Helping English Learners Increase Achievement Through Inquiry-Based Science Instruction

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Abstract

This study summarizes the results of a four-year project in science education conducted in a rural setting with English learners in grades K–6 in the El Centro Elementary School District in southern California. Data were collected to measure student achievement in science, writing, reading, and mathematics for participating students. These data were analyzed relative to the number of years that students participated in kit- and inquiry-based science instruction that included the use of science notebooks. Results indicated that the achievement of English learners increased in relation to the number of years they participated in the project. The longer they were in the program, the higher their scores were in science, writing, reading, and mathematics.

Introduction

The push for accountability in education today is possibly unparalleled in the history of the United States. Educators are increasingly asked to demonstrate the effectiveness of programs through student achievement. This is often shown through the use of standardized assessments or by multiple measures that include standardized assessments. California is no exception. The state has mandated that all students, including English learners enrolled for at least one year in public schools, take the Stanford Achievement Test (SAT-9).

In the area of science, California has debated for some time which type of frameworks it should have, and still, only drafts are available. At the elementary level, the debate has included a discussion of the benefits of kit-based science instruction centered on a constructivist approach as opposed to the benefits of more traditional textbook approaches. Research on kit-based science programs, primarily from the 1980s, indicated that there was great value in their use, especially for females, economically disadvantaged groups, and minority students (Shymansky, Hedges, Woodworth, & George, 1990). In the 1990s, the use of kit-based materials was again hailed as something positive for elementary science instruction. Critics of a kit-based approach maintain that such programs do not provide the depth or quality of information students need to succeed in advanced science courses (Schroeder, 1999). The debate continues on several fronts, including program effectiveness for special populations such as gender and income groups, as well as for English language learners.

In the area of bilingual education, California has dramatically changed its approach to the education of English learners (ELs) since the passage of Proposition 227 in 1998, which called for most EL instruction to be conducted in English. Prior to that date, a transitional model was the most common instructional design used in California (Mora, 1996). Now, most school districts still offering bilingual programs opt for the Structured English Immersion (SEI) model where the use of the native language has been reduced considerably or eliminated altogether. This has resulted in an increased need for specialized teaching skills as well as a renewed emphasis on curricular adaptation in order to make instruction more comprehensible and meaningful for English learners.

In the effort to better meet achievement expectations, many districts have chosen to focus on reforms that target "the basics." This is usually interpreted to include reading, writing, and mathematics. Unfortunately, this is often done at the expense of other subject areas. They now often de-emphasize subjects such as science. However, the El Centro Elementary School District continues to view science as an important component of the instructional day. Science is essential for developing student thinking. Science also provides a context in which students can continue to develop reading and writing skills as well as mathematics. The superintendent of this district has been quoted as saying, "reading scores will improve only so much by doing more reading. If we are really serious about improving reading scores, students need a content area, such as science, to apply their reading and writing skills."

The study presented here was conducted in the El Centro Elementary School District in the Imperial Valley of California. It examined the science performance of ELs. Science was the subject area selected as part of a Local Systemic Initiative, supported by a National Science Foundation grant, to assist local schools in (a) the overall improvement of science education, (b) the development of science process skills, (c) the enhancement of critical thinking, and (d) writing improvement.

The Valle Imperial Project in Science (VIPS) is now being implemented at the elementary level in all 14 school districts in Imperial County. This program supports a constructivist approach in science through the use of kit-based instruction. Since the student population of Imperial County is 81.5% Latino and 46.7% of all students are limited English proficient, the effectiveness of this approach is paramount. With limited research available on the achievement of science of English learners, and even less information regarding the impact that kit-based programs have on other curricular areas, the impact of the VIPS kit-based science on ELs was studied. This paper reports the results of this study on the achievement of English learners in the areas of science, reading, writing, and mathematics when assessed with instruments in English.

El Centro School District and Imperial County

With a total of 11 schools, 6,179 students in K–8 (California Department, 1998–1999), the El Centro Elementary School District is the largest elementary district in the Imperial County. Most often referred to as the Imperial Valley, Imperial County is located in the southeast corner of California along the United States/Mexico border. It is both one of the largest (4,597 square miles.) and most sparsely populated (130,000) counties in California. The county lacks any large metropolitan area, and residents must travel to San Diego (120+ miles) or Los Angeles (200+ miles) to the nearest urban areas.

Many Imperial Valley residents live in extreme poverty, with household incomes declining in real dollars over the last decade. The IRS reported a 1998 mean per capita income of $17,353, the lowest of all California counties. The county's unemployment rates increased from 17.1% in 1991 to 23.2% in 1999, while the statewide unemployment rate for the latter was 5.2 %. Imperial County ranks highest in poverty of all 58 counties in California.

Most Imperial Valley residents have strong cultural and linguistic ties to Mexico. Of the 22,675 K–8 students in the Imperial Valley, 81.5% are Hispanic. In El Centro, that number is higher, at 84.9%. Table 1 describes the demographic profile, including ethnicity, socio-economic status, English proficiency, and Temporary Assistance to Needy Families (TANF), of the El Centro Elementary School District and compares it to the Imperial County and the state.

