Margarita's Parents (case study 4)**

The pre-assessment questions were trying to access three things: (1) parents' experiences of the wetlands with their family, particularly the student in the study, (2) their knowledge of agriculture fields next to the sloughs and the potential consequences of this, and (3) their views about experiencing nature.

***Pre-assessment interview.*** The pre-assessment questions were trying to access three things: (1) parents' experiences of the wetlands with their family, particularly the student in the study, (2) their knowledge of agriculture fields next to the sloughs and the potential consequences of this, and (3) their views about experiencing nature.

When asked if he had experienced the wetlands, Margarita's father said, "No. I've gone to the park (which is adjacent to the Watsonville wetlands) with my family and the kids have played there, but I haven't walked around the trails. The trails are new. Only about three years old so it wasn't easy to get around there before the trails." Margarita's father spoke in English and had a lot of prior knowledge and experience with regard to the area. He has lived in the Watsonville region with his family for about 20 years.

When asked whether he had any interests concerning the wetlands, he said, "It's good to learn anything." He then discussed experiences during his youth with his father in Mexico. He mentioned getting stung by a scorpion and how his father told him to go into the creek and drink water. He described a 'hairy' feeling in his throat. He also explained how poor he and his family were in Mexico, i.e., having to resort to using powder guns to kill doves, armadillos, and rabbits for food. The teacher-researcher shared that her grandfather used to hunt rabbits for food as well.

With regard to the agriculture fields surrounding the wetlands and the use of insecticides and pesticides, Margarita's father had historical knowledge about the wetlands that he shared during the interview. He said, "There used to be a junkyard up where they built the new apartments. I used to ride my bike up there when they were building. At that time, the wetland was treated like a dump site with tires, shopping carts, trash, etc." The teacher-researcher pulled out a trail map and asked him to show her where the dumpsite was located. He put a star at the location and

said, “Oh, I know something you don’t,” and laughed. The teacher-researcher and research assistant also laughed. We appreciated his insight about the area; information we did not have prior to this interview.

Margarita’s father was also very aware of the agriculture fields surrounding the wetlands and mentioned how the use of insecsticides and pesticides can be a problem when it rains because it can wash into the water. He said, “The table water, I’m not sure if that’s correct since Spanish and English are backwards.” The teacher-researcher asked, “Do you mean the water table?” He said, “Yes, if the insecticides and pesticides sink down into the water table, then that’s a problem. I have to be careful when I’m at the harbor (he works as a maintenance worker at the Santa Cruz Harbor) not to use too much insecticides and pesticides near the water. I have to be a certain distance away.”

The teacher-researcher listened intently and appreciated his sharing of his knowledge and experiences with regard to information about the wetlands (new trails and how it was used as a dumpsite) in addition to not using insecticides and pesticides near water (need to be a certain distance away.)

He also mentioned that around Pinto Lake, there are raspberry fields and wasn’t sure if the lake was polluted with insecticides and pesticides. He was very aware of the fact that the new chemical (methyl iodide) is even more toxic than the one used previously (methyl bromide) because he attended parent meetings for 7-10 weeks about the potential detrimental effects of this chemical on nearby residents,

including students at local elementary schools, i.e., one of which his daughter attended and the teacher-researcher worked at as an after-school teacher.

Just as Margarita's father shared his knowledge and experiences, the teacher-researcher did as well. She said, "The wetlands actually help (especially the plants) absorb the insecticides and pesticides because the soil is like clay. The more it rains, the more insecticides and pesticides come into the wetlands and the water is diluted with them. But when the rains stop, the insecticides and pesticides start to sink down into the soil and the water gets clean again."

It is important to note that this part of the interview intrigued the teacher-researcher because she felt as though both she and Margarita's father were co-constructing knowledge together and she enjoyed doing this with a parent. He had knowledge and information she was not aware of and vice versa. Together, they both reconstructed a more complete and accurate picture of the wetlands and the circumstances which affect them.

When asked about his thoughts about nature, he said, "I really like it. Atomic bombs, too much. I worry over there, nuclear bombs are the worst, burned skin, radiation." The teacher-researcher asked if he was referring to the effects of the tsunami on the nuclear power plant in Japan. It is important to note that the pre-assessment interview took place in March 2011 (during the time when the massive earthquake hit Japan and the tsunami had destabilized the nuclear power plant's operating system). He said, "Yes, this is the worst thing that could happen." The

teacher-researcher agreed and said, “I agree because you can never get rid of the waste. It will always be here.”

He then discussed how he connects with nature, or at least, how he used to connect with nature when he was a boy living on a ranch in Mexico, “Yes, I used to live on a ranch in Mexico in a small village. I am not a city person. I used to live on a rancho, not like here but with lots of land. We planted corn, beans, and squash. We were very poor, but we had a lot of property. All the animals were outside. I do not allow animals inside my house here. I believe animals belong outside.” He emphasized how he would never allow an animal in his house after an experience he had with his son letting one of the little dogs into the bathroom and how it pooped everywhere. He said he stepped in it and that was it for him! The teacher-researcher and research assistant laughed, i.e., looking at the fish tank behind him. He turned around and said, “That doesn’t count.” This was a very funny moment.

With regard to his thoughts about experiencing nature with his children, he said he and his family go to the beach and camp at a campground near the reservoir just off Pacheco pass. They often go during Easter vacation. He also said that when he lived in Mexico, his son rode their horses. He said when they moved to the USA, he sold them so his mother didn’t have to worry about feeding them and taking care of them.

He also expressed the importance of experiencing nature and animals first hand, rather than from books like at the university, i.e., waving his hand in the

teacher-researcher's direction, as if to suggest, "like you." The teacher-researcher did not take offense to his 'off the cuff' statement, but rather used it as an opportunity to express her position on the matter as well, "Yes, I agree with you. And this is what we do whenever we go out. We experience the animals first hand."

When asked if he made an effort to experience nature with his children, he asked his oldest daughter (who was working on the computer in the livingroom during the interview) for her opinion on the question. They were speaking to each other in Spanish. When she finished answering her father, he said, "Yes, my wife takes Margarita to the levee and they go walking and running sometimes. They see animals and nature on their walks. I also take the girls sometimes to see the llamas, off San Andreas Road."

The teacher-researcher thought that the action the father took, asking his daughter for her input before answering, was quite endearing as he felt it was necessary to consult with her before answering a question which related to his children on a personal level. This demonstrates a genuine sense of honesty and mutual respect and integrity which was highly appreciated by the teacher-assistant and research assistant.

In addition to this, he shared another personal experience about himself when he was a young boy in Mexico. He said that when he was 10 years old, he was paralyzed from the waste down from a bite (he didn't mention from what). His aunt and uncle made him drink deer blood with boiling water. He described the blood as

being dried into a powder like form. The teacher-researcher asked if it was like a beef bouillion cube, like when you're making soup, and he said, "Yes." This helped him and within no time, he was walking again.

Finally, the interview ended with both the teacher-researcher meeting Margarita's mother and thanking the parents for their time. Margarita's father expressed how important it is to provide support for his children. He touted that he attends all meetings, interviews, and even enrichment classes such as learning how to use computers, etc., but often times, he's the only parent to sign up and they wind up canceling the classes. He said, "Parents are lazy. I'm not, but a lot of them are."

It is clear, based on the interview and his closing words that Margarita's father actively participates in his childrens' education. His son graduated from Cal Poly (San Luib Obispo) in business, and his eldest daughter was in the midst of applying to San Jose State as a business adminstration major. During the doctoral study, Margarita expressed an interest in owning her own business when she grows up. As the teacher-researcher and research assistant departed, the teacher-researcher said, "Now I know where Margarita gets her feistiness from; her father.

***Parent letters.*** Margarita's first parent letter is written in English and addressed only to her father (since her mother speaks only Spanish). She writes about her experience with regard to the polychaete worm and focuses on words she has learned (specific terms) rather than the inquiry process. For instance, she writes, "Now I know where a **polychaete** lives. For example, it likes **marine burrows** and

muddy areas." This is the extent of her letter. Surprisingly, she does not discuss the specifics of the day when both she and her partner Charlena found an actual polychaete at the Watsonville slough. Rather, her letter is extremely short and focuses on the specific terms she learned. She also provides an illustration of a polychaete worm in water surrounded by small plants that look like duckweed. Margarita's first parent letter meets a rubric score of 2 (everyday concepts and specific terms), using English.

Margarita's second parent letter is addressed to both parents and written in English, even though her mother is not proficient in English. Once again, she uses specific terms and a scientific concept (scientific language) to write about her experiences at the Elkhorn slough. The fact that Margarita uses scientific language rather than everyday language indicates that perhaps she thinks her parents, especially her father, will understand since he is knowledgeable about the wetlands and nature in general. For example, she writes, "I learned that at the Elkhorn slough, there is more **diversity** of finding **aquatic invertebrates**. I also learned that the **European green crab** in a **non-native** animal. I think going to the Elkhorn slough helped me learn more about nature. I hope to get to see more interesting animals in life like the ones I saw at the Elkhorn slough." Margarita's second parent letter meets a rubric score of 4 (specific terms and scientific concepts), using English.

Although Margarita saw other animals, such as a snake, and discussed how this was the best part of the field trip during her post-assessment interview, the

general feeling about Margarita's letters is that she regarded the task as an assignment, rather than as a means of sharing her experiences with her parents. Perhaps since her first letter did not initially go to her parents because the teacher-researcher was holding onto them to photocopy for analysis, she may have thought, "Well, this isn't really going to my parents, even though I am writing a letter to them." Margarita illustrated a European green crab in a pool of blue water.

***Parent homework.*** With regard to the parent homework, his question was derived from the pre-assessment interview, "You mentioned during the parent interview that spraying insecticides/pesticides too close to the water can pollute the water table. Can you describe how this happens?"

Since the father answered in Spanish, the research assistant translated it into English. The translation is as follows, "Pesticides go under the dirt, evaporate, and are sprayed on plants. Not only does the person operating the tractor have a high chance of getting sick, but his children and even unborn children do as well. People living near the cultivation fields also get sick with cancer, anemia, and can go crazy. But, it is in God's hands." His illustration included a man operating a tractor spraying insecticides/pesticides while driving through a field of crops.

His response to the homework question is in alignment with the information he provided during the interviews. He has both knowledge and experience with regard to the use of insecticides and pesticides, as he mentioned that he has to stay a certain distance away from the water when he uses them at work (Santa Cruz

Harbor). He is also aware of the harmful effects on people's health from attending community meetings for 7-10 weeks which discussed the use of a new chemical on the strawberry fields within proximity to his daughter's elementary school. He mentioned during the pre-assessment interview that the new chemical is more toxic than the one they used before.

***Post-assessment interview.*** The post-assessment interview was less elaborative on his part, as he had just returned home from work and appeared visibly tired. This interview revealed: (1) his thoughts/feelings about participating in the Science club, (2) his thoughts/feelings about whether his funds of knowledge influenced his daughter's learning experiences in the Science club, (3) his thoughts/ feelings about parental participation, (4) whether Margarita shared her learning experiences with him, and also, if he asked her questions about what she was doing in the Science club, (5) his thoughts/feelings about Margarita's presentation and whether he would consider participating with the Science club again, and (6) a member check question about his level of education.

First, when asked about his thoughts and feelings about participating with the Science club, he said, "Pretty interesting for kids to do natural things." When asked how he felt/thought the learning experience was for Margarita, he said, "She loved to go with you. It's good when kids are interested in learning about little creatures." When asked about his feelings, thoughts, and concerns about wetlands now (six

months after the pre-assessment interview), he said, “It’s important to try and keep them forever, to conserve them for the future.”

With regard to his feelings and thoughts about his funds of knowledge and whether they influenced or informed his daughter’s learning experiences in the Science club, he said, “Animals are pretty much the same in Mexico: frogs, patos (ducks), coots. I watch on Discovery the birds with long beaks peck in sand, another one makes a beep beep sound. There is a nest in the parking lot at my work with these aggressive birds.” When asked about whether his own personal experiences and knowledge have informed Margarita’s learning, he said, “We are animal lovers but we still need to eat them to survive. Nature is interesting.”

With regard to parental participation, he said, “It is important for parents to participate. It’s important for the child. It’s more meaningful for the child if the parents show up; it shows that parents care. When parents participate, they are interested and committed.” The last sentence can be interpreted as the parents are interested and committed or, when parents participate, the children become interested and committed. During the interview, the teacher-researcher interpreted this last sentence to signify that when parents participate, children become more interested and committed in what they are learning.

When asked if Margarita would share her learning experiences in the Science club with him, he said, “She would come home and talk about what she did and saw: worms, duckweed, natural environment, etc.” When asked if he would ask Margarita

about what she was doing or learning in the Science club, he said, “Sometimes, not all the time.”

With regard to the day of the presentations, he said he noticed that the students were nervous. He also said that the presentations were pretty good and that he was proud of Margarita, “I’m always proud of what they do.” When asked if he would participate with the Science club again if we decided to explore another ecosystem, such as tidepools, monarch groves, or estuaries, he said he would be willing, but that it was up to Margarita.

Finally, the interview ended with a member check about his educational level. He said he went up to sixth grade and never really understood the importance of trying to find unknown variables. He expressed that he is able to assist with his children’s math homework up to a certain level.

Overall, Margarita’s father encompassed a great deal of knowledge and experience with regard to historical information about new trails and a section of the wetlands (as a dumpsite), in addition to experience with regard to spraying insecticides and pesticides near water and how one needs to be a certain distance away so as not to contaminate the water table. Although he did not have specific knowledge and experiences with regard to what Margarita was studying (polychaete worm), he had many experiences in nature during his youth in Mexico and was aware of the fact that many of the animals here in Watsonville, i.e., frogs, patos (ducks), and coots, are also in Mexico; similar animals. Thus, when Margarita would come home

after a day in the field and share what she did and saw, her father could relate and understand because many of the animals that are located in the Watsonville wetlands are also residents in Mexico.

**Results (case study 4).**

***Triangulation of data sources.*** This triangulation will only discuss aspects of parents' funds of knowledge which informed Margarita's experiences in the Science club project. Based on the four data sources, it appears that although Margarita's father did not have specific knowledge and experiences with regard to Margarita's inquiry project on the polychaete worm, he possessed both knowledge and experience with regard to historical information about the wetlands, the harmful effects of insecticides and pesticides on the environment (water table) and people (cancer and anemia).

He was also aware of the fact that many of the animals in Watsonville, such as frogs, ducks (patos), and coots are also found in Mexico, thus there are similarities in these two regions. Lastly, with regard to the wetlands, when asked about his feelings, thoughts, and concerns about them, i.e., six months after the pre-assessment interview, he said, "It's important to try and keep them forever, to conserve them for the future."

With regard to Margarita's parent letters, both were written in English. The first letter contained everyday language and one specific terms, whereas Margarita's

second letter contained specific terms and a scientific concepts. Perhaps Margarita used a scientific concept because she thinks her father will understand its meaning.

