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Improving Achievement for Linguistically and Culturally Diverse Learners Through an Inquiry-Based Earth Systems Curriculum

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Abstract

This report describes an inquiry-based Earth systems curriculum and strategies for teaching diverse students, which were embedded in the curriculum. The curriculum was implemented with 5th-grade students with varied linguistic, cultural, and socioeconomic backgrounds in five schools in a large, southeastern U.S., urban school district. At the end of the school year, all schools showed statistically significant improvement on two assessments: (1) an Earth systems unit test and (2) a sample of National Assessment of Educational Progress (NAEP) and Third International Mathematics and Science Study (TIMSS) items. Students' perspectives regarding the cognitive and affective domains of the curriculum are discussed as are implications of the findings and recommendations for future research.

Introduction

The United States is faced with a student population that is becoming increasingly diverse over a short period of time. As a result, our educational systems need to implement the best and most efficient practices in teaching English language skills and academic content simultaneously to students of diverse linguistic and cultural backgrounds (August & Hakuta, 1997; García, 1999). Compounding the spectrum of diverse language learners, the socioeconomic standing of students also plays a pivotal role in the type of education they can access (Golnick & Chin, 2002). Regardless of the student's level of English language proficiency, cultural background, or socioeconomic status (SES), mainstream content area teachers are now responsible for providing comprehensible instruction to all English language learners (ELLs) so that their achievement reaches standards mandated by the No Child Left Behind Act of 2001.

In science, the benefits of inquiry-based instruction for ELLs are well-supported (Amaral, Garrison, & Klentschy, 2002; Bredderman, 1983; Gibbons, 2003; Valadez, 2002).

Despite these findings, effective practices are generally lacking in schools that serve lower SES populations (Banks & McGee Banks, 1989; Chamot, 1983; Jones, 1985; Kessler, Quinn, & Fathman, 1992). Another trend is the growing gap in academic performance between long-term ELLs and native English speakers (Freeman, Freeman, & Mercuri, 2002). To close this gap, Freeman et al. suggest four elements that should be present in instruction: (1) engaging students in challenging, theme-based curricula; (2) building upon students' backgrounds; (3) using collaborative learning and scaffolding; and (4) instilling confidence and respect for learning.

Purpose

This study examined linguistically and culturally diverse students' understanding of Earth systems concepts both before and after their study of an inquiry-based Earth systems science curriculum. *The Living Planet* curriculum was developed for 5th-grade students participating in a larger intervention (Lee, Deaktor, Enders, & Lambert, 2008; Lambert, Lester, Lee, & Luykx, 2007). This curriculum, recommended by Short (1991); Echevarria, Vogt, and Short (2004); and Dobb (2004) incorporates specific strategies, such as connecting with students, focusing on reading comprehension and writing skills, collaborative learning, scientific language, and process skills of inquiry, that teachers should use to help ELLs acquire scientific knowledge and simultaneously develop English language literacy skills.

Precisely, the purpose of the study was to evaluate the program's effectiveness for a group of linguistically and culturally diverse learners as measured by performance tests and student questionnaires. The following questions were of specific interest to the study: (1) Did the instructional strategies embedded in the Earth systems curriculum positively affect the academic achievement of ELLs? If so, how effective were they? and (2) How well did the students connect with *The Living Planet* curriculum and embedded instructional strategies? This second question, which centers on students' engagement in instruction, illustrates the affective factor often overlooked in science teaching (Maatta, Dobb, & Ostlund, 2006). Thus, this report addresses students' perspectives of the curriculum, presents the evidence of the program's success with relation to instructional strategies, and discusses implications of the findings for mainstream teachers of linguistically and culturally diverse learners.

Curriculum and Conceptual Framework

Many, if not most, state policies require the majority of ELL instruction to be in English; therefore, English language and literacy development are prerequisites for content-area instruction (Chamot & O'Malley, 1994; Lee & Fradd, 1998). The Council of Chief State School Officers (CCSSO) (1992) emphasizes that schools must provide ELLs with an instructional environment in which they will "continue to learn and expand the knowledge of new content and therefore, not fall behind peers whose native language is English" (p. 6). Chamot and O'Mally (1994), Freeman et al. (2002), and Echevarria et al. (2004) reiterate the same goal for ELLs, pointing to science as one of the avenues for facilitating students' skills in the language as well as the content.

Fortunately, inquiry-based science presents countless opportunities for students to use science and the English language to strengthen their skills in both (Thier & Daviss, 2002). It has been established that the longer ELLs are exposed to inquiry-based science programs, the better their learning gains and the higher their achievement scores in science (Amaral et al., 2002). Thus, the objectives of *The Living Planet* curriculum are to promote students' understanding of scientific inquiry and Earth systems science through a culturally relevant approach that emphasizes the development of students' English language and literacy skills.