Services Provided to English Learners

The El Centro Elementary School District has provided special services to English learners since 1975. Until the passage of Proposition 227 in 1998, a transitional bilingual education model was widely used in El Centro as well as in California. In this model students received initial instruction in their native language (Spanish) in subject areas such as mathematics, science, and social studies while they studied English. Content instruction delivered in English

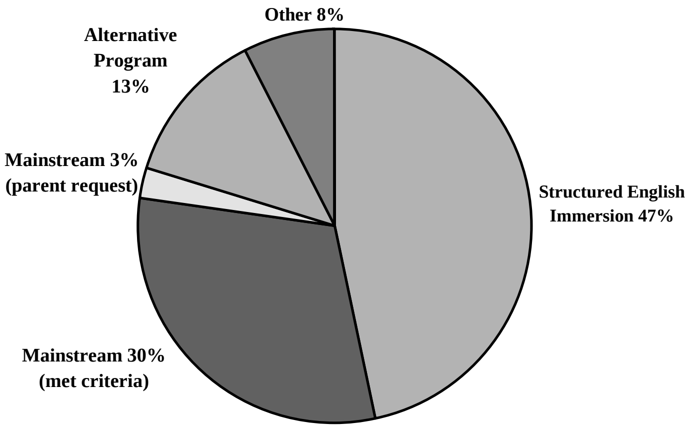
Table 1

Demographic Profile: El Centro, Imperial County, and California, 1998–99

	El Centro	**Imperial County**	**California**
Ethnicity: %			
American Indian	0.1	1.6	0.9
Asian	1.8	1.0	8.0
Pacific Islander	0.2	0.1	0.6
Filipino	0.2	0.4	2.4
Hispanic	84.9	81.5	42.2
African American	3.1	2.0	8.6
White	9.8	13.4	36.9
English Learners	53.9	46.7	24.9
Free/Reduced Lunch	71.8	65.8	47.3
CalWorks (TANF)	28.7	23.3	14.3
Teachers by Ethnicity: %			
American Indian	1.0	N/A	N/A
Asian	2.3	N/A	N/A
Pacific Islander	0	N/A	N/A
Filipino	0.7	N/A	N/A
Hispanic	41.3	N/A	N/A
African American	1.7	N/A	N/A
White	52.7	N/A	N/A
Enrollment: Elementary	6,179	22,675	1,209,110

was increased systematically throughout the student's placement in bilingual classes until such time as the student was ready for a placement in a mainstream or English-only classroom environment. When students developed sufficient proficiency in English, they were re-designated from Limited English Proficient (LEP) to Fluent English Proficient (FEP). Re-designation did not occur automatically within a specified period of time but rather was decided on an individual basis for each student. To examine a student's level of preparedness to transition to an English-only classroom, a team of teachers reviewed the classroom performance and achievement on assessments deemed appropriate for meeting the criteria for re-designation. Until such time, students were enrolled in primary language programs. In 1997, there were 1,569 students out of a total population of 6,349 (or 24.7%) enrolled in primary language programs. Another 588 (or 9.3%) were enrolled in Transitional or Sheltered English (now Structured English Immersion – SEI) classes. These were especially designed for students who had gained a sufficient level of proficiency to receive the majority of their instruction in English but did not score at required levels on standardized assessments to meet criteria for re-designation. During the 1999–2000 academic year, 318 out of a total 6,179 (or 5.1%) were enrolled in primary language classes while 1,537 (or 24.8%) were in SEI classes. The pattern in enrollments was altered within a period of three years. After the passage of Proposition 227, the district established a policy requiring that at least 70% of all instruction in SEI classes be conducted in English. Figure 1 shows the distribution of English learners in California.

Figure 1. 2000 Enrollment of English Learners by Program.



Source: California Department of Education (2000)

Primary language instruction refers to those classroom settings where a transitional model of bilingual education is used, one in which the use of English increases commensurate with the increase of student proficiency in English. At the time of re-designation of a student's status from limited English proficient (LEP) to fluent English proficient (FEP), the use of the native language in the classroom declines until it is eliminated completely. Special instruction in English, also called "sheltered immersion," is a program made up of classes where instruction is delivered in English and is to be geared toward the students' proficiency but without native language support provided to the student. The third program provides native language support but instruction is conducted mostly in English. The native language support is provided by either bilingual teachers or instructional assistants and can be provided within the classroom setting or through the use of pullout classes during the school day.

In 1998, Proposition 227 (now Education Code, Sections 300–340) was passed in California and brought about significant changes in services provided to English learners. School districts struggled with the interpretation of the law during the summer of 1998. Parents wishing to enroll their children in English-only settings continued to have that right. For others, the option of a Structured English Immersion setting for a period of one year was available. The law required parents to sign waivers requesting that their child be assigned to a bilingual classroom. Of the three models, the implementation of the Structured English Immersion was most problematic. While this model called for "a classroom in which the language of instruction used by the teaching personnel is overwhelmingly the English language," (California Department of Education, 1998a) districts were unclear as to how to interpret the meaning [overwhelmingly] and relate it to instructional practice. Could it be represented by having 51% of the instructional day conducted in English? Or was it 75%? Or 95%? In the fall of that year, implementation of services was different from district to district. Some school boards adopted models that had a ratio of 95/5 (English/native language) instruction while others chose 60/40 or 70/30 models. All of these were to be carried out in the context of one-year placements in SEI settings. Teachers were to adhere strictly to the language usage regulations set forth by their school board. The El Centro School District school board voted for a policy of a 70/30 model.