The parent homework emphasized Margarita's father's knowledge and experiences with regard to how insecticides and pesticides are used and their detrimental effects on the water table and people.

Finally, with regard to parent participation, he was very aware of its importance because, "It's more meaningful for the child if the parents show up; it shows that parents care. When parents participate, they are interested and committed." Clearly, Margarita's father is a very proactive parent in his children's education as his son graduated from college and his eldest daughter was in the midst of applying to one (which, by the way, she was accepted to). Margarita also expressed aspirations of attending college and majoring in business adminstration like her siblings.

**Discussion (case study 4).** With regard to the pre and post-assessment interviews, Margarita's father demonstrated historical knowledge about the wetlands (new trails, i.e., only three years old and how a section of the wetlands was used as a dumpsite), in addition to having experience with the use of insecticides/pesticides (at this work site, i.e., he has to be a certain distance away from the water so as not to contaminate the water table).

He is also knowledgeable with regard to insecticide and pesticide use from having attended community meetings for 7-10 weeks about how the new chemical (methyl iodide) is more toxic than the one used previously (methyl bromide). Thus, based on this, it appears that Margarita's father's knowledge and experience may have influenced or informed Margarita's learning experiences in the Science club.

His experiences in Mexico may have also informed Margarita's learning experiences as well. For example, during his youth, he lived in Mexico on a ranch (rancho) with lots of animals. Since he and his family were very poor, they planted corn, beans, and squash. They also hunted doves, armadillos, and rabbits for food. He expressed the importance of experiencing nature and animals first hand, rather than from books like at the university, i.e., waving his hand in the direction of the teacher-researcher as if to suggest, "like you." The teacher-researcher did not take offense to his 'off the cuff' statement, but rather used it as an opportunity to express her position on the subject, "Yes, I agree with you. And this is what we do whenever we go out. We experience the animals first hand."

It is important to mention that there were times during the interview when Margarita's father and the teacher-researcher were essentially co-constructing knowledge together. For example, he had information and insight about aspects of the Watsonville wetlands that the teacher-researcher was not privy to, and likewise, she had knowledge about the functionality of the wetlands that he was not aware of. For instance, he knew that the trails were new and that a section of the wetlands used

to be a dumpsite. He also had first hand knowledge about how to properly use insecticides and pesticides so as not to contaminate the water table, in addition to knowing that the new insecticide/pesticide was even more toxic than the one used previously.

Likewise, the teacher-researcher shared about how the wetlands (particularly the plants) filter the water, thus cleansing it. She described how when it rains, the chemicals wash into the sloughs and become diluted, however, when the rains stop and the water starts to evaporate, the chemicals settle to the bottom and are absorbed into the clay-like soil. The father listened intently, just as the teacher-researcher had when he was sharing his knowledge and experiences with her. Together, the father and teacher-researcher co-constructed a more complete and accurate picture of the wetlands and the circumstances which affect them.

With regard to his funds of knowledge which may have influenced or informed Margarita's learning experiences in the Science club, from his perspective, he states, "Animals are pretty much the same in Mexico: frogs, patos (ducks), coots," these animals reside here in Watsonville just as they do in Mexico. When asked about whether his own personal experiences and knowledge have informed Margarita's learning, he said, "We are animal lovers but we still need to eat them to survive. Nature is interesting."

The teacher-researcher's perspective of Margarita's father's funds of knowledge is that he clearly had both knowledge and experience with regard to

historical information about the wetlands, in addition to first hand use and knowledge about the detrimental effects of insecticides and pesticides on the environment (water table) and people's health.

Although he did not have specifc knowledge and experiences with regard to what Margarita was studying (polychaete worm), he had many experiences in nature during his youth in Mexico and was aware of the fact that many of the animals here in Watsonville also reside in Mexico; similar animals in two different regions. Thus, when Margarita would come home after a day in the field and share what she did and observed, her father could essentially relate, and essentially understand.

With regard to parent letters, both letters were written in English. In her first letter, she uses everyday language and specific terms, i.e., emphasizes learning new words (scientific words) rather than the inquiry process. For instance, "Now I know where a **polychaete** lives. For example, it likes **marine burrows** and muddy areas." Although this letter is very short, it demonstrates that perhaps Margarita uses three specific terms because she knows her father is knowledgeable about the wetlands and nature in general and, as a result, he would/could understand them.

Likewise, in her second parent letter, Margarita continues to use specific terms, but she also uses a scientific concept- diversity. She describes her experiences at the Elkhorn slough, i.e., using such words as **diversity**, **aquatic invertebrates**,

**European green crab**, and **non-native**. Again, perhaps Margarita use a scientific concept such as diversity is because she thinks her father will understand its meaning.

The general feeling about Margarita's approach to her parent letters was that she regarded the task as an assignment, rather than a genuine attempt to share her learning experiences with her parents. Perhaps Margarita surmised this since the teacher-researcher held onto all letters until the end of the study. This was a mistake on the teacher-researcher's part, as she should have photocopied each letter and returned them to the students immediately so that they could share them with their parents.

The parent homework emphasized Margarita's father's knowledge and experiences with regard to how insecticides and pesticides are used and their detrimental effects on the water table and people. Clearly, he has an understanding of this as he uses insecticides/pesticides at his work site in addition to having attended community meetings for 7-10 weeks on the potential harmful effects of these chemicals on people's health (causing cancer and anemia).

Lastly, Margarita rated writing letters to her parents 2 (a little bit helpful) with regard to helping her learn, and 2 (a little bit enjoyable) for level of enjoyment. Again, since the letters did not go to the parents right after Margarita (and the other students) had written them, perhaps they looked at their letter writing as an

assignment rather than a genuine attempt to share their learning experiences with their parents.

During the time of the study, the teacher-researcher did not consider the effect of waiting to distribute parent letters, however, during the analysis she can see that waiting to distribute the first letter may have affected their attitude with writing their second letter to their parents, “Oh, this isn’t really going to my parents, so I’m not going to put much effort into it.”

# Chapter 8: Conclusion

## Research Question 1: Scientific Language

Based on the findings, it can be concluded that all students' use of scientific language increased. However, the new comers (Cecelia and Jacquelina) showed greater gains with a rubric score of 1 and 2 pre study to 4 post study. The old timers (Charlena and Margarita) pre rubric scores were already at 4 and ended at 4. Although the rubric scores are the same, they still showed an increase in the quantity of scientific language they used.

All students demonstrated accurate scientific language use, however in different ways. For example, Cecelia used "ecosystem balanced" during her post assessment interview, in addition to a causal statement, 'oxygen because of plants.' These examples illustrate how this new comer progressed from using everyday language only to accurate scientific language.

Jacquelina demonstrated the use of causal statements and accurate scientific concepts, however, she needed additional scaffolding to generalize terms. Where Jacquelina demonstrated strength was in how she used information learned in one context and applied it to another. For example, she used the scientific language scaffolded in the field to a letter written to a science educator. This demonstrates that she could apply knowledge across contexts (Beach, 1999).

Charlena and Margarita were the old timers of the science project. They had participated in a pilot study six months prior to the study. These students used causal

statements and formulated hypothetical questions during their pre assessment interviews. Charlena used comparison and differentiation statements and demonstrated that she remembered information from the pilot study. Margarita had a firm grasp of taxonomic families.

Three themes emerged from the data sources. First, three case studies used everyday language to convey the meaning of scientific concepts. Second, the letters written to Kenton and Miriam demonstrated specific examples and causal statements. And third, semiotic tables were considered helpful to all students, however, only the newcomers considered the cognate table help. These new comers also used Spanish in their letters to their parents. Their parents speak only Spanish. In contrast, the old timers wrote their letters in English and have at least one parent who speaks English. These students considered the cognate table as not helpful to their learning, nor enjoyable.

The significance of these findings is that instructional conversations raised students' everyday language and contextualized scientific language through the use of semiotic tools and empirical experiences. This provides support for how scientific language is developed (Vygotsky, 1987).

In addition, reviewing terms and concepts and sharing examples with each other made a difference. This is why letters to Kenton and Miriam demonstrated more scientific language use, logical memory, and providing detail and specific

examples. The letters became the "improvable object" as the teacher-researcher and students worked colloboratively to improve these letters (Wells, 1999).

Lastly, discussing inaccuracies provided an opportunity to extend students from their actual level of development to their potential level of development. Thus, it became a teaching, learning, and assessing tool combined.

The implications of these findings are that when the theories represented in this study are put into practice, profound results on students' development of scientific language appear. His has an affect on the overall intellectual development of the child because the products of the development of scientific concepts are higher mental functions such as conscious awareness, volition, comparison/differentiation, and logical memory . These higher mental functions were demonstrated by each student in their own way.

**Research Question 2**: **Scientific Inquiry**

Based on the findings, it can be concluded that all students' understanding of scientific inquiry and their motivation to learn increased, however, one case study had difficultly with the inquiry template assessment as the Elkhorn slough. All students enjoyed "hands-on" seeing and doing science. These activities received the highest ratings for helping students learn and for level of enjoyment.

Cecelia, Jacquelina, and Margarita expressed social concerns about the wetlands such as garbage, roads under water, and pollution. Charlena and Margarita's perceptions of science changed. For example, Charlena stated that she realizes

science is not just something a mad hair scientist does in a laboratory with dangerous chemical, but also includes inquirying about nature and life in general. In the end, she believed that anyone could do science. Margarita came to the realization that science isn't about reading boring textbooks like at school, but includes making observations, and collecting data to answer a research question. She considered science to be fun in her post-assessement interview.

These finding are significant because each student expressed that their inquiry project was 'doing science.' Students believed that they could 'do science' after their experiences in the Science club. This demonstrates a connection with science and potential for continuance (Wells, 1999).

Students differed based on their interests. For example, Cecelia was interested in studying plants and flowers, some of which have medicinal properties. One in particular helps ameliorate asthma. Cecelia has asthma. Jacquelina chose the ruddy duck because she was interested in how the male duck pursued the femal. Throughout the study, Jacquelina demonstrated the strongest observational skills. Charlena and Margarita chose the polychaete worm. Even though the teacher-researcher cautioned the students about the low probability of finding one since they are predominantly found in marine ecosystems, they still wanted to pursue their interest.

The implications for these findings are that when students have a real, experiential experience driven by their interests and scaffolded through instructional

conversations in additon to both semiotic and material tools, they not only come to understand science, but are motivated to learn.

**Research Question 3: Parents' Funds of Knowledge**

The findings support that parents' funds of knowledge informed students' experiences in the science project. For example, Cecelia's inquiry project focused on plants and both parents work at an organic farm where Cecelia sometimes helps her mother pack produce. In addition, Cecelia's parents expressed an interest in gardening and flowers. In their post parent interview they said that Cecelia is more interested in plants than ever before.

Jacquelina's inquiry project focused on the ruddy duck. The mother expressed her interest in birds, particularly the hummingbird. She also discussed how both she and Jacquelina often walk to the levee where they see animals, such as ducks. Both Jacquelina and her mother demonstrated strong observational skills.

Charlena's inquiry project focused on the polychaete. She also expressed in her post-assessment interview how important it is to maintain the Earth. Charlena's mother shared the same belief in her pre parent assessment interview.

Finally, Margarita's inquiry project focused on the polychaete as well. From the beginning of the study she expressed a concern about pollution and how the wetlands can become damaged by it. Margarita's father was an expert with understanding the dangers of these chemicals on the environment, particularly the water table. Not only does he work with these substances, he has attended

community meetings which discuss the harmful affects of these chemical on residents who live nearby agriculture fields.

The significance of these findings is that parents' funds of knowledge informed students' learning and teaching practices. This provided a means for the teacher-researcher to get a better perspective of students as 'whole persons' (Moll, 1992). Overall, parent data sources provided insight into students' interests, concerns, circumstances, behavior, and personality.

**Interconnections**

Taken together, scientific inquiry provided the means for students to engage in an inquiry project based on their interests. These interests were influenced by parents' funds of knowledge. As students gathered information about their inquiry projects, they developed scientific language. Scientific concepts were scaffolded through instructional conversations, semiotic tools, and emperical observations. Through this spiral of learning and teaching through inquiry, students reached new and more complete understandings and shared them with others. In the end, students developed a position about science, "a willingness to wonder, to ask questions, and seek to understand by collaborating with others in an attempt to make answers to them" (Wells, 1999, p. 121).

## Appendix A: Interview Protocols, Assessments, and Data Sources

### Student Interview Questions

***Pre-assessment:***

1. What do you know about wetlands?

2. Have you been to the wetlands before?

3. What was your experience like?

4. Did you go with your family or friends?

5. Did you see anything that interested you or made you wonder?

6. Is there anything that interests you now about wetlands?

7. Do you have any questions or concerns about wetlands?

8. How do you think you might explore your questions? What would you do to find answers to them?

9. What are your thoughts about studying wetlands?

10. Do you think studying about wetlands is important, and if so, why?

11. What are your thoughts about science?

12. Do you think science is important, and if so, why?

13. Do you think you can do science?

14. Do you think you can be an active voice for educating others about wetlands, and if so, how?

15. How would you feel/think if your family joined us on a field outing?

**Post-Assessment**

1. What did you learn from participating in this science club?

2. What experience(s) did you enjoy?

3. What lesson or activity did you find interesting?

4. What did you learn?

5. How do you understand wetlands now?

6. What are your thoughts about wetlands now, after learning about them?

7. Do you think studying about wetlands is important, and if so, why?

8. What did you learn from your inquiry project?

9. What are your thoughts about science now?

10. Do you think science is important, and if so, why?

11. Do you think you can do science now?

12. Do you think the inquiry project was doing science, and if so, how and why?

13. Do you think you can be an active voice for educating others about wetlands, and if so, how?

14. What did you feel/think about your family watching your presentation?

15. What did you feel/think about your experiences in The Nature Center?

16. What did you feel/think about your experiences out in the field? (Also, going out to Elkhorn Slough)

17. Do you have any further questions, concerns, interests, about wetlands, science, this study, etc.

**Specific Term Scientific Concept Assessment at Elkhorn Slough**

1. **Ecosystem:**

   (a) How would you describe the **ecosystem** here at the Elkhorn Slough? How is it similar or different from the Watsonville wetlands?

   (b) Did you know what this word meant before the Science Club project?

   Yes_____ No _____ (If yes, where did you learn the word?)

   (c) Can you name a synonym for ecosystem?

2. **Habitat:**

   (a) Describe a **habitat** that you saw here today at the Elkhorn Slough?

   (b) Did you know what this word meant before the Science Club project?

   Yes ____ No ____ (If yes, where did you learn the word?)

3. **Wetland:**

   (a) Is the Elkhorn Slough a **wetland** and if so, explain why?

   (b) Did you know what this word meant before the Science Club project?

   Yes ____ No ____ (If yes, where did you learn the word?)

   (c) Can you name a synonym for wetland?