Earth Systems

The Living Planet curriculum utilizes Earth systems to teach the basic cycles and systems affecting our planet. Since Earth systems science encompasses the fields of Earth, space, physical, and life sciences, students learn science concepts from many different fields, which helps them to understand more complex issues. For example, in the lesson on photosynthesis and respiration, students learn about the exchange of carbon dioxide and oxygen between plants and animals. In another lesson, students relate their understanding of the photosynthesis and respiration to the processes involved in climate change.

The core goal of Earth systems education is to help citizens understand their interrelationships with other people and organisms worldwide and to learn how their daily activities affect the planet, its resources, and its ability to sustain life. In 1990, the Program for Leadership in Earth Systems Education (part of the Teacher Enhancement Program of the National Science Foundation) developed a framework for Earth systems education. This framework includes seven principles: (1) Earth is unique—a planet of rare beauty and great value; (2) human activities, collective and individual, conscious and inadvertent, affect planet Earth; (3) the development of scientific thinking and technology increases our ability to understand and utilize Earth and space; (4) the Earth system is composed of interacting subsystems of water, rock, air, and life; (5) Planet Earth is more than four billion years old and its subsystems are continually evolving; (6) Earth is a small subsystem of a solar system within the vast and ancient universe; and (7) there are many people with careers that involve the study of Earth's origin, processes, and evolution. *The Living Planet* curriculum incorporates these seven principles, emphasizing them in lessons (e.g., Earth as a planet, phases of the moon, seasons, climate change, photosynthesis and respiration, plate tectonics, rock cycle, heat transfer, ocean currents, renewable and nonrenewable resources, and humans' influence on the environment). While understanding Earth systems provides an international context for communication across linguistic and cultural barriers (Mayer, 2002), several strategies were also embedded in the curriculum to address diverse learners.

Science Inquiry and the Needs of Linguistically and Culturally Diverse Learners

The *National Science Education Standards* (*NSES*) outlines inquiry-based teaching and learning (National Research Council [NRC], 1996, 2000). Within this framework, students use process skills (such as observing, measuring, predicting, and conducting controlled investigations) along with their science content knowledge to conduct inquiry, which entails posing questions, designing investigations, collecting and analyzing data, drawing conclusions based on evidence, and communicating results in multiple formats. Fortunately, inquiry-based science presents countless opportunities for students to use science and the

English language to strengthen their skills in both (H. D. Thier & Daviss, 2001; M. Thier & Daviss, 2002).

English Language and Literacy

The Living Planet curriculum utilizes numerous strategies for ELLs to facilitate comprehension while promoting academic language proficiency. These strategies include avoiding unnecessarily complex grammatical constructions and idiomatic usage, using graphic organizers and other visual aids in the presentation of content, explaining in simple language the meaning of unfamiliar terms, pre-teaching of content, and providing a list of science vocabulary words for each lesson (Echevarria et al., 2004; Short, 1991).

In the context of science education, literacy development goes beyond being able to listen and speak conversationally (Cummins, 1981, 2001); it involves "learning to observe, predict, analyze, summarize, and present information in a variety of formats, such as orally, in writing and drawing, and through tables and graphs" (Lee & Fradd, 1998, p. 14). Inquiry-based instruction of *The Living Planet* curriculum is conducive to infusing content-area goals with literacy objectives (Thier & Daviss, 2002). According to Carrier (2005), "These objectives 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 notetaking, as well as the academic language functions needed to participate in science learning" (p. 6).

Many inquiry-based instructional opportunities specifically designed to strengthen students' English literacy skills were embedded in the curriculum. For instance, as teachers go over the procedures for experiments or other activities, they can model a series of language structures for ELLs as well. Also, to improve students' reading comprehension, each lesson lists vocabulary words before the reading passages. Then, the same vocabulary words appear in bold type within the passages and are reinforced again in the end-of-lesson reviews. Figures and tables visually support concepts presented in the text. To aid reading comprehension further, lessons follow a consistent format: introduction, science vocabulary, a list of materials, an inquiry framework (i.e., question, plan, implement, conclude, and report), questions for review and reflection, writing activities, and, finally, suggested Internet resources. According to Short (1991), such routines help ELLs anticipate what is coming without relying solely on the teacher's verbal cues. In each lesson, reading passages are divided into short sections followed by the corresponding step in the inquiry framework or questions to check comprehension. This lesson structure allows for more frequent modeling of language by the teacher. This is a desirable situation because language forms are not targeted in isolation, but they are immediately applied in the science context. Science inquiry can therefore strengthen literacy skills by infusing them with meaning and purpose, while literacy skills can strengthen science knowledge by giving students a linguistic lens through which to focus and clarify their ideas, inferences, and conclusions (Thier & Daviss, 2002, p. 6).