Professional development for teachers assigned to SEI classrooms was essential. Even those teachers who had received training in Cross-Cultural Language and Academic Development (CLAD) needed additional training in teaching English Language Development (ELD) and Specially Designed Academic Instruction in English (SDAIE). They were provided with opportunities for enhanced professional development. Some of this training came in the form of institutes offered by the local university, San Diego

State University (SDSU), Imperial Valley Campus, while others were given support to attend professional development outside the Imperial Valley, such as the California Association for Bilingual Education (CABE) and the National Association for Bilingual Education (NABE).

Many teachers turned to content areas such as mathematics and science to help English learners improve their content knowledge but also as a way to further develop their skills in English. Teachers chose these areas because they are taught using a constructivist approach in the El Centro School District. In the area of science, especially, a kit-based model had been piloted in two schools and had been expanded to other elementary schools in El Centro. Teachers, administrators, parents, and community representatives began to hear of the success of this reform effort through the ongoing evaluations of the project. When discussions of achievement surfaced, inevitably the question of performance of ELs was raised. Given the demographic profile of this district, it was imperative to analyze data specific to the achievement of ELs to answer some basic questions including: (a) their rate of achievement in science content; process skills, and writing; (b) how the growth of ELs compares to English-only (EO), limited fluent English speakers (L/FES), and re-designated fluent English proficient (R-FEP) students; and (c) how participation in the Local Systemic Reform Initiative affects student achievement.

Program Design and Implementation

The science reform model implemented in the Imperial Valley is based on five elements of effective reform documented in Science for All Children (National Academy of Science, 1997). These elements include: (a) high quality curriculum, (b) sustained professional development and support for teachers and school administrators, (c) materials support, (d) community and top level administrative support, and (e) program assessment and evaluation. It is a National Science Foundation (NSF) funded initiative that now serves over 20,000 students (K–6) in 14 school districts in Imperial County. It is also currently being expanded to junior high schools. It began in the summer of 1998 as a collaborative partnership between the 14 Imperial County school districts and SDSU, Imperial Valley campus.

A three-year pilot program that was established in three schools preceded this reform. It had a fully functioning materials resource center and developed a cadre of lead teachers. This pilot school effort was the result of El Centro's participation as a member of the National Science Foundation funded Pasadena Center Program at the California Institute of Technology. Direct technical assistance and support were provided by the Pasadena Center to build capacity within the district for future district-wide and countywide expansion of the program.

Curriculum

The Valle Imperial Project in Science utilizes a mosaic of second generation, high quality, research-based instructional units in the form of kits or modules drawn from such sources as:

1. *Science and Technology for Children* (STC) developed by the National Science Resource Center (NSRC) at the Smithsonian Institute supported by the National Academy of Sciences;
2. *Full Option Science System* (FOSS) developed at the Lawrence Hall of Science, University of California, Berkeley; and
3. *Insights* created by the Education Development Center in Newton, Massachusetts.

Students are exposed to four instructional units per year except at the kindergarten level where students are exposed to only three. Teachers spend approximately eight weeks teaching lessons from these units. Each unit is comprised of all materials deemed necessary to teach all lessons related to the unit. Each instructional module has an established instructional outcome where teachers continuously strive to have their students understand a "big idea in science." These units differ from more traditional science instructional models in that they contain all tools for students to experiment through a hands-on approach various concepts in science. Sometimes, teachers will be in the middle of an experiment in class and find that they have run out of materials, creating a sense of frustration and sometimes, resulting in reduced experiments and a greater reliance on textbook-driven instruction. In this program, there is a science center that refurbishes all instructional units every time a teacher finishes using one. Before it goes to the next teacher, class sets materials, such as cotton swabs or beakers, are counted out and placed in the kit.

The instructional units provide a balance of topics each year drawn from life, physical, and earth science domains. The units or modules provide students with rich opportunities to become directly engaged in both science content and science process skill development. Fewer science content topics are covered in greater depth as compared to the multitude of briefly addressed topics covered in a traditional textbook approach. In a unit-based model, each topic becomes a vehicle for the construction of important scientific concepts that are designed to be both developmentally appropriate and to engage the natural curiosity of the students. All modules are aligned to the National Science Education Standards. Table 2 is an illustration of the alignment of units per grade.