4. **Biotic:**

   (a) Describe something **biotic** that you saw here today at the Elkhorn slough?

   (b) Did you know what this word meant before the Science Club project?

Yes ____ No ____ (If yes, where did you learn the word?)

5. **Abiotic:**

   (a) Describe something **abiotic** that you saw here today at the Elkhorn Slough?

   (b) Did you know what this word meant before the Science Club project?

   Yes ___ No ___ (If yes, where did you learn the word?)

6. **Vertebrate:**

   (a) Describe a **vertebrate** animal you saw here today.

   (b) Did you know what this word meant before the Science Club project?

   Yes ___ No ___ (If yes, where did you learn the word?)

7. **Invertebrate:**

   (a) Describe an **invertebrate** animal you saw here today.

   (b) Did you know what this word meant before the Science Club project?

   Yes ___ No___ (If yes, where did you learn the word)

8. **Aquatic invertebrate:**

   (a) Describe an **aquatic invertebrate** that you saw here today at the Elkhorn Slough? Is it similar or different from the ones we have seen at the Watsonville slough?

   (b) Did you know what this word meant before the Science Club project?

   Yes ___ No___ (If yes, where did you learn this word?)

**9. Native:**

(a) Describe or name something **native** you saw here today at the Elkhorn Slough?

(b) Did you know what this word meant before the Science Club project?

Yes ___ No ____ (If yes, where did you learn this word?)

**10. Non-native:**

(a) Describe or name something **non-native** you saw here today at the Elkhorn Slough?

(b) Did you know what this word meant before the Science Club project?

Yes ___ No ___ (If yes, where did you learn this word?)

11. **Diversity:**

(a) How would you describe the **diversity** of life here compared to the Watsonville slough? Is there a higher diversity of life here at the Elkhorn Slough, or a lower diversity of life?

(b) Did you know what this word meant before the Science Club project?

Yes ____ No ____ (If yes, where did you learn this word?)

**12. Migration:**

(a) Name or describe an animal that **migrates** to the Elkhorn slough.

(b) Did you know what this word meant before the Science Club project?

Yes ___ No___ (If yes, where did you learn this word?)

**13. Adaptation:**

(a) Can you describe an adaptation that you saw here at the Elkhorn slough?

(b) Did you know what this word meant before the Science Club Project?

Yes_____ No____ (If yes, where did you learn this word?)

**14. Camouflage:**

(a) Can you describe an animal that **camouflages** well at the Elkhorn Slough?

(b) Did you know what this word meant before the Science Club Project?

Yes ____ No ____ (If yes, where did you learn this word?)

15. (a) Can you name an animal that **breeds** here in the Elkhorn Slough during the summer months?

**(b)** Did you know what this word meant before the Science Club Project?

Yes ____ No____ (If yes, where did you learn this word?)

16. History/culture: Can you describe something left behind by the **Ohlone Indians** which is evidence that they used to inhabit the Elkhorn Slough?

17. (Fill in four specific terms/scientific concepts unique to each student's inquiry project)

18. Note: Last three are blank because the scientific concept and/or term pertained to student's specific inquiry project (left blank and written in).

**Table 1**

***Cecelia Post Pre Specific Term Scientific Concept Assessment***

| Scientific concept | Specific term | Question | Learned where? | Answer |
|---|---|---|---|---|
| Ecosystem | | How would you describe the ecosystem here at the Elkhorn slough? How is it similar or different from the Watsonville slough? | Mr. Murphy (middle school science teacher) | The Elkhorn slough has different kinds of animals and it is kind of in the middle. The Elkhorn slough has salt and fresh water. |
| | Habitat | Describe a habitat that you saw here today at the Elkhorn slough. | Mr. Murphy | I saw a bird habitat and the crab's habitat. |
| | Wetland | Is the Elkhorn Slough a wetland and if so, explain why? | Mr. Murphy | I think no it's not because the Elkhorn slough has saltwater mixed with freshwater. |
| | Slough | Can you name a synonym for wetland? | Science club | I think a synonym for wetland is an ecosystem. |
| | Biotic | Describe something biotic that you saw here today at the Elkhorn slough. | Mr. Murphy | I saw lots of birds (pelican) and lots of animals (snake) |
| | Abiotic | Describe something abiotic that you saw here today at the Elkhorn slough. | Mr. Murphy | I saw rocks and sand and dirt. |
| | Vertebrate | Describe a vertebrate animal you saw here today. | Science club | I saw a duck and birds |
| | Invertebrate | Describe an invertebrate animal you saw here today. | Science club | I saw a snail and lots of plankton. |
| | Aquatic invertebrate | Describe an aquatic invertebrate that you saw here today at the Elkhorn slough. Is it similar or different from the ones we have seen at the Watsonville slough? | Science club | I saw a polychaete worm and some are similar. |
| | Native | Describe or name something native you saw here today at the Elkhorn slough? | Science club | We saw that CA Poppy |
| | Non-native | Describe or name something non-native you saw here today at the Elkhorn slough? | Science club | We saw mustard |

| | | | | |
|---|---|---|---|---|
| Diversity | | How would you describe the diversity of life here compared to the Watsonville slough? Is there a higher diversity of life here at the Elkhorn slough, or lower diversity of life? | Science club | In the Watsonville slough the animals are more quiet and in the Elkhorn slough they are noisier. The diversity of life is higher at the Elkhorn slough. |
| Migration | | Name or describe an animal that migrates to the Elkhorn slough. | Science club | Pelican migrate |
| Adaptation | | Can you describe an adaptation that you saw here at the Elkhorn slough? | Science club | I saw pickleweed and it adapts really well to salt water. |
| Camouflage | | Can you describe an animal that camouflages well at the Elkhorn slough? | Mr. Murphy | I saw lots of snakes and frogs. |
| Breeds | | Can you name an animal that breeds here in the Elkhorn slough during the summer months? | Science club | Crabs come to the Elkhorn slough. So do sharks and sting rays. |
| | Ohlone Indians | Can you describe something left behind by the Ohlone Indians which is evidence that they used to inhabit the Elkhorn slough? | Science club | We saw lots of milk bottles. |
| Invasive | | Can you tell me what invasive means? | Science club | I think invasive means when a plant is used for so many things. |
| Restoration | | Can you tell me what restoration means? | Science club | I think it means when you take non-native plants and plant native ones. |
| Medicinal | | Can you tell me what medicinal means? | Science club | Ms. Lisa said they used poison hemlock to kill this person. Medicinal is when they used plants to make medicine. |

**Table 2**

***Jacquelina Post Pre Specific Term Scientific Concept Assessment***

| Scientific concept | Specific term | Question | Learned where? | Answer |
|---|---|---|---|---|
| Ecosystem | | How would you describe the ecosystem here at the Elkhorn slough? How is it similar or different from the Watsonville slough? | Science club | It is different because the Elkhorn slough is a mixture of both salt and fresh water. The Watsonville is only fresh water. |
| | Habitat | Describe a habitat that you saw here today at the Elkhorn slough. | Science club | Biome |
| | Wetland | Is the Elkhorn Slough a wetland and if so, explain why? | Science club | Yes, because it's a wetland because of all the ecosystem and habitats they provide for the animals. |
| | Slough | Can you name a synonym for wetland? | | Pond |
| | Biotic | Describe something biotic that you saw here today at the Elkhorn slough. | Science club | A white egret, crabs cormorants, seagulls, shark, frog, and a lizard |
| | Abiotic | Describe something abiotic that you saw here today at the Elkhorn slough. | Science club | Trees, dirt, bridge |
| | Vertebrate | Describe a vertebrate animal you saw here today. | Science club | Plankton, polychaete, mosquito larva |
| | Invertebrate | Describe an invertebrate animal you saw here today. | Science club | Lettuce, plants, algae |
| | Aquatic invertebrate | Describe an aquatic invertebrate that you saw here today at the Elkhorn slough. Is it similar or different from the ones we have seen at the Watsonville slough? | Science club | No, but except the polychaete larva |
| | Native | Describe or name something native you saw here today at the Elkhorn slough? | Science club | Plants and birds |
| | Non-native | Describe or name something non-native you saw here today at the Elkhorn slough? | Science club | Some plants and birds |

| | | | | |
|---|---|---|---|---|
| Diversity | | How would you describe the diversity of life here compared to the Watsonville slough? Is there a higher diversity of life here at the Elkhorn slough, or lower diversity of life? | Science club | It's in the middle |
| Migration | | Name or describe an animal that migrates to the Elkhorn slough. | Science club | Pelican |
| Adaptation | | Can you describe an adaptation that you saw here at the Elkhorn slough? | Science club | Some animals live in a mixture of water |
| Camouflage | | Can you describe an animal that camouflages well at the Elkhorn slough? | Science club | The pipefish, crabs, sharks |
| Breeds | | Can you name an animal that breeds here in the Elkhorn slough during the summer months? | Science club | Pelicans, crabs, egret |
| | Ohlone Indians | Can you describe something left behind by the Ohlone Indians which is evidence that they used to inhabit the Elkhorn slough? | Science club | Glass milk bottles, poles, migrating plants, bushes |
| Courtship behavior | | Can you tell me what courtship behavior means? | Science club | Want to have a relationship with the female duck |
| | Plumage | Can you tell me what plumage means? | Science club | Their feathers change by the seasons |
| Foraging | | Can you tell me what foraging means? | Science club | When a duck is feeding itself or taking care of itself |

## Table 3

### *Jacquelina Post Pre Specific Term Scientific Concept Assessment*

| Scientific concept | Specific term | Question | Learned where? | Answer |
|---|---|---|---|---|
| Ecosystem | | How would you describe the ecosystem here at the Elkhorn slough? How is it similar or different from the Watsonville slough? | Science club | Full of plants and places to hide. It is similar to Watsonville because they both have a large variety of animals. They are different because Elkhorn has salt water. |
| | Habitat | Describe a habitat that you saw here today at the Elkhorn slough. | Science class at school | One habitat in the Elkhorn slough that I saw was the water (fishes and crabs). |
| | Wetland | Is the Elkhorn Slough a wetland and if so, explain why? | Fourth grade field trip | Yes, because of all of the water, slough is another word for wetlands. |
| | Slough | Can you name a synonym for wetland? | | Slough |
| | Biotic | Describe something biotic that you saw here today at the Elkhorn slough. | Science club | Crabs |
| | Abiotic | Describe something abiotic that you saw here today at the Elkhorn slough. | Science club | Rocks |
| | Vertebrate | Describe a vertebrate animal you saw here today. | Science club | Great egret |
| | Invertebrate | Describe an invertebrate animal you saw here today. | Science club | Polychaete worm |
| | Aquatic invertebrate | Describe an aquatic invertebrate that you saw here today at the Elkhorn slough. Is it similar or different from the ones we have seen at the Watsonville slough? | Science club | Polychaete worm. It is similar to the one in the Watsonvill slough because they were both polychaete worms. |
| | Native | Describe or name something native you saw here today at the Elkhorn slough? | Science club | Sticky monkey bush |
| | Non-native | Describe or name something non-native you saw here today at the Elkhorn slough? | Science club | The plant that Socrates drank. |

| | | | | |
|---|---|---|---|---|
| Diversity | | How would you describe the diversity of life here compared to the Watsonville slough? Is there a higher diversity of life here at the Elkhorn slough, or lower diversity of life? | Science club | The diversity is larger because I saw more animals and plants. |
| Migration | | Name or describe an animal that migrates to the Elkhorn slough. | 3rd or 4th grade | Brown pelican |
| Adaptation | | Can you describe an adaptation that you saw here at the Elkhorn slough? | Science club | Gopher snake adapts to its surroundings because it finds out where to hide and all the places to go |
| Camouflage | | Can you describe an animal that camouflages well at the Elkhorn slough? | Somewhere else | Skeleton worm looks like a twig |
| Breeds | | Can you name an animal that breeds here in the Elkhorn slough during the summer months? | Science club | Sting rays |
| | Ohlone Indians | Can you describe something left behind by the Ohlone Indians which is evidence that they used to inhabit the Elkhorn slough? | Science club | Baskets and tools made out of shells and bones |
| Hermaphrodite | | Can you tell me what hermaphrodite means? | Science club | Both male and female |
| Cannibalism | | Can you tell me what cannibalism means? | Already knew it | Eats someone of the same species |

**Table 4**

***Margarita Post Pre Specific Term Scientific Concept Assessment***

| Scientific concept | Specific term | Question | Learned where? | Answer |
|---|---|---|---|---|
| Ecosystem | | How would you describe the ecosystem here at the Elkhorn slough? How is it similar or different from the Watsonville slough? | Science club | It is similar like the Watsonville wetlands because it is a habitat to some animals. |
| | Habitat | Describe a habitat that you saw here today at the Elkhorn slough. | 5th grade science class | I saw where the polychaete lives. |
| | Wetland | Is the Elkhorn Slough a wetland and if so, explain why? | Science club | Yes, because a wetland has plants, animals, and insects and that is what the Elkhorn slough is. |
| | Slough | Can you name a synonym for wetland? | | Slough |
| | Biotic | Describe something biotic that you saw here today at the Elkhorn slough. | Science club | I saw a crab that was dead. |
| | Abiotic | Describe something abiotic that you saw here today at the Elkhorn slough. | Science club | I saw a gopher snake. |
| | Vertebrate | Describe a vertebrate animal you saw here today. | Science club | I saw a seagull. |
| | Invertebrate | Describe an invertebrate animal you saw here today. | Science club | I saw lots of cocopods. |
| | Aquatic invertebrate | Describe an aquatic invertebrate that you saw here today at the Elkhorn slough. Is it similar or different from the ones we have seen at the Watsonville slough? | Science club | I saw a polychaete worm. |
| | Native | Describe or name something native you saw here today at the Elkhorn slough? | 6th grade science teacher | I saw a California poppy. |
| | Non-native | Describe or name something non-native you saw here today at the Elkhorn slough? | Science club | The European green crab. |

| | | | | |
|---|---|---|---|---|
| Diversity | | How would you describe the diversity of life here compared to the Watsonville slough? Is there a higher diversity of life here at the Elkhorn slough, or lower diversity of life? | Science club | Don't remember Elkhorn slough |
| Migration | | Name or describe an animal that migrates to the Elkhorn slough. | Science club | The pelican migrates. |
| Adaptation | | Can you describe an adaptation that you saw here at the Elkhorn slough? | Science club | The crabs are adapted to hide or play dead when it thinks a predator is coming. |
| Camouflage | | Can you describe an animal that camouflages well at the Elkhorn slough? | Science club | The fish we saw camouflages. |
| Breeds | | Can you name an animal that breeds here in the Elkhorn slough during the summer months? | Science club | The eggs in the green European crab. |
| | Ohlone Indians | Can you describe something left behind by the Ohlone Indians which is evidence that they used to inhabit the Elkhorn slough? | | The sticks they made the baskets out of. |
| Hermaphrodite | | Can you tell me what hermaphrodite means? | Science club | Both female and male |
| Cannibalism | | Can you tell me what cannibalism means? | Science club | Eat each other |

**Parent Interview**

**Q1.** Have you ever been to the Watsonville Wetlands?

**Q2:** Did you go with your family? Did you go with your child who is participating in this study?

**Q3:** What was your experience like?

**Q4:** Do you have any interests concerning wetlands?

**Q5:** Do you know that there are agriculture fields surrounding many of the wetlands?

**Q6:** What are your thoughts about this?

**Q7:** Do you think it is important to learn about wetlands, and if so, why?

**Q8:** Would you be interested in joining us on our field outings?

**Q9:** Do you have any questions for me?

**Q10:** What are your thoughts about nature? What do you think about the natural environment?

**Q11:** Do you see yourself connected with nature?

**Q12:** What are your thoughts about experiencing nature with your children?

**Q13:** Do you make an effort to experience nature with your children?

**Parent Homework Assignments**

**For Cecelia's father.** "You mentioned during the parent interview that you enjoy gardening. What kind of plants, flowers, vegetables or fruits do you plant? You can also draw a picture. Please give the letter to Cinthya and she'll give it back to me on June

25th."