The inclusion of hands-on activities, an essential component of the inquiry-based approach, depends less on formal mastery of the instruction language and offers better access to students with limited science experience than decontextualized textbook knowledge (Echevarria et al., 2004; Lee, 2002; Lee & Fradd, 1998; Rosebery, Warren, & Conant, 1992; Short, 1991). For instance, by putting together a puzzle of the crustal plates, students can observe the pattern of plate boundaries and the location of earthquakes and volcanoes, which can help them understand the cause of earthquakes, tsunamis, and volcanoes. By beginning their science lesson with concrete practical experiences, even recently arrived ELLs will develop some understanding of what the lesson is about. In addition, because comprehension precedes production (Krashen, 1982), ELLs can show their understanding by hands-on demonstrations rather than by providing detailed explanation.

Collaborative work, another component of inquiry-based learning, provides ELLs with systematic opportunities to improve their English proficiency in the context of authentic peer communication. Group interactions with the focus on the task rather than the language provides a nonthreatening opportunity for the second language learner to listen to other children's discourse and, once confident, to contribute to the conversation (Amaral et al., 2002; Echevarria et al., 2004). As part of *The Living Planet* instruction, students participate in cooperative learning groups where speaking and listening are the primary means of sharing information and ideas.

Writing, which is frequently overlooked in science lessons, is especially emphasized in *The Living Planet* curriculum. Echevarria et al. (2004) stress the importance of content activities that integrate all language skills: reading, writing, listening, and speaking. Throughout an inquiry-based lesson, teachers help ELLs "in moving from registers expressing their firsthand experience in oral language to those expressing academic knowledge in writing" (Gibbons, 2003, as cited in Dobb, 2004, p. 18). Students can gain a deeper understanding of science when they write about their thinking because the act of writing may cause new ideas and relationships to be integrated into their prior knowledge (Fellows, 1994). Text representation encourages students to probe printed materials for deeper understanding. To improve students' writing skills and allow them to represent what they have read, *The Living Planet* curriculum unit contains a consumable student edition. While working through lesson activities, students use their consumable edition to record observations in tables, construct graphs, answer questions, and write explanations for and reactions to their findings. The goal is to move students from being able to write a complete sentence to a complete paragraph and, eventually, to a fluent report.

Donahue, Evans, and Galguera (2005) suggest three specific ways to represent text, which are embedded in student assignments in the curriculum: (1) genre-transforming exercises, (2) cooperative dialog writing, and (3) role-playing. For example, students are asked to view 30-second to two-minute public service announcement videos (called *eco-announcements*) about current environmental issues produced by the Earth Communications Office (see www.oneearth.org for more information). After students view the videos, they are asked either to answer open-ended questions or to write their own eco-announcements. This important genre-transforming exercise confirms and reinforces their comprehension of the language. Second, in several lessons, students are asked to use cooperative dialog writing to document scientifically based decisions that helped them locate and develop an imaginary island on Earth. At the end of each lesson, the "Literacy Connection" gives students the opportunity to discuss and summarize their learning or respond to a question related to the science content (e.g., students write a description of Earth to be sent to intelligent life in another solar system). Other lessons involve role-playing exercises that require students to apply previously learned science content to real-world situations. In one exercise, students participate in a simulation-type board game on threats to sea turtles. Students represent either a nest of hatchlings or a predator (e.g., a raccoon, pelican, or shark). In the island development lesson, students are asked to pretend to be the developer of an imaginary island.

Students' Home Language and Culture

Few studies address specifically the articulation of school science with students' cultural knowledge and experiences. In response to this gap in the literature, Lee and Fradd (1998) proposed the notion of *instructional congruence*, understood as the mediation of academic content with students' linguistic and cultural experiences to make such content accessible, meaningful, and relevant. This notion emphasizes the need to develop congruence not only between students' cultural expectations and norms of classroom interaction, but also between academic disciplines and the knowledge students bring from their own cultural environments. Recognizing that students' cultural beliefs and practices are sometimes inconsistent with modern Western science, effective science instruction should enable students to cross cultural borders between their home cultures and the culture of science (Aikenhead & Jegede, 1999; Snively & Corsiglia, 2001). Thus, instructional congruence underscores the role of instruction (or instructional interventions) as teachers explore the relationship between academic disciplines and students' knowledge, devising ways to link the two. Instructional congruence can serve as a conceptual and practical guideline for curricular design, teachers' professional development, classroom practices, and student assessment (Fradd, Lee, Sutman, & Saxton, 2002; Lee, 2002, 2003; Luykx & Lee, 2007).

The National Science Foundation has emphasized the need for culturally relevant curricular materials that recognize the diverse perspectives and scientific contributions of various peoples. Some researchers have argued that such materials foster higher achievement in science, more positive attitudes toward science, and enhanced cultural identity among ethnically and linguistically diverse students (Aikenhead, 2001; Freeman et al., 2002; Matthews & Smith, 1994). Studies indicate that most science materials, however, are not culturally relevant to nonmainstream students (Barba, 1993; Powell & Garcia, 1985) and that problems remain unresolved in materials that address cultural diversity in superfluous ways (Ninnes, 2000). Developing culturally relevant curricula requires a knowledge base from which examples, analogies, and beliefs from a range of different cultures can be drawn in relation to specific science topics and scientific practices.