Table 2

Curricular Units by Grade

Grade	Life Science	Earth Science	Physical Science	Other
K	Myself and Others (I)	Sunshine and Shadows (D)	Wood (F)	
1	Living Things (I)	Finding the Moon (D)	Solids and Liquids (F)	Senses (I)
2	Growing Things (I)	Soils (STC)	Sink or Float (D)	Butterflies (STC)
3	Brine Shrimp (D)	Earth Materials (F)	Sound (I)	Amazing Air (D)
4	Microworlds (STC)	Solar System (D)	Changes of State (I)	The Mysterious Powders (I)
5	Crayfish*	Reading the Environment (I)	Circuits and Pathways (I)	Bones and Skeletons (I)
6	Experiments with Plants (STC)	Solar Energy (F)	Magnets and Motors (STC)	Measuring Time (STC)

Note. *not a commercial kit;
(I) Insights by Kendall Hunt; (F) FOSS: Encyclopedia Britannica, now Delta; (D) Delta Education; (STC) Science and Technology for Children by Carolina Biological Supply Company.

Language of Instruction

Most of the instruction in bilingual and in SEI classrooms is in English. Teachers have the freedom to use Spanish for facilitation of instruction, including the use of support materials written in translation. Students are encouraged to interact in English but are allowed to use Spanish as necessary during instruction. Sometimes this is done with peer assistance. Students make entries in science notebooks and these can be written in Spanish as needed. All language use in English and Spanish adheres to the guidelines set forth by the school board for the district's bilingual, SEI, or English-only settings. Instruction in English-only classrooms is all in English but students can sometimes work in pairs and use Spanish to discuss a concept.

Professional Development

Teachers are provided with at least 100 hours of professional development designed to deepen their own content understanding, address pedagogical issues, and to prepare them to teach the units at their grade level. Training took place continuously and cumulatively over four years. Teachers are introduced to the content of the module in the same manner as their students with a major focus of the initial training concentrating on the developmental storyline of the unit. The purpose of the developmental storyline is for teachers to experience and understand that the activities of the unit are connected and lead to big ideas in science. They also become acquainted with the individual lessons in the modules and with instructional and pedagogical and implementation strategies to bring the content and concepts to their students.

Teachers receive in-classroom professional support from a cadre of resource teachers (four of six are bilingual) and ultimately have an opportunity to meet in grade level groups to deconstruct or reflect on their teaching practices. Examination of student science notebooks where students have recorded their work is a major component of the reflective teaching practices in these sessions. Advanced topics in content, literacy, language acquisition, and module-specific multiple measure assessment strategies are also provided.

The inquiry-based science program initially started with 14 pioneer teachers from two school sites. The pioneers were volunteers and represented a variety of grade levels and teaching experiences. Five of the 14 teachers are bilingual. As the program progressed, more teachers and sites were added to the program until, in 1999, the program became available to all teachers at all sites. Teachers were introduced to the program gradually, with two units being introduced during the first year and the two remaining units added the following year.

Materials Support

The project's science/math resource center provides complete materials support for all the science instructional units. This support includes all equipment necessary for the unit as well as complete class sets of all the consumables and blank student science notebooks. The kits are picked up by district personnel and delivered to individual school sites. Teachers use the unit with their students for eight weeks at which point they are collected and returned to the materials center for refurbishment and redistribution to another site.

Administrative Support

There has been a high degree of community and top-level administrative support during the pilot stage that continued as the program expands across the county. The El Centro School District superintendent attended and often led training sessions for the building principals at the three original pilot sites. Each school principal attended a two-day symposium at the initiation of the project and continued to attend yearly follow up sessions. These wellinformed administrators were able to encourage and support teachers as they went for unit training and started implementing inquiry-based science in their classrooms.

Assessment and Evaluation

The Valle Imperial Project in Science uses formative assessment to gather information for program improvement and summative assessment to determine overall program effectiveness. Inverness Research Associates performs the formal program evaluation that they report to the project leadership team and the funding source (National Science Foundation). The VIPS research team from SDSU, Imperial Valley campus has focused its efforts on measuring student learning as an indicator of program effectiveness.

Student Learning Measures

The population in this study included students who had been enrolled in the El Centro School District for the previous four years, regardless of school of attendance. Students not enrolled for the full four years were excluded as data on the type of science instruction they had received in other districts were not available. The study population consisted of 615 students in fourth grade and 635 students in sixth grade. Students were divided into groups based on the number of years (0–4) they had been in the VIPS program. Student achievement in the academic areas of science and writing proficiency were compared across the program participation groups. Science was chosen to determine if there were differences in student science content knowledge and science processing skills. Three areas of science content were measured: earth, physical, and life science. These are consistent with the curricular model followed for instruction. Writing was selected for study because of the emphasis placed on the development of writing skills through the use of science notebooks. Other areas of achievement examined included reading and mathematics.

Achievement in Science

California has recently enacted a new set of school accountability laws, curricular standards, a new state testing program, and a new promotion/ retention law designed to legislatively move California public school classrooms into standards-based instruction. In response to the state emphasis on accountability, the leadership team of the Valle Imperial Project in Science designed a study that would document the learning of students who had participated in the inquiry science program. The study consisted of administering the science section of the Stanford Achievement Test, ninth edition, Form T, to all fourth and sixth grade students. The Stanford Achievement Test, ninth edition, Form T, was adopted by the California State

Board of Education in 1997 as the statewide test to measure student achievement in basic academic skills. The reading, language, spelling, and mathematics sections of this test comprise the secured state mandated test in California, and the science section is optional at the K–8 level. The state also requires all students who have been enrolled in California public schools for at least one year to take the test in English regardless of language background or proficiency level. Exemptions can be granted when parents request a waiver from testing in English.