"Mencionaste durante la entrevista de padres que disfrutas la jardinería. Qué clase de plantas, flores, vegetales o frutas siembras o plantas? También puedes hacer un dibujo. Por favor de dar la carta a Cinthya y ella me la entregara el 25 de junio."

**For Jacquelina's mother.** "You mentioned during the parent interview that you enjoy seeing the hummingbirds in the tree across the street. Can you describe what you see and why you enjoy seeing it? You can also draw a picture. Please give the letter to Jackey and she'll give it back to me on June 25th."

"Mencionaste durante la entrevista de padres que disfrutas mirar a los colibrís en el árbol al otro lado de la calle. Puedes describir lo que vez y por qué te gusta verlo? También puedes hacer un dibujo. Por favor de dar la carta a Jackey y ella me la entregara el 25 de junio."

**For Charlena's mother.** "You mentioned during the parent interview how important it is that people pick up their trash in nature. How do you think picking up trash will help the environment and animals in the wetlands? You can

also draw a picture.  Please give the letter to Chantal and she'll give it back to me on June 25th."

“Mencionaste durante la entrevista de padres la importancia de que cada quien recoja su basura.  Como piensas que el recoger la basura ayudara al medio ambiente y a los animales en los humedales?  También puedes hacer un dibujo.  Por favor de dar la carta a Chantal y ella me la entregara el 25 de junio.”

**For Margarita’s father.** "You mentioned during the parent interview that spraying insecticides/pesticides too close to the water can pollute the water table.  Can you describe how this happens?  You can also draw a picture.  Please give the letter to Maritza and she'll give it back to me on June 25th."

“Mencionaste durante la entrevista de padres que la pulverización de insecticidas y pesticidas muy cerca del agua puede contaminar la mesa de agua.  Puedes describir como sucede eso?  También puedes hacer un dibujo.  Por favor de dar la carta a Maritza y ella me la entregara el 25 de junio.”

## Guiding Principles for Learning and Teaching

### Principle 1

Tapping into students' intellectual resources, i.e., prior knowledge, experiences, everyday and native language, funds of knowledge, and interests to inform the learning and teaching practices in addition to fostering congruency between home and school (informal science learning project).

### Principle 2

Providing dynamic instruction and assessment for developing scientific language and inquiry skills. Providing guided facilitation and imitation for developing scientific language (speaking and writing) and social practices within students' zone of proximal development. Providing learning opportunities within the spiral of learning and teaching through inquiry. Providing opportunities for students to use their native language, through the use of cognates, as a foundation for building and making connections across languages: scientific- native language (Spanish) through the use of cognates- everyday language. Students created and used generative semiotic tables to develop these connections.

### Principle 3

Providing opportunities to practice inquiry principles, i.e., build a community of inquirers within a real life context; sharing experiences and co-constructing knowledge through progressive discourse; and developing scientific ways of thinking, writing, and doing.

**Principle 4**

Providing multiple participatory opportunities, i.e., with the teacher/ researcher, science educator, visiting scientist, and other members within the community to experience new roles from multiple entry points, i.e., interested students, experts in a particular area of interest, budding scientists, advocates for the wetlands, etc. Presenting scientific findings to an audience of local community members, parents, and science educators/scientists. Providing an opportunity for students to respond to questions and provide justifications for their findings.

**Teacher Researcher Evaluation Sheet**

(Based on a Likert scale 1-5, 1 representing least)

1. Does the teacher/researcher provide guided facilitation in order for the child to transform an external action into a recognized, meaningful action?
2. Does the teacher/researcher provide opportunities for generative discussions on students' topic of interest?
3. Does the teacher/researcher provide resources for the students to explore their topics of interest?
4. Does the teacher/researcher mediate the discussions and allow the students' voices to take center stage?
5. Does the teacher/researcher provide assistance with "demonstrations, leading questions, and by introducing the initial elements of the task's solution?" (Vygotsky, 1987, p. 209).
6. Does the teacher/researcher provide opportunities for students to engage collaboratively with adults?
7. Does the teacher/researcher provide opportunities for students to engage collaboratively with peers?
8. Does the teacher/researcher guide and facilitate students' note taking, scientific speaking/writing, and organizational skills in a meaningful and informed way?

9. Does the teacher/researcher build connections between students' everyday concepts and ways of knowing with scientific concepts and ways of doing through systematic instruction, modeling (imitation), and knowledge construction?
10. Does the teacher/researcher provide opportunities for students to take action and demonstrate their understandings through action?
11. Does the teacher/researcher provide an open space (during pre/post learning and teaching sessions) for students to express whether they have developed a deeper understanding of a topic and in what ways?
12. Does the teacher/researcher observe and take notes on how students are engaged, what they are doing, and what they are saying during the spiral of learning and teaching through inquiry sessions, especially during the knowledge building phase?
13. Does the teacher/researcher provide opportunities for parental participation?
14. Does the teacher/researcher integrate parents' funds of knowledge and areas of expertise into the students' learning experiences?
15. Does the teacher/researcher provide a platform for students to present their findings from their scientific inquiry projects?
16. Does the teacher/researcher provide an opportunity for students to voice their opinions and concerns?

17. Does the teacher/researcher provide an opportunity for students to take action and apply what they have learned to real-life contexts?
18. Does the teacher-researcher provide an opportunity for students to bring awareness to the socially valued ways of thinking and acting on a particular issue of concern to them?

**Student Rating Sheets**

***(scale 1-5)***

**A. How would you rate this activity for helping you learn? What <u>specifically</u> helped you or didn't help you learn?**

***<u>1 not helpful!</u> <u>2 a little bit helpful</u> <u>3 helpful</u> <u>4 very helpful</u> <u>5 Wow!</u>***

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**B. How would you rate this activity for level of enjoyment? Please provide an explanation.**

***<u>1 not fun!</u> <u>2 a little bit fun</u> <u>3 fun</u> <u>4 very fun</u> <u>5 Wow!</u>***

**Students' ratings related to learning activities pertaining to each research question.**

**Cecelia (**Case study 1**)**

**RQ1:**

**Students' ratings in helping them learn:**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **5**
2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such a plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **5**

   **Comment:** "Yes, because it helped me in my Spanish words."
3. When you wrote letters to science educators and/or scientists. **5**

   **Comment:** "Yes, because I learned a lot of scientific stuff."

The first two questions pertain to the semiotic tools used to facilitate the development of scientific concepts and specific terms with everyday words (Table 3) and scientific concepts/specific terms, cognates, everyday words (Table 4). Based on Cecelia's ratings, it appears that these tools were helpful with Cecelia's learning of scientific language and her native language, Spanish. Interestingly, Cecelia does not state that the cognates assisted her with learning scientific concepts, but rather learning Spanish words. In addition, Cecelia used these semiotic tables when

constructing her science letters to science educators and/or scientists. Cecelia rated the science letter writing activity 5, which indicates that this activity helped with her learning. This was a surprise to say the least, as my experience with 6th grade students engaged in the writing process is usually one of indifference rather than a positive experience that assisted them in their learning.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project.

   **4**

   **Comment:** "Because I learned more words."

2. When Cindy would talk with you about the wetlands, animals, etc. **3**
3. When we went to the Elkhorn Slough. **5**

   **Comment:** "Yes, because I saw animals that I never had saw."

4. When Kenton showed us the European green crab and other animals, plants, etc.

   **5**

5. When Kenton showed us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **5**
6. When we were using the microscopes and saw animals magnified with Kenton.

   **5**

   **Comment:** "Yes, because I saw aquatic invertebrates."

7. When you spoke with Crysti at The Nature Center. **5**

8. Your general feeling/thinking about the Science Club. **5**

   **Comment:** "Because it helped me a lot in school."

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **5**

These ratings provide evidence that Cecelia's experiences in particular activities with particular participants ranged from helpful to Wow! In fact, Cecelia states that the Science club helped her in school. Again, the intersection of formal science learning in school with informal science learning out of school intersects with a successful outcome. Not only did Cecelia demonstrate an increase in scientific language usage, but more importantly, and understanding of the concepts/terms and a profound appreciation for science, nature, and how both are essential to live.

**Students ratings in level of enjoyment**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **3**

   **Comment:** I didn't like how we were sitting for like 2 hours.

2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such as plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **5**

   **Comment:** Because it was crazy seeing so many words that are the same.

3. When you wrote letters to science educators and/or scientists. **5**

**Comment:** Because they made my learning fun.

These ratings indicate that Cecelia perceived these activities as fun to Wow! The first comment about not enjoying sitting for two hours may have felt like two hours, but it was more along the lines of 45 minutes to an hour. Often before or after a field day, we would discuss concepts and terms encountered in their research or that came up when out in the field. Early in the study, these discussions occurred in The Nature Center and the students sat on the carpet because there were no tables or chairs. This changed as the teacher/researcher found another space (Pajaro Valley High School) which had adequate tables and chairs for the students. This change in space made a significant difference in their mood, attention span, and overall disposition. Note: They loved going to the high school.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project. **4**

**Comment:** Yes, because it was crazy.

2. When Cindy would talk with you about the wetlands, animals, etc. **1**

**Comment:** I don't like her; not trying to be mean.

3. When we went to the Elkhorn Slough. **5**

**Comment:** Because I saw animals I never saw.

4. When Kenton showed us the European green crab and other animals, plants, etc. **5**

5. When Kenton show us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **5**

6. When we were using the microscopes and saw animals magnified with Kenton. **5**

7. When you spoke with Crysti at The Nature Center. **5**

8. Your general feeling/thinking about the Science Club. **4**

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **5**

It is clear based on Cecelia's ratings that every activity with Kenton was Wow! What is also clear are Cecelia's feelings about Cindy, i.e., not enjoying talking with her in the least (1 not fun!). This was not surprising as the students often confided with me throughout the project about how they felt Cindy did not like them, did not care about them, appeared mad, was more interested in animals than them, etc. Upon reflecting on this, I can remember Cindy being more concerned with us getting in the way of visitors with our backpacks, notebooks, and boots, rather than making an effort to welcome us. In fact, she showed up late (20 minutes) twice during the winter months and I can remember waiting for her in the cold thinking, "Why is she late? She knows we're waiting for her to open the door to The Nature Center." As a result, I felt it was necessary to find a neutral space where we could work comfortably (tables and chairs), have access to computers (for students' research on their scientific inquiry projects), and have positive interactions with others (Mary who was a

sustainable garden teacher who offered workshops for the public every third Saturday of the month). In contrast, Cecelia rated her interaction with Crysti (another science educator) 5, Wow! This wasn't surprising as I recall Cecelia taking an interest in Crysti, even though they had only met once, because Crysti demonstrated a genuine interest in the students as whole persons. She was very warm, polite, curious, and Latina.

**RQ2:**

**Students' ratings in helping them learn**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **5**
2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates **5**
3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **5**

   **Comment:** Because they helped me a lot in the invertebrates I didn't understand.
4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **2**

5. When you used the computer to research information about your animal/plant of interest **5**
6. When you designed your Science Inquiry Book **5**

   **Comment:** Yes it helped me because I got to organize my data.
7. When we discussed the data together and organized it into tables or graphs **5**
8. When you prepared and practiced your presentation in front of another student **5**
9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **5**

   **Comment:** Because it helped me identify some animals.
10. When you used clay or watercolors to design your animal of interest for the presentation **5**
11. When you did your presentation in front of your family **5**

    **Comment:** I love this day because I talked about the things I loved.

Overall, these ratings indicate that the scientific inquiry activities were considered as, Wow, with regard to helping Cecelia learn. Specifically, questions 1, 5, and 7 relate to the process of inquiry (collecting data, researching information, and organizing information into tables or graphs). These three aspects of the scientific inquiry process were rated 5 (Wow!). With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Cecelia rated this 5 (Wow!). She also

rated practicing and performing her presentation as Wow, stating, “I love this day because I talked about the things I loved.”

With regard to identifying aquatic invertebrates, Cecelia rated these 5 (Wow!), whether receiving assistance from PVHS mentors or Ms. Lisa and Roxanne. However, doing this activity without assistance was rated 2 (a little bit helpful). Cecelia had stated during the activity that it was “too hard” to do with just her peers. She felt she needed more guided facilitation from either the mentors, or Roxanne and the teacher/researcher.

With regard to collecting water quality data, Cecelia rated this 5 and stated how it helped her identify some animals. During the water quality activity, students would also survey their surroundings and record plants, animals, litter, and other observations. The teacher/researcher and Roxanne most often facilitated the recorder with these field observations. Finally, Cecelia rated using clay or watercolors to design a representation of her plants a 5. Note: Cecelia did a watercolor painting for each plant in her inquiry study. These were mounted and put on display during the presentations. It can be argued that this creative display of artwork is an artistic form of learning.

**Students’ ratings in level of enjoyment:**

The following eleven ratings pertain to the development of scientific inquiry and students’ motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **5**

   **Comment:** I remember I would always scream because of the animals.

2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates **5**

   **Comment:** Thanks to what's her face, I got my phone back.

3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **5**

   **Comment:** Because I love the little animals.

4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **2**

   **Comment:** Because it was hard.

5. When you used the computer to research information about your animal/plant of interest **5**

   **Comment:** Because they were beautiful pictures on the Internet.

6. When you designed your Science Inquiry Book **5**
7. When we discussed the data together and organized it into tables or graphs **5**
8. When you prepared and practiced your presentation in front of another student **5**

9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **5**

10. When you used clay or watercolors to design your animal of interest for the presentation **5**

    **Comment:** Because I like doing art.

11. When you did your presentation in front of your family 5

    **Comment:** Because it was fun having everyone listen to what I love.

Overall, these ratings demonstrate that Cecelia regarded all but one of the activities as Wow with regard to level of enjoyment. Specifically, questions 1, 5, and 7 relate to the process of inquiry (collecting data, researching information, and organizing information into table or graphs). These three aspects of the scientific inquiry process were rated 5 (Wow!). With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Cecelia rated this 5 (Wow!). She also rated practicing and performing her presentation as Wow, stating, "Because it was fun having everyone listen to what I love."