Curriculum materials alone cannot ensure culturally relevant teaching. Teachers must also understand students' cultural legacy and recognize that students' own knowledge may be a valuable instructional resource. Above all, teachers' pedagogical orientation should empower students by linking curricular content to students' issues and concerns rather than taking a remedial, "deficit" view (Ladson-Billings, 1994). The limited body of research on culturally relevant science instruction illustrates some of the many challenges for teachers (Moje, Collazo, Carillo, & Marx, 2001; Westby, Dezale, Fradd, & Lee, 1999).

The Living Planet curriculum aims to address both aspects of culturally relevant instruction (i.e., curricular materials and teachers' orientation toward student diversity), particularly the notion of instructional congruence. To increase the curriculum's cultural relevance for Hispanic and Haitian ELLs within the study's population, Spanish and Haitian Creole glosses accompanied the English vocabulary words in each lesson. Moreover, several lessons provide opportunities for teachers to draw on students' cultural beliefs and backgrounds to make instruction more interesting and meaningful. For example, teachers can ask students about family experiences related to weather, climate, and the oceans. While the video eco-announcements show students how individuals are connected to their communities and globally to one another, they also stimulate discussions about cultural backgrounds. In the lesson based on readings of the Lorax, students are made more aware of the difference between their needs and their wants and the unequal distribution and consumption of resources on Earth.

In the island development lesson, student teams utilize content knowledge from the unit to develop and manage their own imaginary island. For example, students must decide where the island would be located relative to major ocean currents and tectonic plate boundaries as well as what kind of climate and ecosystems it would have. Each decision offers students—especially those who have migrated from island nations like Haiti or Cuba—an opportunity to incorporate their own knowledge of island environments. This final lesson also allows students to select the cultural values they consider important in making an ecologically sustainable community.

Methods

Research Setting and Participants

This study was implemented in a large southeastern urban school district with a high degree of linguistic and cultural diversity. The five elementary schools participating in the research were selected to represent the diversity of the school district with regard to students' ethnic and linguistic backgrounds, SES, English proficiency, and mobility rates, among other factors. Schools 1 and 2 served predominantly Hispanic students (87% and 92%, respectively). At School 1, most students were born in the U.S. (only 19% limited English proficient [LEP]) and from low to middle SES homes (44% received free or reduced lunch). School 2 had many students who were newly arrived or first-generation immigrants (47% LEP) from low SES homes (85% of students received free or reduced lunch). School 3 served students of predominantly Haitian (41%) and African American descent (28%); many were LEP (46%), and most were from low SES homes (95% received free or reduced lunch). Most of the students at the two remaining schools (Schools 4 and 5) were native English speakers (only 10% and 1% LEP, respectively); of White, Hispanic, and African American descent; and were from middle SES homes (19% and 16% free or reduced lunch, respectively). Approximately 600 5th-grade students participated in the study.

Professional Development

To implement *The Living Planet* curriculum, all 23 teachers were given complete sets of materials, which consist of student books, trade books related to the science topics in the curriculum unit, science supplies, and teacher's guides. The teacher's guide contains an explanation of the conceptual framework for the curriculum. Each lesson in the teacher's guide includes the state science standards addressed in the lesson, a list of materials for activities, transparencies, instructional information, and answers to questions. All teachers attended four all-day workshops throughout the school year, with each workshop being conducted at approximately two-month intervals. Following the sequence of lessons in *The Living Planet* curriculum, the workshops focused on three to four lessons at a time. These professional development opportunities gave teachers a chance to familiarize themselves with the curricular and instructional components of the curriculum unit, thus preparing them to implement *The Living Planet* curriculum effectively. By implication, teachers who effectively implement the curriculum are also able to teach the Earth systems science material using an inquiry-based approach that develops students' English language and literacy skills and incorporates their home language and culture.

Elementary school teachers are often less familiar with integrated science content and inquiry-based learning; therefore, the workshops concentrated on reviewing the curriculum's content and inquiry-based approach. Biological Sciences Curriculum Study (1989) developed the 5-E inquiry instructional model (i.e., Engage, Explore, Explain, Elaborate, and Evaluate), which Pratt and Pratt (2004) recommended as a research-based model that integrates inquiry and literacy strategies into science instruction. At the workshops, the 5-E model was demonstrated as the instructional approach for *The Living Planet* curriculum unit. Teachers also received specific training on the conceptual frameworks used to develop the curriculum. For each lesson, the workshop facilitators identified the English language and literacy skills development strategies and the methods to incorporate students' home language and culture that are embedded within the curriculum. Teachers taught *The Living Planet* lessons for an average of two hours per week, and most of them completed instruction of the unit by the end of the school year. (For a more detailed description of the professional development, see Lambert et al., 2007.)