This study of the VIPS program utilized SAT-9, Form T, Intermediate 1 for Grade 4, and SAT-9, Form T, Intermediate 3, for Grade 6. Each item was classified by the science content it measured and according to the science process it assessed. The content clusters included in both the Intermediate 1 and Intermediate 3 levels assess content from earth/space science, physical science, and life science as well as science process skills. The science process skills were classified into the following areas: (a) using and analyzing evidence and models, (b) recognizing consistency and patterns of change, and (c) comparing form and function. Intermediate 1 and Intermediate 3 levels were comprised of 40 content items including 12 questions from earth/space science, 14 questions from physical science, and 14 questions from life science. Thirty of these items were also designed to assess science process skills.

Achievement in Writing

Student science notebooks are an integral part of the science program as students are expected to collect, record, analyze, and report data for each of the inquiry units. Students are encouraged to make entries in English whenever possible, but the use of their native language is also acceptable. There is a dual goal in having ELs use science notebooks: to develop cognitive knowledge of science content and processing skills and to enhance their English writing skills. Teachers learn the effective use of notebooks for science instruction during each kit training session. For example, student notebooks from previous classes provide exemplars of student work that help teachers visualize possible student outcomes from the unit. Staff development sessions also address methods of using notebooks to enhance vocabulary and concept development, especially among English learners.

The VIPS program researchers examined the relationship between writing achievement and the number of years students had participated in the science program. The El Centro School District measures student achievement in writing through the district writing proficiency test, a locally developed assessment that uses prompts requiring a specific type of writing at each grade level. The study utilized the fourth and sixth grade district writing proficiency results from the spring 1999 administration. Classroom teachers administered the tests, but a team of trained evaluators at the district level scored them. The assessment was scored using a four-point holistic rubric covering content and the conventions of writing.

Findings

All fourth and sixth grade students in attendance during the administration of the Stanford Achievement Test, ninth edition, Form T, were assessed on the science section of the test. In 1999, the science component of the test was available to school districts to use without incurring additional expense for test administration or scoring services. Students categorized as LEP are not by definition at a level of proficiency deemed appropriate to participate in English-only instruction (and therefore, in English-only testing programs). The question of whether the assessment is valid as it measures understanding of scientific concepts or whether it is more a measure of the students' understanding or the language presented on the test can be debated. Yet, the El Centro School District felt that it could use the test as one of multiple indicators to gauge the level of success of its students in science instruction relative to the number of years they have participated in the program.

The data were first disaggregated to form a group that included only students who had attended an El Centro Elementary School District school continuously for the previous four years. This group was then further disaggregated into groups representing the number of years the student had been a member of a classroom that had participated in the district science program. Once these groups were identified, they were further disaggregated by proficiency designation. Results were analyzed for each of five different groups. The first is the limited English proficient (LEP) defined to include those students who have not yet attained proficiency levels in English in oral, reading, or written skills as measured by district-administered instruments such as the Bilingual Syntax Measure and writing proficiency tests. The second group is the limited/fluent English speaking (L/FES) which includes students who have met re-designation criteria on district-developed assessments but have not reached the threshold set by the district on standardized achievement tests (SAT-9) in the areas of reading and language arts. The third group is the fluent English proficient (FEP), defined as those students who have always been in English-only classrooms in the district but who also speak a language in addition to English. The fourth group is the re-designated/fluent English proficient (R-FEP), those students who were placed in bilingual programs for a part of their academic life in the district but who have met criteria for re-designation and have made the transition to English-only classrooms. And finally, the fifth is comprised of English-only (EO) students, those who are monolingual English speakers.

In the El Centro Elementary School District, all student cumulative records are electronically stored, and it is possible to retrieve individual student demographic information, achievement data, and their teacher for each of the previous four years. A sub-file for teachers was established, which referenced the year they began participating in the professional development program and had implemented the district science program in their individual classroom. The number of years each student had participated in inquiry-based science was computed by matching students with teacher implementation information.

Achievement in Science

The data from Table 3 indicate that there are distinct differences between students who participated in the district science program (for all five categories of language proficiency) during the 1998–99 school year and had been in attendance in the El Centro School District continuously for the prior four years. The data are consistent with that described by Bredderman (1983) in a quantitative analysis of 57 research studies comparing the learning effects of kit-based programs to traditional textbook programs. Bredderman reported a 14 percentile point difference, favoring the kit-based programs. The data are also consistent with a meta-analysis of 81 research studies conducted by Shymansky et al. (1990) contrasting the performance of students in hands-on, activity-based programs with that of students in traditional textbook-based programs.

Table 3 represents the total raw score data in science from the SAT-9 test disaggregated by number of years of participation in the district science program.

Table 3

Results in Raw Scores, Grades 4 and 6

Years of Participation	Grade 4		Grade 6	
	Mean Raw Score	No. Students Tested	Mean Raw Score	No. Students Tested
0	17.39	137	16.88	173
1	20.28	143	18.53	119
2	22.66	141	21.03	132
3	23.76	103	22.81	107
4	26.29	91	26.02	104

Note. Standford Achievement Test, 9th Edition, Form T, Science Section, Spring 1999, All Language Proficiency Designations, Disaggregated by Years of Student Participation in District Science.