With regard to identifying aquatic invertebrates, Cecelia rated these 5 (Wow!), whether receiving assistance from PVHS mentors or Ms. Lisa and Roxanne. However, Cecelia rated this activity 2 (a little bit fun) without assistance from anyone. Cecelia had stated during the activity that it was "too hard" to do this

activity with just her peers. She felt she needed more guided facilitation from either the mentors or Roxanne and the teacher/researcher.

With regard to collecting water quality data, Cecelia rated this 5 (Wow!). Lastly, Cecelia rated using watercolors to represent her plants of interest 5, stating, "Because I like doing art." Cecelia's watercolor paintings were mounted and displayed on the day of the presentations.

**RQ3:**

With regard to rating writing parent letters, Cecelia rated this activity 5 (Wow) for helping her learn and 5 (Wow) for level of enjoyement. She also stated in her post-assessment interview that of all the Science club activities, having her parents see her present was her favorite activity. The parents also shared the same sentiment in that they both stated how they were nervous on the day of the presentations because they had never seen Cecelia give a presentation. They expressed how it was a 'big deal' for them and how proud they were of Cecelia. Perhaps since Cecelia rarely sees her parents, only for a short time in the evening when they return home from work, that the Science club activities may have provided an entry point for sharing experiences and information, learning from each other, and celebrating key moments, such as the day of the student presentations.

**Jacquelina (Case study 2)**

**RQ1:**

**Students' ratings in helping them learn:**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **5**

   **Comment:** Because we got to learn all what the words meant.

2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such a plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **4**

   **Comment:** Because we got to learn what they meant in Spanish.

3. When you wrote letters to science educators and/or scientists. **4**

   **Comment:** Because that is a way of appreciation to them.

The first two questions pertain to the semiotic tools used to facilitate the development of scientific concepts and specific terms with everyday words (Table 3) and scientific concepts/specific terms, cognates, everyday words (Table 4). Based on Jacquelina's ratings, it appears that these tools were helpful with Jacquelina's learning of scientific language and her native language, Spanish. Interestingly, Jacquelina does not say that the cognates assisted her with learning scientific concepts, but rather what the concepts also mean in Spanish. In addition, Jacquelina used these semiotic tables when constructing her science letters to science educators and/or scientists.

Jacquelina rated the science letter writing activity 4, which indicated that this activity was very helpful in her learning scientific language.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project.

   **4**

   **Comment:** Because it helped me to get started in science.

2. When Cindy would talk with you about the wetlands, animals, etc. **3**

   **Comment:** Because she was mad/attitude. Because she introduced us to the wetlands and the ecosystems.

3. When we went to the Elkhorn Slough. **5**

   **Comment:** We saw a lot of ecosystems.

4. When Kenton showed us the European green crab and other animals, plants, etc.

   **4**

   **Comment:** We learned about how it migrated over here.

5. When Kenton showed us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **3**

   **Comment:** We got to look at them up close.

6. When we were using the microscopes and saw animals magnified with Kenton.

   **4**

   **Comment:** We look at them up closer.

7. When you spoke with Crysti at The Nature Center. **4**

   **Comment:** She told us what type of animals we saw.

8. Your general feeling/thinking about the Science Club. **5**

   **Comment:** Because we got to have time with you and friends.

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **5**

   **Comment:** We shared how we felt to you.

10. When we went to UCSC and you spoke with Miriam. **5**

    **Comment:** She taught us about the aphids.

These ratings provide evidence that Jacquelina's experiences in particular activities with particular participants (Gutierrez & Rogoff, 2003) ranged from helpful (3) to Wow! (5). What's particularly interesting is how Jacquelina states how sharing and spending time with her peers, me, Roxanne (research assistant), Cindy, Crysti, Kenton, etc was helpful to her learning. Even though she states that she felt Cindy was mad and had an attitude, she still acknowledges the fact that Cindy did introduce the students to the Watsonville wetland ecosystem. Specifically, she states how sharing how she felt with the teacher/researcher was extremely helpful (Wow!) with her learning. This is interesting because it demonstrates how critical it is to allow students an opportunity to express what is happening in their lives rather than just focusing the content or learning objective.

**Students' ratings in level of enjoyment**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **3**
2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such as plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **4**
3. When you wrote letters to science educators and/or scientists. **4**

These ratings indicate that Jacquelina considered learning about scientific concepts and/or specific terms as fun (3). In particular, she rates learning about cognates and writing science letters as very fun (4). Based on observations from the teacher/ researcher, Jacquelina loved typing letters using the computers at Pajaro Valley High School. This occurred when Jacquelina wrote her first letter toMiriam. She was very focused and thorough with her writing.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project.

2. When Cindy would talk with you about the wetlands, animals, etc. **1**

3. When we went to the Elkhorn Slough. **5**

**Comment:** Lot of fun.

4. When Kenton showed us the European green crab and other animals, plants, etc. **4**

5. When Kenton show us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **4**

6. When we were using the microscopes and saw animals magnified with Kenton. **5**

7. When you spoke with Crysti at The Nature Center. **4**

8. Your general feeling/thinking about the Science Club. **5**

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **5**

10. When we went to UCSC and you spoke with Miriam. **5**

**Comment:** Lot of fun

It is clear based on Jacquelina's ratings that every activity with Kenton was rated either very fun (4) or Wow! (5). In addition, Jacquelina rated her time spent with (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other as Wow! (5), however, when specifically referring to Cindy, not fun! (1). Cecelia and Jacquelia perceptions of Cindy are similar. They both did not like her and considered her unapproachable, in addition, both rated Crysti (another science educator) favorably. It will be interesting to see how Charlena and Margarita rate Cindy as well. Wow ratings also went to Miriam and the general feeling/thinking of the Science club experience. This provides evidence that not only did Jacquelina feel/think the Science club experience was (Wow!) helpful in her learning about scientific concepts and/or specific terms, but was also a very fun (Wow!) experience.

**RQ2:**

**Students' ratings in helping them learn**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **4**

   **Comment:** Because we got to know our animal more better.

2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates **5**

   **Comment:** Because they showed us all types of aquatic invertebrates.

3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **4**

   **Comment:** Because we saw them up closer and identified them all.

4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **3**

   **Comment:** Because I couldn't consintrate (concentrate) the microscope well.

5. When you used the computer to research information about your animal/plant of interest **5**

   **Comment:** Because we learned more about our interest.

6. When you designed your Science Inquiry Book **4**

   **Comment:** Because we got to share our project that we did.

7. When we discussed the data together and organized it into tables or graphs **3**

   **Comment:** Because it was fast and confusing for me.

8. When you prepared and practiced your presentation in front of another student **4**

   **Comment:** It got me all prepared.

9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **4**

   **Comment:** We saw how the water was.

10. When you used clay or watercolors to design your animal of interest for the presentation **5**

    **Comment:** We got to show our work we did.

11. When you did your presentation in front of your family **3**

    **Comment:** Yes, but then no, because my family couldn't make it.

Overall, these ratings indicate that the scientific inquiry activities were considered as, helpful to Wow, with regard to helping Jacquelina learn. Specifically, questions 1, 5, and 7 relate to the scientific inquiry process (collecting data, researching information, and organizing information into tables or graphs). However, with regard to question 7, which asked how helpful it was for students when we

discussed the data together and organized it into tables or graphs, Jacquelina rated this activity 3 (helpful), but her comment suggests it wasn't, "Because it was fast and confusing for me." Reflecting on Jacquelina's comment, it is understandable why she would say this. We had to move quickly as we were approaching the presentation day and the teacher/researcher may have moved too fast with showing students how to organize their data into tables and graphs.

With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Jacquelina rated this 4 (very helpful), commenting, "Because we got to share our project that we did." Jacquelina also rated practicing her presentation 4 (very helpful) because, "It got me all prepared. However, she rated the day of the presentation 3 (helpful) and stated, "Yes, but no because my family couldn't make it."

With regard to identifying aquatic invertebrates receiving assistance from the PVHS mentors, Jacquelina rated this activity 5 (Wow) commenting, "Because they showed us all types of aquatic invertebrates." When the teacher/researcher and Roxanne assisted the students, Jacquelina rated this activity 4 (very helpful) commenting, "Because we saw them up closer and identified them all." When identifying aquatic invertebrates without assistance, Jacquelina rated this 3 (helpful) commenting, "Because I couldn't consintrate (concentrate) the microscope well."

With regard to collecting water quality data, Jacquelina rated this activity 4 (very helpful) commenting, "We saw how the water was." Lastly, when using clay or watercolors to represent her animal of interest (ruddy duck), Jacquelina used clay to

mold a beautiful representation of the ruddy duck. She also painted her mini-sculpture. With regard to helping her learn, Jacquelina rated this activity 5 (Wow), commenting, "We got to show our work we did.

**Students' ratings in level of enjoyment**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **4**
2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates **5**

   **Comment:** To see how well we know the invertebrates.
3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **5**
4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **4**
5. When you used the computer to research information about your animal/plant of interest **4**

   **Comment:** We got to know them better.
6. When you designed your Science Inquiry Book **5**
7. When we discussed the data together and organized it into tables or graphs **4**

8. When you prepared and practiced your presentation in front of another student **4**

   **Comment:** Got to share.

9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **5**

10. When you used clay or watercolors to design your animal of interest for the presentation **5**

    **Comment:** Lots of extreme fun. We got to express ourselfs (ourselves).

11. When you did your presentation in front of your family **4**

    **Comment:** No, because my parents didn't make it.

Overall, these ratings demonstrate that Jacquelina regarded the three scientific inquiry activities (1, 5, and 7) 4 (very enjoyable). These activities pertain to scientific inquiry skills (collecting data, researching information, and organizing information into tables and graphs). With regard to designing her Scientific Inquiry Book, Jacquelina rated this activity 5 (Wow) for level of enjoyment. With regard to practicing her presentation, Jacquelina rated this 4 (very helpful) stating, "Got to share." However, when rating and commenting on the day of the presentation, Jacquelina's feelings were mixed. She rated the activity 4 (very helpful), yet her comment suggests ambivalence, "No, because my parents didn't make it." This

feeling from Jacquelina was very apparent on the day of the presentation. She was happy to be there, but at the same time, sad that her parents were not there.

With regard to identifying aquatic invertebrates, either receiving assistance from the PVHS mentors or Ms. Lisa and Roxanne, Jacquelina rated this activity 5 (Wow). However, without assistance, she rated the activity one notch lower 4 (very helpful). When rating the water quality activity for level of enjoyment, Jacquelina rated this 5 (Wow!) This is not surprising as Jacquelina was always the first to volunteer to collect a water sample.

Lastly, with regard to using clay and/or watercolors to represent their plant and/or animal of interest, Jacquelina rated this 5 (Wow!). She used clay to sculpt a male ruddy duck. She also painted it as well (using a very bright blue for its beak). Her comment, "Lots of extreme fun. We got to express ourselves (ourselves)," says how she feels about this art activity. All of the study thoroughly enjoyed representing their plant and/or animal of interest through artistic means, i.e., using clay to form a sculpture or water colors to paint their plants (flowers).

**RQ3:**

Jacquelina rated writing letters to her parents 5 (Wow) for helping her learn and also for level of enjoyment. Her comment for helping her learn said, "Because it helped me communicate with them and tell them what's going on," and her comment for enjoyment was, "We got to share fun things with them." These high ratings in addition to how parent involvement helped Jacquelina learn and how she had fun

sharing what she was learning demonstrate that parent participation in a child's learning is powerful and meaningful for the student.

**Charlena** (Case study 3)

**RQ1:**

**Students' ratings in helping them learn**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **3**
2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such a plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **1**
3. When you wrote letters to science educators and/or scientists. **2**

The first two questions pertain to the semiotic tools used to facilitate the development of scientific concepts and specific terms with everyday words (Table 3) and scientific concepts/specific terms, cognates, everyday words (Table 4). Based on Charlena's ratings, it appears that Table 3 was helpful in her learning of scientific and/or specific terms, however Table 4 (with Spanish cognates) was not. In fact, she rated this activity 1 (not helpful!). This is interesting and reminds me my post-interview discussion with Charlena's mother (Maria). We were talking about the students' presentations and Maria expressed how impressed she was with Margarita's presentation, i.e., translating in Spanish for parents who only spoke Spanish. Charlena was in the room during this parent interview and appeared annoyed with her mother. Charlena's mother said, "I try and encourage Charlena to speak Spanish, to

become more bilingual, but she resists." When I asked Charlena why this was so, she said, "Because we live in the United States and people here speak English, not Spanish." Interestingly, Charlena uses Spanish to communicate with her father (semi-fluent in English), but not with her mother (fluent in English). Her attitude about speaking English and not Spanish may explain the low rating for the cognate activity, i.e., using Table 4 to bridge student's native language (Spanish) to scientific concepts and/or specific terms. Charlena also rated writing science letters a 2 (a little bit helpful). This is understandable as Charlena mentioned in her post written statement had she gets tired and sleepy when she has to write about something she doesn't want to write about. This was apparent in her second letter to Noelle, however, her third letter to Kenton demonstrated not only enthusiasm, but also specific examples and explanations of her experiences both in the field and laboratory while visiting the Elkhorn slough.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project. **3**
2. When Cindy would talk with you about the wetlands, animals, etc. **4**
3. When we went to the Elkhorn Slough. **5**
4. When Kenton showed us the European green crab and other animals, plants, etc. **5**

5. When Kenton showed us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **3**
6. When we were using the microscopes and saw animals magnified with Kenton. **4**
7. When you spoke with Crysti at The Nature Center. **3**
8. Your general feeling/thinking about the Science Club. **2**

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **5**

These ratings provide evidence that Charlena's experiences in particular activities with particular participants (Gutierrez & Rogoff, 2003) ranged from 2, (a little bit helpful) to 5 (Wow!). Most surprising is Charlena's low rating, 2 (a little bit helpful) of the Science club in general. Perhaps since Charlena had participated in the pilot study for six months prior to the doctoral study, she may have felt that her experiences at the Watsonville slough were saturated, i.e., in other words, that she really didn't learn anything knew. This is somewhat puzzling because her post/pre scientific concept and/or specific term assessment at the Elkhorn slough revealed that she learned 13 concepts and terms from the Science club experience (ecosystem, biotic, abiotic, vertebrate, invertebrate, aquatic invertebrate, native, non-native, diversity, adaptation, breeds, Ohlone Indians, hermaphrodite). She also learned about

her animal of interest (polychaete worm), even though she and Margarita found only one at the Watsonville slough. A member check on this rating would have provided more clarity as to why she rated the Science club experience a little bit helpful in her learning. Activities she considered helpful were the wetland book at the beginning of the study, collecting aquatic invertebrates with Kenton, and her discussion with Crysti. Activities she considered very helpful were talking with Cindy about the wetlands and asking her questions in addition to using the microscopes with Kenton. Finally, activities Charlena rated as 5, (Wow!) are, not surprising, going to the Elkhorn slough, learning about the European green crab, and talking/collaborating with me, Roxanne, Cindy, Crysti, Kenton, and others. My interpretation of Charlena's high rating of her experiences at the Elkhorn slough is attributed to the fact that this was a novel experience for her, i.e., doing and seeing new things and meeting a scientist (Kenton) who took the time to show the students: (1) how to properly use a net to collect specimens for observation, (2) how non-native species are 'imported' into the Elkhorn slough, and (3) how to use high powered microscopes to identify aquatic invertebrates (including polychaete larvae) they had never seen before.