Data Collection and Analysis

The research employed quantitative and qualitative data sources, including two assessments (i.e., a pre- and post-unit test as well as the National Assessment of Educational Progress [NAEP]/Third International Mathematics and Science Study [TIMSS] test) and an open-ended student questionnaire. The Earth systems science unit test and a scoring rubric were developed by Lambert to assess the conceptual accuracy of students' responses, the completeness of the responses, and the use of science terms related to the Earth systems unit. The unit test contained 16 items, including six multiple choice and ten short answer. The NAEP/TIMSS test consisted of publicly released items from the NAEP and the TIMSS that related to the instructional materials. Student performance is measured in reference to these national and international sample items. (See the Appendix for sample items from the unit test and the NAEP/TIMSS test.)

Cronbach coefficient alphas for the post-unit test and the post NAEP/TIMSS were 0.81 and 0.58, respectively. Quantitative data were analyzed using pre- and post-paired sample t-tests to compare the mean for the percentage of questions that students at different schools answered correctly on the pre- and post-unit and NAEP/TIMSS tests.

An open-ended questionnaire was designed for this study to support and help explain the quantitative results. It provided the 5th-grade students with an opportunity to reflect on their experiences with *The Living Planet* curriculum unit. Teachers were asked to have students respond to a questionnaire at the end of the curriculum unit and to collect the responses.

The qualitative data analysis involved summarizing and organizing the students' responses at the different schools into patterns and themes (Miles & Huberman, 1984). These patterns and themes (i.e., scientific understanding, English language literacy development, integration of home language and culture, view of science as a career, and relevance in life) were predetermined based on *The Living Planet* curriculum and conceptual framework when Lambert constructed the questionnaire and were embraced within the cognitive and affective types of questions. Questions were designed to provide insight into the 5th-grade students' cognitive and affective views of the curriculum unit's impact. The cognitive questions focused on the integration of science, English language and literacy, and home language and culture, and the affective questions focused on the more attitudinal outcomes of studying the unit. Table 2 shows the list of questions for each domain. The data were analyzed to compare and contrast the perspectives of students across schools of different ethnicities, linguistic abilities, and SES by both calculating the frequency of responses and categorizing the students' written responses into the themes previously described.

Results

Achievement

All five schools showed statistically significant improvements in their science achievement from the pretest to the posttest for both assessments (see Table 1 below). The *t*-test results indicate a significant change for the Earth systems test ($t = 30.34$ for all schools), and the analysis for the changes for all of the schools yielded large effect sizes (Cohen's *d* magnitudes). The *t*-test results indicated a significant change for the NAEP/TIMSS test ($t = 13.62$ for all schools), and the analysis of change for four of the schools (Schools 1, 2, 3, and 4) yielded medium effect sizes, with one school yielding a large effect size (School 5). The average change from pretest to posttest scores was greatest for Schools 2 and 5 on both the unit test and the NAEP/TIMSS test.

Table 1. Student Achievement on Earth Science Unit and NAEP/TIMSS Assessments

School	Fall (M, SD)	Spring (M, SD)	Change	Change SE	*t*	Cohen's *d*	d[a] (magnitude)
Unit							
1	22.85 (12.26)	43.45 (16.21)	20.60	1.39	14.85	1.68	large
2	25.05 (10.35)	50.54 (14.30)	25.49	1.08	23.54	2.46	large
3	21.12 (10.87)	32.91 (13.21)	11.79	1.28	9.25	1.08	large
4	32.29 (12.49)	45.17 (15.47)	12.88	1.49	8.64	1.03	large
5	32.38 (13.78)	70.28 (16.33)	37.90	1.80	21.09	2.75	large
All	26.00 (12.35)	47.33 (17.74)	21.33	0.70	30.34	1.73	large
NAEP/ TIMSS							
1	41.95 (15.21)	52.04 (18.22)	10.09	1.61	6.27	0.66	medium
2	41.13 (13.27)	52.54 (15.94)	11.41	1.36	8.39	0.66	medium
3	36.92 (12.78)	46.10 (17.06)	9.18	2.12	4.33	0.72	medium
4	51.97 (17.57)	61.59 (16.15)	9.62	1.80	5.35	0.55	medium
5	50.11 (15.58)	63.73 (17.34)	13.62	1.82	7.35	0.87	large
All	43.46 (15.64)	54.13 (17.70)	10.66	0.78	13.62	0.68	medium

[a] d > 0.20 is "small" effect size; d > 0.50 is "medium"; and d > 0.80 is "large."