A linear regression analysis between years in program and the respective mean science achievement scores was conducted for each grade level. This measure established a positive correlation between the two variables with $r = .9909$ for Grade 4 and $r = .9934$ for Grade 6. The data are consistent with the reported findings from both Wise (1996) in a meta-analysis of 140 published comparisons between hands-on and traditional textbook programs and Stohr-Hunt (1996) in a study of 24,599 students in 1,052 schools with regard to the frequency of hands-on experience strongly influencing student achievement. Both studies reported higher achievement scores for students with hands-on learning when compared to traditional textbook instruction. Neither of these studies, however, examined the effect of hands-on science instruction with English language learners. To address this question, the results from the VIPS study were analyzed according to years in program by language proficiency designation. Table 4 represents the total raw score data in science for Grade 4 students from the SAT 9 test disaggregated by years of student participation in the district science program as well as by language proficiency designation.

Table 4

Results in Mean Raw Scores for Grade 4

Years in Program	LEP	L/FES	FEP	RFEP	EO
0	15.8	19.1	19.1	20	18.5
1	18.6	20.9	20.9	24.8	21.9
2	19.1	25.1	25.1	24.6	23.2
3	20.2	27	27	27	26.4
4	24.4	27.6	27.6	30	26.5

Note. Stanford Achievement Test, 9th Edition, Form T, Science Section, Spring 1999, Disaggregated by Years of Student Participation in District Science Program, disaggregated by Language Proficiency Designations.

The Limited English Proficient (LEP) population was comprised of two sub-groups, the LEP and L/FES (Limited/Fluent English speaking) students. The English proficient population in the study consisted of three sub-groups: Fluent English proficient (FEP), English-only (EO), and re-designated fluent English proficient (R-FEP). A breakdown of the number of the LEP and EP students is reported in Table 5.

Table 5

Total Number of Students by Language Proficiency and by Years of Participation in Program Grades 4 and 6

Grade 4							
Years in program	**LEP**			**EP**			
	LEP	**L/FES**	**TOTAL**	**FEP**	**R-FEP**	**EO**	**TOTAL**
0	67	11	78	23	2	34	59
1	73	18	91	14	11	28	53
2	36	15	51	36	6	48	90
3	43	7	50	20	3	30	53
4	17	6	23	19	3	46	68
TOTALS	236	57	293	112	25	186	323
Grade 6							
Years in program	**LEP**			**EP**			
	LEP	**L/FES**	**TOTAL**	**FEP**	**R-FEP**	**EO**	**TOTAL**
0	81	42	123	9	5	36	50
1	40	43	93	7	5	24	36
2	23	47	70	13	16	33	62
3	9	29	38	18	16	35	69
4	3	11	14	19	10	61	90
TOTALS	156	172	338	66	52	189	307

The findings of growth in science achievement as measured by standardized assessments for students in Grade 4 shows consistent improvements among English learners the longer they were exposed to the program. That is, the longer they were exposed to the inquiry-based science program, the higher their achievement scores in science. A univariate analysis of variance was conducted for the data found in Table 6. The five levels of proficiency (LEP, L/FES, FEP, R-FEP, and EO) were regrouped into two general groups: limited English proficient (which included LEP and L/FES) and English proficient (including FEP, R-FEP, and EO). There was an *n* of 293 in the LEP group and 322 in the EP group. There was a consistent difference between the limited English proficient and English proficient populations. A two-factor (2x5) ANOVA revealed the main effect of proficiency to be significant, F (1, 614) = 54.06, $p < .001$. There was also a significant main effect of years in the program in scores, F (4, 614) = 29.24, $p < .001$.

Table 6

Results in Mean Raw Scores for Grade 6

Years in Program	**LEP**	**L/FES**	**FEP**	**R-FEP**	**EO**
0	14.4	17.3	19.8	19.8	20.6
1	16.8	16.8	23.4	18.8	20.1
2	19.5	19.5	24.2	24.1	21.9
3	22	22	21.6	26.2	23.7
4	25	25	26	26	26.1

Note. Stanford Achievement Test, 9th Edition, Form T, Science Section Spring 1999, Disaggregated by Years of Student Participation in District Science Program, Disaggregated by Language Proficiency Designations.

Fluent English proficient (mean of 23.9) and re-designated English proficient (mean of 25.2) students fairly consistently outscored both LEP (mean of 19.6) and English-only (mean of 23.3) students.

Similar results were found in Grade 6. A two-factor (2x5) ANOVA revealed the main effect of proficiency to be significant, F (1, 634) = 35.29, $p < .001$. As was the case in Grade 4, R-FEP and FEP (means of 22.9 and 23.0) students outperformed LEP, L/FEP, and EO (means of 19.5, 20.1 and 22.4, respectively) students.