**Students' ratings in level of enjoyment**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **1**

2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such as plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **1**
3. When you wrote letters to science educators and/or scientists. **2**

These ratings indicate that Charlena considered learning about scientific concepts and/or specific terms as not fun (1) to a little bit fun (2). This is understandable as Charlena mentioned in her post written statement that she enjoys being outdoors doing hands-on learning (touching things) rather than inside doing paper work and writing about things she does not want to write about (makes her tired and sleepy).

Note: At the beginning of the study, when we were generating a list of words we came across in the field or in their research reports, the scientific concepts and specific terms were written on 3 x 5 index cards. Each student had their own stack and did their own writing. When we had generated a stack of cards, tables were constructed. Note: This writing activity took place at The Nature Center on either the carpet or very small children's table with tiny chairs (very uncomfortable ergonomics). When the students expressed their discomfort, the teacher/researcher sought a more suitable place (Pajaro Valley High School) to work.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project. **1**

2. When Cindy would talk with you about the wetlands, animals, etc. **1**

3. When we went to the Elkhorn Slough. **5**

4. When Kenton showed us the European green crab and other animals, plants, etc. **5**

5. When Kenton show us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **5**

6. When we were using the microscopes and saw animals magnified with Kenton. **5**

7. When you spoke with Crysti at The Nature Center. **4**

8. Your general feeling/thinking about the Science Club. **5**

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **3**

It is clear based on Charlena's ratings that all experiences at the Elkhorn slough were rated 5 (Wow!) for level of enjoyment. In addition, she rated the Science club a 5 (Wow!) for level of enjoyment. She rates her time with Crysti a 4 (very enjoyable), and a 1 (not enjoyable!) with Cindy. This is interesting and is in alignment with both Cecelia and Jacquelina's assessment of their experiences with Cindy. Interestingly, she rates speaking with me, Roxanne, Cindy, Kenton, and others a 3 (enjoyable.) Lastly, she rates the teacher/researcher's reading of the wetland book

a 1 (not fun!). This is understandable based on her post written statement of preferring to be outdoors doing hand-on learning (touching things).

**RQ2:**

**Students' ratings in helping them learn**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **5**
2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates (absent)
3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **5**
4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **4**
5. When you used the computer to research information about your animal/plant of interest **5**
6. When you designed your Science Inquiry Book **5**
7. When we discussed the data together and organized it into tables or graphs **3**
8. When you prepared and practiced your presentation in front of another student **2**

9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **3**

10. When you used clay or watercolors to design your animal of interest for the presentation **1**

    **Comment:** But very enjoyable

11. When you did your presentation in front of your family **2**

Overall, these ratings indicate that the scientific inquiry activities were considered helpful to Wow, with regard to helping Charlena learn. Specifically, questions 1, 5, and 7 relate to the process of inquiry (collecting data, researching information, and organizing information into tables and graphs). These three aspects of the scientific inquiry process were rated 3 (helpful) to 5 (Wow!). With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Charlena rated this 5 (Wow!). However, Charlena rated practicing her presentation and performing her presentation 2 (a little bit helpful) with regard to helping her learn.

When identifying aquatic invertebrates, Charlena rated these 5 (Wow) when Ms. Lisa and Roxanne assisted the students and 4 (very helpful) without assistance. Note: Charlena was absent when the high school mentors showed the students how to identify aquatic invertebrates.

When rating water quality measurements, Charlena rated this 3 (helpful). Finally, Charlena rated using clay or watercolors to represent her animal of interest 1 (not helpful) with regard to helping her learn. However, she did find the activity very enjoyable, stating, "But very enjoyable."

**Students' ratings in level of enjoyment**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **5**
2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates (absent)
3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **5**
4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **4**
5. When you used the computer to research information about your animal/plant of interest **4**
6. When you designed your Science Inquiry Book **2**
7. When we discussed the data together and organized it into tables or graphs **1**

8. When you prepared and practiced your presentation in front of another student **4**
9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **3**
10. When you used clay or watercolors to design your animal of interest for the presentation **5**
11. When you did your presentation in front of your family **4**

Overall, these ratings indicate that the scientific inquiry activities (questions 1, 5, and 7) ranged from 1 (not enjoyable) for organizing data into tables and graphs, to 5 (Wow!) for collecting data on her animal of interest, to 4 (very enjoyable) for using the computers to research information on the polychaete worm. The teacher/researcher did not realize that Charlena found organizing the data into tables and graphs unenjoyable. Perhaps it has to do with the fact that the teacher/ researcher rushed through this inquiry step due to time constraints. Interestingly, Jacquelina also rated this low and said it was too fast and confusing.

With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Charlena also rated this 2 (a little bit enjoyable). This was surprising to the teacher/researcher, as it appeared that Charlena was enjoying

herself when ever she was working on it. Charlena rated practicing and presenting her presentation 4 (very enjoyable).

When identifying aquatic invertebrates, Charlena rated these activities 5 (Wow) when receiving assistance from the teacher/researcher and Roxanne, and 4 (without assistance). With regard to collecting water quality data, Charlena rated this activity 3 (enjoyable). Finally, Charlena rated using clay to represent her polychaete 5 (Wow!) with regard to level of enjoyment. Charlena used clay to create a polychaete sculpture. She also painted it using the same colors she observed when we found one at the Watsonville slough.

**RQ3:**

Finally, Charlena rated writing letters to her parents 1 (not helpful) with regard to helping her learn, and 1 (not enjoyable) with regard to level of enjoyment. This is somewhat consistent with Charlena's post interview in addition to the pre and post parent interviews which revealed a lack of sharing knowledge, experiences, and materials (Earth cards). Thus it appears that the data sources did not triangulate with regard to Charlena's parents' funds of knowledge informing Charlena's experiences in the Science club. Charlena's mother did however provide financial (work) and physical (attended presentation and parent interviews) support, but there is some evidence of a lack of intellectual and emotional support from her mother.

**Margarita** (*Case study 4*)

**RQ1:**

**Students' ratings in helping them learn:**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **3**
2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such a plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **2**
3. When you wrote letters to science educators and/or scientists. **4**

The first two questions pertain to the semiotic tools used to facilitate the development of scientific concepts and specific terms with everyday words (Table 3) and scientific concepts/specific terms, cognates, everyday words (Table 4). Based on Margarita's ratings, it appears that the first semiotic table (Table 3) was helpful to her learning of scientific concepts, yet the cognate table (Table 4) was only considered a little bit helpful. Her rating of science letters was rated very helpful. Although Margarita did not provide specific examples or explanations in some of her letters (two signifiers of understanding), she still states that this activity was helpful with her learning (development) of scientific concepts.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project.

   **3**

2. When Cindy would talk with you about the wetlands, animals, etc. **2**

3. When we went to the Elkhorn Slough. **5**

   **Comment:** I loved it.

4. When Kenton showed us the European green crab and other animals, plants, etc.

   **5**

   **Comment:** I was really excited.

5. When Kenton showed us how to collect aquatic invertebrates (looking through plastic bins and placing animals in glass jars). **5**

   **Comment:** I was impressed.

6. When we were using the microscopes and saw animals magnified with Kenton.

   **5**

7. When you spoke with Crysti at The Nature Center.

   **Comment:** Absent

8. Your general feeling/thinking about the Science Club. **5**

   **Comment:** I loved it.

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **4**

10. When we went to UCSC and you spoke with Miriam. **4**

These ratings provide evidence that Margarita considered every activity with Kenton as Wow! In addition, her general feeling/thinking about the Science club was also rated as Wow! Very helpful activities were talking and collaborating with (Me, Roxanne, Cindy, Miriam, Kenton, and others). Margarita rated Ms. Lisa reading of a wetland book at the beginning of the study as helpful. Lastly, she rated talking with Cindy as a little bit helpful. Note: Margarita was absent on the day the students met Crysti (another science educator).

**Students' ratings in level of enjoyment**

The following three ratings pertain to the development and usage of scientific concepts and/or specific terms.

1. When you learned about scientific concepts and everyday concepts. **3**

   **Comment:** fun

2. When Ms. Lisa brought awareness to the fact that there are words in Spanish, such as plume (feather), that have the same root name and meaning as scientific concepts such as plumage. **2**

   **Comment:** Alright

3. When you wrote letters to science educators and/or scientists. **3**

   **Comment: Cool**

These ratings indicate that Margarita considered learning about scientific concepts and/or specific terms as fun (Table 3). However, she rates learning about cognates as a little bit fun (Table 4). She rates science letters as fun.

The next ratings pertain to participatory structures (doing particular activities with particular individuals).

1. When Ms. Lisa read a book to you about wetlands at the beginning of the project. **3**

2. When Cindy would talk with you about the wetlands, animals, etc. **2**

3. When we went to the Elkhorn Slough. **5**

**Comment:** Amazing

4. When Kenton showed us the European green crab and other animals, plants, etc. **5**

**Comment:** Super fun

5. When Kenton show us how to collect aquatic invertebrates (looking through plastic

bins and placing animals in glass jars). **5**

**Comment:** Super fun

6. When we were using the microscopes and saw animals magnified with Kenton. **5**

**Comment:** Awesome

7. When you spoke with Crysti at The Nature Center. **X**

**Comment:** Absent

8. Your general feeling/thinking about the Science Club. **5**

**Comment:** I loved it.

9. Talking and collaborating with others (Me, Roxanne, Cindy, Crysti, Kenton, etc) and with each other. **3**

   **Comment:** Cool

10. When we went to UCSC and you spoke with Miriam. **4**

    **Comment:** Expectacular

Margarita rates all activities with Kenton as Wow in terms of level of enjoyment. In addition, she rates her overall feeling/thinking about the Science club as Wow! She rates her time spent with Miriam as spectacular (expectacular). Activities rated as fun were talking and collaborating with (Me, Roxanne, Cindy, Kenton, etc) and with each other in addition to Ms. Lisa reading a wetland book at the beginning of the study. Margarita, in addition to all of the students, considered talking with Cindy as a little bit fun. Most of the students felt she had 'attitude' with them and did not have a genuine interest in getting to know them as 'whole persons.' The teacher/researcher experienced similar feelings about Cindy.

**RQ2:**

**Students' ratings in helping them learn**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **3**

2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates **4**

   **Comment:** It was fun meeting Rosemary and Yadira; also very helpful.

3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **4**
4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **2**
5. When you used the computer to research information about your animal/plant of interest **4**

   **Comment:** It was very helpful.

6. When you designed your Science Inquiry Book **4**
7. When we discussed the data together and organized it into tables or graphs **3**
8. When you prepared and practiced your presentation in front of another student **3**
9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **3**
10. When you used clay or watercolors to design your animal of interest for the presentation **4**
11. When you did your presentation in front of your family **5**

**Comment:** I got to be a little scientist.

Overall, these ratings indicate that the scientific inquiry activities were considered helpful to very helpful with regard to helping Margarita learn. Specifically, questions 1, 5, and 7 relate to the process of inquiry (collecting data, researching information, and organizing information into tables or graphs). With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Margarita rated this 4 (very helpful). She rated practicing her presentation 3 (helpful) and actually performing her presentation 5 (Wow), stating, "I got to be a little scientist."

With regard to identifying aquatic invertebrates, Margarita rated these 4 (very helpful) in reference to receiving assistance from either the high school mentors or Ms. Lisa and Roxanne. However, she rated this acitity 2 (a little bit helpful) without assistance, i.e., only from her peers. With regard to collecting water quality data, Margarita rated this activity 3 (helpful). Finally, Margarita rated using clay and/or watercolors to design a representation of her animal of interest 4 (very helpful) to her learning. Note: It can be argued that this creative display of artwork is an artistic form of learning.

**Students' ratings in level of enjoyment**

The following eleven ratings pertain to the development of scientific inquiry and students' motivation to learn.

1. When we would all go out to the Watsonville slough and collect data on your area of interest **3**
2. When the students from PVHS visited you and showed you how to identify the aquatic invertebrates **4**

   **Comment:** Great
3. When you identified the aquatic invertebrates (using the microscope) with Ms. Lisa and Roxanne **4**

   **Comment:** Great
4. When you identified the aquatic invertebrates on your own (w/o help from me or Roxanne) **3**

   **Comment:** Fun
5. When you used the computer to research information about your animal/plant of interest **4**

   **Comment:** Awesome
6. When you designed your Science Inquiry Book **4**

   **Comment:** Exciting
7. When we discussed the data together and organized it into tables or graphs **4**

   **Comment:** Awesome
8. When you prepared and practiced your presentation in front of another student **4**

   **Comment:** Exciting

9. When we collected data for water quality (temp, water level, surface appearance of water, types of animals we saw, etc) and used the kit to measure pH, DO, Nitrates, and Phosphates) **3**

   **Comment:** Alright

10. When you used clay or watercolors to design your animal of interest for the presentation **4**

    **Comment:** Expectacular

11. When you did your presentation in front of your family **5**

    **Comment:** Amazing

Overall, these ratings indicate that the scientific inquiry activities (questions 1, 5, and 7) ranged from 3 (enjoyable) to 4 (very enjoyable). All three of these questions relate to the process of inquiry (collecting data, researching information, and organizing information into tables or graphs). With regard to designing her Science Inquiry Book, which included all of the inquiry steps, Margarita rated this 4 (very enjoyable). She also rated practicing her presentation 4 (very enjoyable) and 5 (Wow) for actually presenting. Margarita also provided a comment for the day of the presentation, "Amazing."

With regard to identifying aquatic invertebrates, Margarita rated these 4 (very enjoyable) when receiving assistance from either the high school mentors or Ms. Lisa and Roxanne. She rated this activity 3 (enjoyable) without assistance. With regard to collecting water quality data, Margarita rated this 3 (enjoyable).

Finally, Margarita rated using clay and/or watercolors to represent her animal of interest 4 (very enjoyable). She also provided a comment for this activity, "Expectacular."