Table 2. Students' Perspectives Related to the Cognitive and Affective Domains of the Intervention

		Cognitive Domain					Affective Domain		
School	*n*	Q 8. Science Knowledge (%)	Q 9. State Science Assessment (%)	Q 10. Text to Write in (%)	Q 13. Reading Level (%)	Q 14. Vocabulary (%)	Q 3. Science Career (%)	Q 5. Daily Activities (%)	Q 11. Value of *Living Planet* Student Edition (%)
1	82	94	82	91	83	79	40	84	80
2	55	93	89	87	84	87	38	89	95
3	18	94	100	100	100	78	50	83	94
4	47	81	74	70	74	64	45	62	53
5	45	98	84	91	89	84	40	53	87
Average	247	92	84	87	84	77	41	75	81

Cognitive Questions

Q 8. Do you feel you have learned a lot of science during this unit? Why or why not?
Q 9. Do you feel that this unit helped you on the science Florida Comprehensive Assessment Test (FCAT)? If so, how?
Q 10. Do you like having a science book to both read and write in? Explain.
Q 13. Was the reading in the unit hard to understand? (Percentage who answered "No" is reported.)
Q 14. Was the science vocabulary difficult for you? (Percentage who answered "No" is reported.)

Affective Questions

Q 3. Would you consider being a scientist? If "Yes," what kind? Why? Did this unit influence your decision?
Q 5. Is there anything you will do differently in your daily life from now on because of something you learned in this unit? Explain.
Q 11. Will you keep *The Living Planet* textbook that you used during this unit? Why or why not? If you will keep this textbook, what do you think you may use it for in the future?

Students' Perspectives on the Curriculum and Instructional Strategies

Students' perspectives of *The Living Planet* curriculum are summarized in Table 2. The percentage of students who responded positively (i.e., as the authors would hope) for each of the questions is reported for the five schools.

Cognitive Domain

Ninety-two percent of the students thought that they had learned a lot of science from their study of *The Living Planet* curriculum unit. Ninety percent or more of the students at all schools, except School 4, believed that they had learned a lot of science from the unit as a whole. Most quotes relate to the amount of science learned from *The Living Planet* curriculum such as the following:

> *I have learned a lot of science during this unit because I had no idea about most of the information in this unit but now I know about the Earth and how it works and most of this book I would probably remember for most of my life.* (School 1)

> *Yes, there are at least 30 new things I've learned in this unit. I think so because now I am more interested in science.* (School 1)

Some students gave specific examples. The following quote, for example, is representative:

> *Yes, I had always wondered why earthquakes happen, how mountains form, and especially about the greenhouse effect. I had heard something about it and was eager to learn what it was. Until now, I'd always wondered about it.* (School 1)

Eighty-four percent of the students thought that the unit had helped them on the science Florida Comprehensive Assessment Test (FCAT). More students at Schools 1, 2, and 3 (schools with a high percentage of LEP students—i.e., students who spoke Spanish or Haitian Creole) said the unit helped them on the FCAT than students at schools with a high percentage of English speakers. Many responses indicated that questions on the FCAT were similar to those in the curriculum or were related to the lessons. A typical quote was, "This helped me on the science FCAT because almost all (not everything) I learned in this book was on the FCAT science test" (School 2). The analysis of the students' responses to the questionnaire indicates that the curriculum unit had helped students prepare for the statewide science FCAT mainly by increasing their abilities to construct and interpret data tables and graphs and their knowledge of specific content presented in the unit.

Eighty-seven percent of the students said that they liked having a student edition of *The Living Planet* textbook in which they could both read and write. Many students said that writing in their student editions helped them learn more and made it easier to follow along with the teachers. One student (School 2) said, "It gave me the skills I needed for reading and for the writing." Another student (School 3) said, "I like having a science book to both read and write in because I can read the book and write notes about what I read." Others wrote about being able to express their feelings through the "Literacy Connection" and eco-announcement writing prompts. Other students gave more practical reasons such as not having to "waste time copying questions from books."

Eighty-four percent of the students thought that the reading level was appropriate, and 77% thought that the vocabulary was not too difficult. More students at Schools 1, 2, and 3 (schools with a high percentage of LEP students) thought the reading level and vocabulary were not too difficult than students at schools with a high percentage of English speakers. General comments from School 1 students claimed the "definitions helped in back and the words were not very hard because the definition is always explained in the book." Several students at Schools 1 and 2 wrote responses similar to the following: "I know Spanish which helped me in the lessons because some of the words come from Latin roots." Students also indicated that their reading comprehension had improved. Students said that being able to write in their student edition; highlight content; and find vocabulary and translations of words in English, Spanish, and Haitian Creole were the primary reasons for this.