Rosebury, Warren, and Sylvan (1995) have observed that science instruction in classrooms with English learners, when occurring at all, is used simply as a context for developing English language skills (p. 1). Inquiry-based instruction in the VIPS program attempts to do both: provide students with a strong understanding of scientific content and an enhanced level of linguistic proficiency in English.

Achievement in Writing

Students in the El Centro School District were given a test of writing proficiency developed by local educators. It reflects the writing genre emphasized in the curriculum for each grade level. The focus selected for Grade 4 is descriptive writing (object, event, or experiences) and in Grade 6 it is reporting information to help the reader understand a procedure or process. A score of 3 is needed to pass the writing proficiency test. Table 7 indicates the average level achieved by fourth grade students within each level of language proficiency.

Table 7

Grade 4 Writing Proficiency Pass Rate

Years of Participation	Grade 4		Grade 6	
	Pass Rate	**No. of Students Tested**	**Pass Rate**	**No. of Students Tested**
0	57.6%	137	22.5%	173
1	65.7%	143	68%	119
2	80.1%	141	71.9%	132
3	67.9%	103	90.6%	107
4	86.8%	91	89.4%	104
Total *n*		615		635

Note. All Students, Spring 1999 Administration, Disaggregated by Years of Participation in District Science Program.

In Grade 6, students were given a prompt where they are presented with a problem and they must propose solutions they must describe how they would go about reaching the solution(s). There was a hypothesis regarding the nature of the science inquiry method used in science instruction and a correlated increase in the ability among students to generate solutions and be able to write effectively (e.g., Dana, Lorsbach, Hook, & Briscoe, 1991; McColskey & O'Sullivan, 1993) about them. This was thought possible as a result of the increased practice students received in journal writing and the thinking process of inquiry that they experience during kit instruction. Findings indicate that student pass rates for Grade 6 increased proportionately in relation to the number of years of participation.

The performance of students in writing was also analyzed by language proficiency designation. Tables 8 and 9 report scores for students in grades 4 and 6 according to level of language proficiency as well as years in the program.

Table 8

Grade 4 Writing Proficiency Pass Rate, English Learners and English Proficient Students, Spring 1999 Administration

Years in Program	**Limited English Proficient (LEP & L/FES)**		**English Proficient (FEP, R-FEP, EO)**	
	Students Tested	**% correct**	**Students Tested**	**% correct**
0	78	52.5	59	64.4
1	91	59.3	52	76.9
2	51	60.8	90	90.0
3	50	54.0	53	81.1
4	23	78.3	68	89.7
Total *n*	293		322	

Table 9

Grade 6 Writing Proficiency Pass Rate, English Learners and English Proficient Students, Spring 1999 Administration

Year	Limited English Proficient (LEP & L/FES)		English Proficient (FEP, R-FEP, EO)	
	Students Tested	% correct	Students Tested	% correct
0	123	15.4	50	40
1	83	62.7	36	80.6
2	70	62.9	62	82.3
3	38	76.3	69	98.6
4	14	92.9	90	88.9
Total *n*	328		307	

Writing proficiency tests are administered each winter and spring. Scorers, who are often classroom teachers, receive training regarding procedures for holistically scoring writing samples. Samples are then used during the training until a level of calibration is achieved that ensures scorers consistently score samples alike, within acceptable parameters. Teachers score writing essays blindly and do not score the work of their own students. The scoring criteria are the same for all groups. That is, student samples are recorded with a student number and grade only. Neither student name nor level of language proficiency is available to teachers during the scoring process. Therefore, teachers cannot identify each according to proficiency group.

Achievement in Reading and Mathematics

The VIPS study did not start out to demonstrate that the program would impact achievement in reading and mathematics. Numerous innovations have occurred in both areas in the El Centro School District that could influence gains in achievement. Also, the renewed emphasis in general on increased achievement in reading, language arts, and math could possibly account for many improvements in these areas. In analyzing the data available, however, it was impossible to ignore increases that appeared to be related solely to the number of years of participation. The researchers considered some of the literature that suggests that inquiry methods teach problem solving and critical thinking (Edwards, 1997; Wenglinsky, 2000) and this could account for some of the increases found in student achievement in these areas. Table 10 provides mean NCE scores for students in grades 4 and 6 and their achievement in reading.

Table 10

Results in Mean NCEs, Grade 4 and Grade 6

Grade 4					
Total LEP			**Total EP**		
Years in Program	**LEP**	**L/FES**	**FEP**	**R-FEP**	**EO**
0	16.7	35.7	35.4	37.7	27.7
1	28.8	39.8	40.0	65.6	40.0
2	33.7	44.0	46.3	51.2	51.2
3	37.2	51.8	56.0	51.7	58.0
4	46.0	57.3	67.3	62.8	73.5
Grade 6					
Total LEP			**Total EP**		
Years in Program	**LEP**	**L/FES**	**FEP**	**R-FEP**	**EO**
0	24.9	32.2	38.8	40.0	46.7
1	33.9	31.2	52.6	47.5	44.2
2	36.4	39.1	58.5	56.7	47.8
3	30.5	42.8	54.1	62.1	53.4
4	43.2	57.2	60.4	68.4	63.8

Note. Stanford Achievement Test, 9th Edition, Form T, Reading Section, Spring 1999 Disaggregated by Years of Student Participation in District Science Program, Disaggregated by Language Proficiency Designations.