**RQ3:**

Lastly, Margarita rated writing letters to her parents 2 (a little bit helpful) with regard to helping her learn, and 2 (a little bit enjoyable) for level of enjoyment. Again, since the letters did not go to the parents right after Margarita (and the other students) had written them, perhaps they looked at their letter writing as an assignment rather than a genuine attempt to share their learning experiences with their parents. During the time of the study, the teacher/researcher did not consider the effect of waiting to distribute parent letters, however, during the analysis she can see that waiting to distribute the first letter may have affected their attitude with writing their second letter to their parents, "Oh, this isn't really going to my parents, so I'm not going to put much effort into it."

## Appendix B Rubrics and Tables

***5 point-scale rubric to assess students' language pre and post study***:

1= Everyday concepts

2= Everyday concepts and specific terms

3= Specific terms

4= Specific terms and scientific concepts

5= Scientific concepts

***Grammatical constructions used to determine accurate usage of scientific concepts:***

- X is a kind of Y
- X is the result of Y
- X causes Y
- X is found in Y locations/contexts

A ***grammatical metaphor*** is an expression of one kind which is followed shortly afterwards by a related expression with a different structural profile (Halliday & Martin, 1993, p. 206). For example: *will not be refracted enough... for want of a sufficient Refraction*. This example demonstrates how a verb or adjective in the first expression has been reworded in the second as a noun. These grammatical metaphors are a reflection of how grammar has evolved through the practice of science. In other words, grammatical metaphors are both the product and process of thinking and doing science. They are the derivatives of the development of scientific discourse. Through this development, scientists can essentially participate in the construction of theories,

which defines science as not just a way of thinking about the world, but more so, how the world is experienced.

***Scientific inquiry rubric scale***

A three-point scale (1 = no, 2 = somewhat, and 3 = yes) will be used to assess these 9 criteria: **[Total possible points = 27]**

- Research question testable
- Accurate assessment of tools needed
- Accurate assessment of data collection
- Accurate assessment of type of inquiry
- Accurate datasheet (for recording data)
- Reasonable interpretation of data (imagined data)
- Reasonable explanation
- Reasonable alternative explanation
- Reasonable conclusion

## Table 1

### *Everyday concepts*

| General | Specific | Explanation |
|---|---|---|
| Duck | | General term for a type of bird |
| Bird | | General term for an animal with feathers |
| Caterpillar | | General term for larva |
| Nature | | General term for environment |
| | Environment | Specific name for nature |
| Wet | | General term in relation to water |
| | Humid | Specific term conveying moisture in the air/atmosphere |
| Ruddy | | General term for the color red |
| | Ruddy duck | Specific name for a bird (thing) |
| | Science | Specific name for a subject domain |
| | Earth | Specific name for a planet (thing) |
| | Wetland | Specific name for a place |
| | Slough | Synonym for wetland |
| | Estuary | Specific term: river and ocean mix into a body of water (estuary) |
| | Biotic | Represents living things: plants/ animals |
| | Abiotic | Represents non-living things: rocks, sand, dirt, water, air, humidity, etc |
| | Habitat | Specific name for home (place) for a plant and/or animal |
| | Vertebrate | Animal (thing) with a backbone |
| | Invertebrate | Animal (thing) without a backbone |
| | Aquatic invertebrate | Animal (thing) without a backbone that lives in water |
| | Native | Describes a plant/animal (thing) which resides in its place of origin |
| | Non-native | Describes a plant/animal that does not reside it its place of origin |
| | Plumage | Specific name for feathers |
| | Vegetation | Specific name for plants |
| | Flora | Specific name for flowers |
| | Fauna | Specific name for animals |
| | Wade | Specific term for walk |

| | | |
|---|---|---|
| | Mate | Specific term for partner or to make babies |
| | Companion | Specific term for partner |
| | Offspring | Specific term for babies, young |
| | Aquatic plant | Specific type for plant |
| | Chlorophyll | Green pigment in plants (thing) |
| | Arid | Specific term for dry |
| | Rhizome | Specific term for plant root (thing) |
| | Vascular | Specific type of plant with vessels (veins) |
| | Non-vascular | Specific type of plant w/o vessels |
| | Annual | Specific term for a plant which lives or grows for one year/season |
| | Perennial | Specific term for a plant which lives many years |
| | Bill | Specific term for beak (object) |
| | Pelican | Specific kind of bird (thing) |
| | Cormorant | Specific kind of bird (thing) |
| | Mallards | Specific kind of bird (thing) |
| | Robins | Specific kind of bird (thing) |
| | House finch | Specific kind of bird (thing) |
| | Hummingbird | Specific kind of bird (thing) |
| | Owl | Specific kind of bird (thing) |
| | Nocturnal creature | Specific kind of animal (thing) which is active at night |
| | Polychaete | Specific kind of animal (thing) |
| | Bristles | Multiple appendages (thing) polychaetes use for movement. |
| | Burrow | Hole (thing); to dig |
| | Female | Type of gender (thing) male or female |
| | Observe | Specific type of behavior |
| | Observation | Type of behavior |
| | Aphid | Specific type of insect |
| | Wasp | Specific type of insect |
| | Mummies | Describes how the aphid becomes a host (mummy) for wasps' eggs |
| | Stress | Tension |
| | Pesticides | Chemicals used to deter unwanted animals (pests) |

## Table 2

### *Scientific Concepts*

| Scientific concept | In relation to other concepts | Explanation |
|---|---|---|
| Ecosystem | Interaction, biotic, abiotic, factors, environment, balance, etc | The concept ecosystem conveys meaning within a definite system of other concepts (interaction, biotic, abiotic, factors, environment, balance, etc) |
| Biome | Synonym for ecosystem | (same def as above) |
| Diversity | Describes whether there is variety (different types) of plants and/or animals | The concept diversity does not correspond with one particular object, but describes whether there are different types of plants and/or animals within a particular ecosystem |
| Migration | Describes an animal which travels from one place to another during particular seasons | The concept migration does not correspond with one particular animal. There are many animals which migrate seasonally from one location to another. |
| Adaptation | Describes whether a plant/animal has a characteristic or unique ability (advantage) to survive within its environment | The concept adaptation can be used to describe both plant and animal adaptations. It has a high level of generality. |
| Camouflage | Describes whether an animal blends into its environment (a means of concealment) for protection and/or to sneak up on its prey | The concept camouflage is a description of whether an animal blends into its environment. It does not represent a particular animal (thing). |
| Breed | To produce offspring; to reproduce | Pertains to reproduction of animals in general. |
| Reproduce | To produce offspring: to breed | Synonym for breed |
| Courtship | Concept for dating (pursuing) | Pertains to animal behavior (courting, dating, pursuing) |
| Forage | In search of/to look for food | Pertains to feeding behavior of animals (looking for food) |
| Preen | Bird, clean, feathers | Pertains to cleaning behavior of birds |
| Invasive | A non-native species which spreads and/or consumes native species food source | This concept pertains to both non-native plants and animals. |
| Restoration | To return a habitat to its original condition, i.e., taking out non-native plants and replacing with native; cleaning litter; removing any unnatural or foreign objects, etc | Broad concept which can pertain to any ecosystem or habitat |
| Medicinal | Having the properties of medicine: remedies or cures for ailments | Concept pertains to particular plants which have an ameliorative effect on ailments |
| Protect | Not associated with an object, but rather a circumstance or situation to protect, i.e., to keep from harm, injury, or attack; guard. | Concept pertains to people protecting the environment and/or animals or animals (mothers) protecting their offspring |

| | | |
|---|---|---|
| Damage | Not associated with an object, but rather a circumstance or situation where something or someone is harmed, hurt, degraded. | Impairment of the usefulness or value of person or property; loss; harm. Can relate to the environment as well. |
| Maintain | Not associated with an object, but rather a circumstance or situation to maintain, i.e., to preserve or retain. | Concept pertains to preserving or retaining. |
| Water cycle | Many interactive components to this concept: transpiration (water in atmosphere from trees), evaporation (from oceans, lakes, and ponds), condensation (cloud formation), and precipitation (rain, sleet, snow, hail). | Concept operates within a definite system of component concepts which interact in relation to one another (evaporation, transpiration, sublimation, condensation, precipitation, and water collection/ storage) |
| Food web | Many words associated with each other in order to convey meaning of food webs: producers, consumers, herbivores, carnivores, omnivores, interconnected, interdependent, etc. | Concept pertains to many other scientific concepts in relation to each other (interconnected, interdependent, sunlight, photosynthesis, producers, consumers, herbivores, carnivores, omnivores, decomposers, etc) |
| Metaphor | Language form and function. Requires examples (using words in association with each other) to covey a metaphor. | A term that ordinarily designates an object or idea is used to designate a dissimilar object or idea in order to suggest comparison or analogy |
| Endangered | This concept is associated with animal, danger, status, population, and extinction. | A species in danger of extinction. Pertains to both plants and animals. |
| Biomass | Associated with plant, amount, quantity, mass, weight | Amount of a plant |
| Photosynthesis | Associated with plant, sun, sunlight, sugar, oxygen | Plants use sunlight to make food (sugar) |
| Omnivore | Associated with food web, plants, animals | An animal that eats both plants and animals (meat) |
| Interact | Concept associated with action, in context, with participants | The conjoining of two or more individuals |
| Attract | Concept associated with a liking of another (attraction) | An act of liking or finding desirable |
| Impress | Concept associated with making an impression (something to remember or like, or find appealing) | An act of impression (noticeable) |
| Hermaphrodite | Concept associated with male, female, sex organs, reproduction | An animal with both male and female reproductive organs |
| Cannibalism | Concept associated with eating other animals similar to itself (same species) | An animal which eats others like itself |
| Animal kingdom | Concept associated with taxonomic nomenclature | First category in taxonomy nomenclature (kingdom, phylum, class, order, family, genus, and species) |
| Behavior | Concept associated with animal, interacts, environment, others, foraging, courtship, preening, breeding, etc | Concept associated with how an animal interacts within its environment and with others |
| Water temperature | Concept associated with water, temperature, degrees, thermometer, measurement, Celsius, Fahrenheit | A measurement of water temperature in degrees |
| pH | Concept associated with acids, neutral, bases, alkaline, scale, etc. | A measurement of a substance that falls within a range of acidic, neutral, or basic (alkaline). |

| | | |
|---|---|---|
| Predator | Concept pertain to an animal that consumes another animal, i.e., an animal functions in a particular way within an ecosystem | An animal that eats another animal |
| Prey | Concept pertains to an animal that is consumed by another animal, i.e., an animal functions in a particular way within an ecosystem | An animal that gets eaten by another animal (predator) |
| Pollution | Pollution is associated with many concepts, i.e., can pertain to air, land, soil, water, noise, etc | Pollute:  to make impure or unclean; contaminate |
| Percent | Concept pertains to one part in a hundred, i.e., can relate to math and other subject domains | One part in a hundred |
| Data | Concepts associated with information, i.e., information organized for analysis or decision making | Information organized for analysis or decision making |
| Scientific | Concept associated with many concepts, not just a thing or object. | The act of acting in a scientific manner. |

# Table 3

## *Scientific Language and Everyday Words*

| **Scientific language (scientific concepts & specific terms)** | **Everyday words (meaning)** |
|---|---|
| Environment | Specific term for nature, surroundings |
| Ecosystem | Living and non-living things coexist |
| Biome | Synonym for ecosystem |
| Habitat | Home for animals/plants |
| Wetland | Habitat submerged in water |
| Wet (Note: General term) | Has moisture (water) |
| Humid | Synonym for wet |
| Slough | Synonym for wetland |
| Biotic | Living things |
| Abiotic | Non-living things |
| Vertebrate | Animal with backbone |
| Invertebrate | Animal w/o backbone |
| Aquatic invertebrate | Water invertebrate |
| Vegetation | Plants |
| Native | Belongs (originally from here) |
| Non-native | Does not belong here |
| Invasive | Synonym for non-native |
| Flora | Flower (plants) |
| Fauna | Animals |
| Food web | How plants & animals are interconnected and interdependent |
| Migration | Animal travels seasonally from one location to another |
| Wade | To walk |
| Adaptation | Unique feature which gives plants/animals an advantage |
| Camouflage | An animal which blends into its environment |
| Mate | A partner or to make babies (reproduce) |
| Companion | A partner |
| Reproduce | To have babies (reproduce) |
| Offspring | Babies, children, young |
| Breed | To mate, reproduce |
| Courtship | Courting (dating) |
| Forage | Feed (look for food) |
| Plumage | Feathers |
| Preen | Bird cleans its feathers |

| | |
|---|---|
| Metaphor | A term that ordinarily designates an object or idea is used to designate a dissimilar object or idea in order to suggest comparison or analogy |
| Endangered | A species in danger of extinction |
| ***Words related to Cecelia's project*** | |
| Aquatic plant | Water plant |
| Biomass | Amount (mass) of a plant |
| Photosynthesis | Plants use sunlight to make food (sugar) |
| Chlorophyll | Green pigment in plants |
| Annual | Living or growing for one year or season |
| Perennial | Plant lives many years |
| Arid | Dry |
| Drought tolerant | A plant that can live without water for extended periods of time |
| Rhizome | A root-like plant stem that sends roots below and leaves and shoots above |
| Vascular | Plants that contain vessels (veins) for fluid circulation (water, sap, etc.) |
| | |
| Non-vascular | Plants w/o vessels (veins) |
| Medicine or Medicinal | Plant that has healing effects |
| Restoration | To return (restore) a habitat to its original composition of plants and animals |
| ***Words related to Jacquelina's project*** | |
| Ruddy (Note: General term) | Red |
| Bill | Beak |
| Breed | To mate (reproduce) |
| Interact | The conjoining of two or more individuals |
| Attract | An act of liking or finding desirable |
| Impress | An act of impression (noticeable) |
| Courtship | Pertains to reproduction animal behavior (courting, dating, pursuing) |
| Mate | A partner or to make babies (reproduce) |
| Forage | Feed, look for food |
| Omnivore | An animal that eats both plants and animals (meat) |
| Preen | Bird cleans its feathers |
| Plumage | A specific term for feathers |
| Migration | An animal that travels seasonally from on location to another |
| Wade | A specific term for walk |
| ***Words related to Charlena and Margarita's project*** | |
| Aquatic invertebrate | Water insect |
| Marine | Lives in ocean, salty water |
| Bristles | Hair-like appendages |
| Crevice | Crack |

| | |
|---|---|
| Burrow | Hole (noun) and/or to dig a hole (verb) |
| Hermaphrodite | Animal has both male/female reproductive organs |
| Cannibalism | Animals eats other animals like itself (same species) |