Affective Domain

Forty-one percent of the students said that they would consider becoming a scientist as a result of studying *The Living Planet* curriculum unit. The greatest percentage of students wanting to become scientists was at School 3, the school with students of predominantly Haitian and African American descent. The reasons they gave, such as the following, were related to science being interesting and experimental in nature:

> *I would probably consider being a scientist because of this book and because of how interesting the solar system and plants and animals are. I could be an astronomer or biologist. I would say this unit did influence me to become a scientist because of the way this book was detailed really helped me understand every lesson.* (School 1)

> *No, but I would like to teach science. The book did kind of influence me because I would like to be a teacher.* (School 3)

Within one teacher's class at School 1, students' quotes indicated that the lesson on Rachel Carson and ecology had influenced students' responses. A student said, "I would like to be a scientist on marine life. The lesson on Rachel Carson showed me that I was a marine girl."

Seventy-five percent of the students said that they would do something differently in their daily lives as a result of the curriculum unit. More students at the schools with predominately Hispanic and Haitian Creole speakers wrote that they would act differently in their daily lives than students at schools with predominately English speakers. Most comments were related to taking care of the planet (e.g., not cutting down trees, littering, or wasting energy; recycling; cleaning parks and beaches). Several students' comments reflected a desire to change their activities to help reduce carbon dioxide levels in the atmosphere. A student at School 1 said, "I think about how I should treat the Earth instead of cutting down a whole forest and increasing carbon dioxide into the atmosphere." A few of the students also expressed concern about water use:

> *Yes, I do things differently now because of what I learned from "The Earth's Resources and the Lorax." Now that I've studied the lesson, I don't let my the water run while brushing my teeth, I recycle my garbage, and I appreciate what I have.* (School 1)

I think I am going to try to conserve water because I learned that the Earth doesn't have a lot of fresh water. (School 4)

A few students (Schools 2 and 5) said that they were planning to become scientists to help "discover more and save the planet."

An average of 81% of the students said they would keep *The Living Planet* student edition. A lower percentage (53%) of students at School 4 said they would keep their student edition. Two very common responses were related to someday teaching from it or passing it on to a family member and using it as a reference for future science coursework. The following are a few representative quotes:

I would like to read it again. I would probably give it to my niece, nephew, or my child and help them for the FCAT. (School 3)

Vocabulary and maps will help me in the future. (School 1)

It will help my studies when I become a scientist. (School 2)

The questionnaire asked three other questions to assess students' interest in the curriculum topics and embedded instructional strategies. The first was "What were your favorite lessons in the unit?" Students' favorite lessons varied from one that involved using a data table to compare and contrast the inner and outer planets to the more hands-on lessons (e.g., ocean currents or seasons) or the simulation-type activity on sea turtles. In the second question, students were asked, "What was your favorite part of the lessons?" Students' preferred components of the lessons were varied, with responses indicating the inquiry activities, "Literacy Connection," "Eco-Announcements," and "Island Development." The third question was "How did watching the eco-announcements affect you?" All of the schools, except for School 1, showed the eco-announcements to the students. Students' responses were mostly related to their novel understanding of the need to protect Earth. The following are a few representative quotes:

Watching the eco-announcements affected me because nature is a very pretty place and people are polluting it. (School 3)

I liked the videos about Earth, and it made me cry a little bit. (School 2)

The video really showed me how the earth is changing and how we are damaging it. We need to start taking care of Earth. (School 5)

Based on students' responses, the eco-announcements also provided an experience that the students wanted to write about. One student at School 2 said, "My favorite part of the lessons was the eco-announcements. I like them because you get to talk about the movie and write about what you feel." A student at School 3 said, "I like doing the eco-announcements because it gives you the experience to write your expressions about things." Another student at School 5 said, "I liked the eco-announcements because you would get to be an announcer and choose whatever you want to say."

Discussion and Implications

Based on the results, the data suggest that the instructional intervention was effective in terms of increasing linguistically and culturally diverse students' understanding of Earth science concepts. Students at School 5, a university laboratory school with 1% LEP and the highest SES, made the greatest improvement on both the Earth science and the NAEP/TIMSS assessments; while students at School 3, predominately African American and Haitian with the lowest SES, made the least improvement on these assessments. Students at School 2, who were predominantly first generation Hispanic, 47% LEP, and 85% on free or reduced lunch, made the second highest gains on both post-assessments. It is unclear whether the improvement of School 2 students was due to the teachers' implementation, the curriculum being designed especially for diverse learners, or socially motivating factors (i.e., a greater emphasis on education in first-generation immigrant families).

The study's findings with respect to students' perspectives on the effectiveness of *The Living Planet* curriculum provide possible explanations for the quantitative findings. Within the cognitive domain, a greater percentage of students at Schools 1, 2, and 3 (the higher need schools based on the percentage of LEP and SES) said that they had learned a lot of science from the curriculum and performed higher on the science FCAT than students at Schools 4 and 5. These students also did not think that the reading level and vocabulary were too difficult. Most students preferred having a workbook in which they could write.

The affective domain, which is frequently overlooked in quality science teaching but essential in making a positive connection with ELLs (Maatta et al., 2006) was examined in this study. Students were encouraged to express their views both throughout *The Living Planet* curriculum and in the questionnaire. Their responses indicate that the curriculum presented science in a way that was purposeful. The students' responses definitively support the premise that *The Living Planet* encouraged their interest in science and their contemplation of a career in science. In fact, several students reported being much more confident in their scientific knowledge, which may have played a role in their seeing themselves as scientists. After completing the curriculum unit, students also expressed an interest in modifying their own personal behavior. Over 80% of the students at the Hispanic and Haitian schools (Schools 1, 2, and 3) said they would change some aspect of their daily life.

The findings encourage questions as to what promoted changes in attitudes toward the discipline. Did the students feel better about science because, in their view, they achieved greater mastery of the content knowledge upon completing *The Living Planet* unit? The hypothesis is that students' positive experience in mastering the science content positively influenced their perceptions/perspectives of science.

Assuming that improved mastery of content knowledge positively influenced students' perspectives, the next question is why was the correlation stronger for higher-need schools? Several students (at Schools 1 and 2) indicated that the Latin basis of their native language (Spanish) helped them recognize and understand the science vocabulary words. This is not surprising as research in second language acquisition points out certain benefits of vocabulary transfer between romance languages that use words of Latin and Greek origin (Cummins, 2001). Role-playing activities, like the one on "Island Development," gave students with Cuban and Haitian lineage a way to incorporate their existing cultural knowledge and beliefs, which may have given them a stronger connection to the material. Perhaps Earth systems, as Mayer (2002) suggested, or the purposefulness of learning about global environmental issues are appealing to diverse students.

This study prompts a number of interesting questions—ones that further research may answer. By revising the methodology, the authors may find a better means of determining the role language and culture plays in developing students' understanding of specific concepts and attitudes toward science. Moreover, follow-up interviews may provide more insight into the differences of responses among school groups. It may also be important to determine the effectiveness of each specific instructional intervention in influencing the long-term academic success and behavior of linguistically diverse learners.

As the United States tries to maintain and increase its worldwide preeminence in science and technology, the demand for scientists is growing. Nationally, educators are looking for strategies that successfully stimulate students' interest in the science disciplines. This endeavor requires meeting two objectives: (1) improving students' attitudes about science and (2) improving students' understanding of learning science. The approach used in *The Living Planet* curriculum appears to have accomplished both. A thematic curricular approach based on a topic of global concern may help students at higher needs schools learn science, improve literacy skills, and become more motivated to pursue future studies in science.

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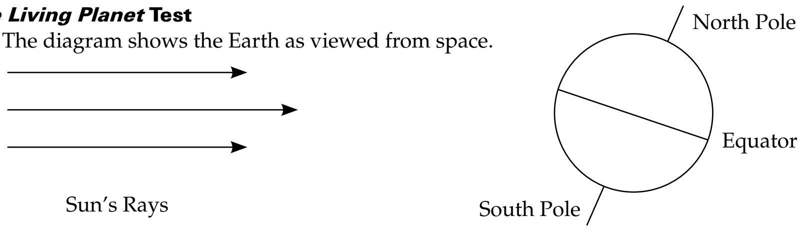
Appendix

Sample Items from *The Living Planet* Curriculum Unit and the NAEP/TIMSS Tests

***The Living Planet* Test**

6. The diagram shows the Earth as viewed from space.



   a. Based on the diagram, what season are people in the Northern Hemisphere experiencing?
   b. Based on the diagram, what season are people in the Southern Hemisphere experiencing?

NAEP/TIMSS Test Sample Items

3. Which BEST describes the movement of the plates that make up the Earth's surface over millions of years?
   a. They moved for millions of years but have now stopped.
   b. They stayed the same for millions of years but are now moving.
   c. They have been continually moving.
   d. They have never moved.

4. Which of the following is an important factor in explaining why seasons occur on Earth?
   a. Earth rotates on its axis.
   b. The Sun rotates on its axis.
   c. Earth's axis is tilted.
   d. The Sun's axis is tilted.

5. What is predicted to be a result of global warming?
   a. Rising ocean level
   b. More severe earthquakes
   c. Larger volcanic eruptions
   d. Thinning ozone layer

9. Jane and Mario were discussing what it might be like to live on other planets. Their science teacher gave them data about the Earth and an imaginary planet, Athena. The table shows these data.

	Earth	**Athena**
Atmospheric Conditions	21% oxygen 0.03% carbon dioxide 78% nitrogen Ozone layer	10% oxygen 80% carbon dioxide 5% nitrogen No ozone layer
Distance from a Star Like the Sun	148,640,000 km	103,600,000 km
Rotation on Axis	1 day	200 days
Revolution Around Sun	3,651/4 days	200 days

   Write one important reason it would be difficult for humans to live on Athena if it existed.

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