## Table 4

### *Cognates*

| Scientific language | Cognates (Spanish) [Bridge] | Everyday language |
|---|---|---|
| Environment | Ambiente | Specific term for nature, surroundings |
| Ecosystem | Ecosistema | Living and non-living things coexist |
| Biome | Bioma | Synonym for ecosystem |
| Habitat | Habitat | Home for animals/plants |
| Wetland | De los humedales | Habitat submerged in water |
| Wet (Note: General term) | Humedo | Has moisture (water) |
| Humid | Humedo | Synonym for wet |
| Slough | | Synonym for wetland |
| Biotic | Biotico | Living things |
| Abiotic | Abiotico | Non-living things |
| Vertebrate | Vertebrado | Animal with backbone |
| Invertebrate | Invertebrado | Animal w/o backbone |
| Aquatic invertebrate | Invertebrados de agua | Water invertebrate |
| Vegetation | Vegetacion | Plants |
| Native | Nativo | Belongs (originally from here) |
| Non-native | No natives | Does not belong here |
| Invasive | Invasor | Synonym for non-native |
| Flora | Flora | Flower (plants) |
| Fauna | Fauna | Animals |
| Food web | | How plants & animals are interconnected and interdependent |
| Migration | Migracion | Animal travels seasonally from one location to another |
| Wade | | To walk |
| Adaptation | Adaptacion | Unique feature which gives plants/ animals an advantage |
| Camouflage | Camuflaje | An animal which blends into its environment |
| Mate | Companero | A partner or to make babies |
| Companion | Companero | A partner |
| Reproduce | Reproducir | To have babies (reproduce) |
| Offspring | Hijos | Babies, children, young |
| Breed | | To mate, reproduce |
| Courtship | Cortego | Courting (dating) |
| Forage | Forraje | Feed (look for food) |
| Plumage | Plumaje | Feathers |
| Preen | Plumas limpias | Bird cleans feathers |

| | | |
|---|---|---|
| Metaphor | | A term that ordinarily designates an object or idea is used to designate a dissimilar object or idea in order to suggest comparison or analogy |
| Endangered | | A species in danger of extinction |
| ***Specific words related to Cecelia's project*** | | |
| Aquatic plant | Plantas acuaticas | Water plant |
| Biomass | Biomasa | Amount (mass) of a plant |
| Photosynthesis | Fotosintesis | Plants use sunlight to make food (sugar) |
| Chlorophyll | Clorofila | Green pigment in plants |
| Annual | Annual | Living or growing for one year or season |
| Perennial | Planta perenne | Plant lives many years |
| Arid | Arid | Dry |
| Drought tolerant | Tolerantes a la sequia | A plant that can live without water for extended periods of time |
| Rhizome | Rizoma | A root-like plant stem that sends roots below and leaves and shoots above |
| Vascular | Vascular | Plants that contain vessels (veins) for fluid circulation (water, sap, etc.) |
| Non-vascular | No vasculares | Plants w/o vessels (veins) |
| Medicine or Medicinal | Medicina | Plant that has healing effects |
| Restoration | Restauracion | To return (restore) a habitat to its original composition of plants and animals |
| ***Words related to Jacquelina's project*** | | |
| Ruddy (Note: General term) | Rojo | Red |
| Bill | | Beak |
| Breed | | To mate (reproduce) |
| Interact | Interactuar | The conjoining of two or more individuals |
| Attract | Atraidos | An act of liking or finding desirable |
| Impress | Impresiona | An act of impression (noticeable) |
| Courtship | Cortego | Pertains to reproductive animal behavior (dating, pursuing) |
| Mate | Companero | A partner or to make babies (reproduce) |
| Forage | Forraje | Feed, look for food |
| Omnivore | Omnivoro | An animal that eats both plants and animals (meat) |
| Preen | | Bird cleans its feathers |
| Plumage | Plumaje | A specific term for feathers |
| Migration | Migracion | An animal that travels seasonally from one location to another |
| Wade | | A specific term for walk |
| ***Words related to Charlena and Margarita's project*** | | |
| Aquatic invertebrate | Invertebrados de agua | Water insect |

| | | |
|---|---|---|
| Marine | Marina | Lives in ocean, salty water |
| Bristles | Cerdas | Hair-like appendages |
| Crevice | | Crack |
| Burrow | | Hole (noun) and/or to dig a hole (verb) |
| Hermaphrodite | Hermafrodita | Animal has both male/female reproductive organs |
| Cannibalism | Canibalismo | Animals eats other animals like itself (same species) |

**Table 5**

***Cross Case Analysis of Case Studies Pre Assessment***

| Pre-assessments | Interview | Letter 1 | Elkhorn | Field-notes |
|---|---|---|---|---|
| ***Cecelia*** | Rubric score: 1 (everyday concepts) however, uses everyday language to convey meaning of conservation | Rubric score: 2 (everyday concepts and specific terms) 1 st | Rubric score: 4 (specific terms and scientific concepts) 2 sc, 3 st | Rubric score: 2 (everyday concepts and specific terms) bio and an example of ecosystem- ocean |
| ***Jacquelina*** | Rubric score: 2 (everyday concepts and specific terms) 1 st | Rubric score: 4 (specific terms and scientific concepts) 4 sc, 7 st | Rubric score: 1 (learned all concepts/terms from Science club | Rubric score: 2 (everyday concepts and specific terms) |
| ***Charlena*** | Rubric score: 4 (specific terms and scientific concepts) 1 sc, 7 st | Rubric score: 4 (specific terms and scientific concepts) 1 sc, 8 st | Rubric score: 4 (specific terms and scientific concepts) 3 sc, 1 st | Rubric score: 4 (specific terms and scientific concepts) understood ecology, citric acid, remembered cormorant information from pilot study |
| ***Margarita*** | Rubric score: 4 (specific terms and scientific concepts) 5 sc, 6 st Note: Uses many causal statements and everyday language which conveys meaning of scientific concepts: conservation, restoration, preservation, migratory place, stewardship, and advocacy | Rubric score: 4 (specific terms and scientific concepts) 2 sc, 5 st | Rubric score: 2 (everyday concepts and specific terms) 2 st | Rubric score: 4 (understand that animals with similar characteristics are categorized in the same taxanomic family; also used concept dependent and term biotic on her own, prior to instructional conversation |

***Table 6: Cross Case Analysis of Case Studies Post Assessments***

| **Post-assessments** | **Interview** | **Letters 2, 3** | **Elkhorn** | **Field-notes** |
|---|---|---|---|---|
| ***Cecelia*** | Rubric score: 4 (specific terms and scientific concepts) 2 sc, 3 st Cecelia uses: ecosystem balanced, and oxygen because of plants as her two scientific concepts. Demonstrates (1) using words within a system, and (2) causal statement | Rubric score: 4 (specific terms and scientific concepts) *Second letter*: 1 st; *Third letter*: 2 sc, 5 st | Rubric score: 4 (specific terms and scientific concepts) 5 sc, 5 st | Rubric score: 4 (specific terms and scientific concepts) Intersection of school with Science club: mathematical concepts (correlations), food web concepts, passing math and science |
| ***Jacquelina*** | Rubric score: 4 (specific terms and scientific concepts) 7 sc, 7 st | Rubric score: 4 *Second letter*: 5 sc, 8 st; *Third letter*: 6 sc, 5 st | Rubric score: 4 (specific terms and scientific concepts) 7 sc, 4 st | Rubric score: 2 (everyday concepts and specific terms) Excelled with transition of everyday language to scientific language, particularly during field observations |
| ***Charlena*** | Rubric score: 4 (specific terms and scientific concepts) 1 sc, 3 st Charlena also uses comparison/differentiation when discussing wetlands and estuaries, and two causal statements when using everyday language to convey the meaning of three scientific concepts: conservation, preservation, and restoration. | Rubric score: 4 (specific terms and scientific concepts) *Second letter*: 2 sc, 2 st; *Third letter*: 2 sc, 4 st | Rubric score: 4 (specific terms and scientific concepts) 5 sc, 10 st | Rubric score: 4 (specific terms and scientific concepts) Developed/reinforced meaning of the following words with Kenton: European green crab, non-native, larvae, ecosystem, breed, native, species, habitat |
| ***Margarita*** | Rubric score: 4 (specific terms and scientific concepts) 1 sc, 6 st | Rubric score 4: (specific terms and scientific concepts) *Second letter*: 0 sc, 5 st; *Third letter*: 5 sc, 3 st | Rubric score 4: (specific terms and scientific concepts) 6 sc, 7 st | Rubric score 4: (specific term and scientific concepts) mathematical relationships, i.e., correlations, hypothesis, and sensory tentacles |

## References


Ash, D. (2008). Thematic continuities: Talking and thinking about adaptation in a socially complex classroom. *Journal of Research in Science Teaching, 45 (1*), 1-30.

Ballenger, C. (1997). Social identities, moral narratives, scientific argumentation: Science talk in a bilingual classroom. *Language and Education, 11*(*1*), 1-14.

Beach, K. (1999). Consequential transition: In A. Iran-Nejad & P. D. Pearso (Eds.), Review of research in education (Vol. 24, pp. 101-139). Washington, DC: American Educational Research Association.

Bradsford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school* (Expanded ed.). Washington, DC: National Academy Press.

Calabrese Barton, A. (2003). *Teaching science for social justice*. NewYork:Teachers College Press.

California State Science Framework and Content Standards, K-12. (1998).

Carrier, K. A. (2005). Supporting science learning through science literacy objectives for English Language learners. *Science Activities, 42* (2), 5-11.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches.* London: Sage Publications, Inc.

Dewey, J. (1897). My pedagogical creed. *School Journal, 54*, 77-80.

Dewey, J. (1915). *The school and society: The child and the curriculum*. New York: Dover Publications, Inc.

Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*. New York: The Free Press.

Dewey, J. (1938). Experience and education. New York: Macmillan.

Donovan, M. S., & Bransford, J. D. (2005). In How Students Learn: History, Mathematics, and Science in the Classroom. Washington DC: National Academy Press.

Duran, B.J., Dugan, T., Weffer, R. (1998). Language minority students in high school: The role of language in learning biology concepts. *Science Education, 82*, 311-341.

Fradd, S.H., Lee. O, Sutman, F.X., & Saxton, M.K. (2001). Promoting science literacy with English language learners through instructional materials development: a case study. *Bilingual Research Journal, 25(4),* 417-439.

Gandara, P. (1989). 'Those' children are ours: Moving toward community. *Equity and Choice, March, 5(2*), 5-12.

Gonzalez, N., Moll, L. C., & Amanti, C. (Eds.). (2005). *Funds of knowledge: Theorizing practices in Households, communities, and classroom.* NJ: Lawerence Erlbaum Associates, Publishers.

Halliday, M. A. K. (1993). Toward a language-based theory of learning. *Linguistics*

*and education, 5*, 93-116.

Halliday, M. A. K., & Martin, J. R. (1993). Writing science: Literacy and discursive power. In J. J. Webster (Ed.), *The Language of Science, V 5 in the Collected Works of M. A. K. Halliday,* (pp. 199-225). London: Continuum.

Hansen, L. (2006). Strategies for ELL success. *Science and Children, 43*(4), 22-25.

Gutiérrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher, 32*(5), 19-25.

Haneda, M. & Wells, G. (2010). Learning science through dialogic inquiry: Is it beneficial for English-as-additional –language students? *International Journal of Educational Research, 49*, 10-21.

Keenan, S. (2004). Methods and strategies: Reaching English Language Learners. Strategies for teaching science in diverse classrooms. Science and Children, p. 49-51

Lave, J., & Wenger, E. 1991. *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Lee, O., & Fradd, S. H. (1998). Science for all, including students from non-English Language backgrounds. *Educational Researcher, 27*, 1-10.

Lee, O., & Avalos, M. A. (2002). Promoting science instruction and assessment for English Language Learners. *Electronic Journal of Science Education, 7(2)*, 1-24.

Lee, O. (2003). Equity for linguistically and culturally diverse students in science education: A research agenda. *Teachers College Record, 105(3*), 465-489.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38* (3), 296-316.

Magnusson, S. J. & Palincsar, A. S. (2004). Learning from text designed for scientific thinking. In W. Saul (Ed.), *Crossing Borders in Literacy and Science Instruction*, (pp. 316-339). Neward, DE: International Reading Association.

Medina-Jerez, W., Clark, D. B., Medina, A., & Ramirez-Marin, F. (2007). Science of ELLs: Rethinking our approach. *The Science Teacher, 74* (3), 52-56.

Merino, B. & Scarcella, R. (2005). Teaching science to English Learners. *UC LMRI Newsletter, 14(4)*, 1-8.

Moje, E., Collazo, T., & Carrillo, R. (2001). "Maestro, what is 'quality'?" Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching, 38* (4), 469-498.

National Center for Education Statistics (1999b). The condition of education, 1999. Washington, DC: National Academy Press.

National Research Council (1996). National science education standards. Washington, DC: National Academy Press.

National Academy of Science (2003). How people learn. Bridging research and practice: Learning with understanding seven principles. Washington DC: National Academy Press.

The Nations Report Card. http://nationsreportcard.gov/science_2005

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park: Sage Publications, Inc.

Rice, D. C., Pappamihiel, E. N., & Lake, V. E. (2004). "Lesson adaptations and accommodations: working with native speakers and English language learners in the same science classroom." *Childhood Education*, 121 (7).

Rogoff, B. (1993). Children's Guided Participation and Participatory Appropriation in Sociocultural Activity, p. 121-153.

Rogoff, B. (1994). Developing understanding of the idea of communities of learners. Mind, Culture, andActivity, 1 (4): 209-229.

Rogoff, B. (1995). Observing sociocultural activity on three planes: Participatory appropriation, guided participation, and apprenticeship. In J. V. Wertsch, P. del Rio, & A. Alvarez (Eds.), Sociocultural studies of mind (pp. 139-164). Cambridge: Cambridge University Press.

Rosebery, A. S., Warren, B., Conant, F. R., & Hudicourt-Barnes, J. (1992). ChecheKonnen: Scientific sense-making in bilingual education. *The Journal of Science and Learning Sciences, 1(2),* 1-8.

Stoddart, T., Pinal, A., Latzke, M. & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching, 39*(8), 664-687.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1987). The development of scientific concepts in childhood. In *Thinking and speech*. In The Collected Works of L.S. Vygotsky, Vol. 1 (ed. R.W. Reiber & A.S. Carton, trans. N. Minick). New York: Plenum.

Warren, B., Ballenger, C., Ogonowski, M., & Rosebery, A.S. (2002). Rethinking diversity learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 35(5)*, 529-552.

Wells, G. (1999). *Dialogic inquiry: Towards a sociocultural practice and theory of education*. New York: Cambridge University Press.

Wells, G. (2002). Learning and teaching for understanding: The key role of collaborative knowledge building. *Social Constructivist Teaching, (9),* 1-41.

Wells, G. (2008). Learning to use scientific concepts. *Cultural Studies of Science Education, 3*, 329-350.

Wells, G. (2009). *The meaning makers: Learning to talk and talking to learn* (2nd ed.). Bristol, UK: Multilingual Matters.

Wertsch, J. V. (1985). The social origin of higher mental functions. In Wertsch, J. V., Vygotsky and the Social Formation of Mind. Cambridge, MA: Harvard University Press.