In the area of mathematics, similar results were found for each group (see Table 11). Achievement for students in Grade 6 in mathematics is higher than it is for fourth graders. Within each grade, there are still consistent increases for each proficiency group.

Table 11

Results in Mean NCEs

Grade 4					
Total LEP			**Total EP**		
Years in Program	**LEP**	**L/FES**	**FEP**	**R-FEP**	**EO**
0	18.4	24.6	20.4	24.2	17.9
1	35.8	34.5	34.8	35.6	35.2
2	45.9	46.4	45.9	46.3	44.9
3	54.7	57.1	56.6	55.1	57.0
4	73.7	72.5	71.2	68.0	73.1
Grade 6					
Total LEP			**Total EP**		
Years in Program	**LEP**	**L/FES**	**FEP**	**R-FEP**	**EO**
0	33.9	43.9	39.6	42.7	43.4
1	45.2	40.2	48.9	44.7	46.2
2	42.8	45.0	58.9	60.4	49.0
3	50.4	48.9	61.0	70.9	56.7
4	70.0	66.0	73.2	72.3	68.0

Note. Stanford Achievement Test, 9th Edition, Form T, Mathematics Section, Spring 1999.

There are some occasional increases and decreases in math achievement scores for certain groups that cannot be explained within this study. Further study of this group would be required in order to draw any conclusions.

Science Instruction for English Learners

A glimpse into classrooms that have English learners in them may provide some important background about the process some teachers utilize for developing skills in English while teaching science. Some observations have been conducted in three different types of classrooms: (a) bilingual classrooms, where there are only students who are limited English proficient and instruction usually consists of a 40/60 ratio of English/Spanish instruction; (b) structured English immersion classrooms with the same student population, but where the teachers use English whenever possible but never less than a 70/30 ratio; and (c) English-only or mainstream classrooms where the student population consists of groups with mixed levels of proficiency and instruction is conducted only in English.

VIPS teachers in bilingual classroom settings often introduce the topic for the day in Spanish. Lesson materials from the science kits are readily available and set up in advance by the classroom teacher. These are now given to the students. As the teacher distributes the materials, s/he begins to name the items being distributed in English while asking students to name them in Spanish or point to the appropriate item being named as a way to check for understanding. During each unit, the teacher creates a bulletin board which includes a list of key vocabulary related to concepts and materials used. A list of this vocabulary is also included in their science notebooks in the form of a glossary. Students are now given a series of instructions along with questions that help to lead students through their own inquiry. The teacher often writes students' questions on an overhead slide (or on the board) as a way to provide students visual and linguistic cues and share the ideas of each student with the entire class. These are often written in English but the teacher occasionally provides specific examples or a summary to students in Spanish. During a unit where observation is key, for example, students spend some time observing and sharing their impressions of their observations with a partner. They are then asked to generate questions they have about it. This generally occurs in the language with which they feel most comfortable. Each student then records his or her questions in their own science notebook. They are encouraged to write in English whenever they can but are allowed to write in Spanish those things they can not yet write in English. This leads to a design of their own experiment to determine results for one of the research questions they developed.

In a structured English immersion classroom, the teacher begins and maintains instruction in English. The students are expected to do their part in English as well but are allowed to switch into Spanish if needed. There is a greater level of reliance on peer translation and assistance. The teacher goes to greater lengths to explain the same concept in a variety of ways rather than relying on the quicker method of translation.

In the English-only or mainstream classroom, all instruction is in English. While the teacher is still responsible to ensure that students understand the curriculum, the teacher does not use Spanish even if s/he is proficient. Rather, there is an even greater reliance on peer assistance for those students who may not understand some vocabulary word, a direction, or a concept being taught.

Because of the nature of instruction in inquiry-based science, it is considered a good approach for English learners, regardless of classroom type. The use of real materials that students can explore, the ability to do some work independently but also work in small groups (Sutman, 1993), and whole classroom activities provide a diversity of approaches that can benefit students who learn linguistically in different ways. Also, the time provided for students to share their experiences and findings orally gives English learners great opportunities to use expressive skills for academic language. Chamot and O'Malley (1994) have written extensively about the need to develop academic language and have cited science as one of the areas conducive to that development. As important is the further practice of linguistic development of writing skills in science notebooks. This combines with the practice of explaining the process used during an experiment or the students' thinking about how a conclusion was reached, and it combines to further develop their cognitive abilities and linguistic proficiency at all levels. An integration of science and language learning (Fathman, Quinn, & Kessler, 1992) is viewed as one way to enhance overall skills of ELs. The following are possible additional reasons why inquiry-based science benefits ELs:

1. Time to build context: Through the process of exploration, students have opportunities to discuss and learn about the context for content learning. Kit-based instruction places materials directly in the hands of students and teachers guide discussions about the things they can see, touch, etc., and explore their background knowledge of the topic first. It is a much more concrete exercise than when a student merely reads about it, so there is a greater context provided for the lesson.
2. Builds common experiences: Students all share in these experiences equally. Because observation and exploration are used, there are more opportunities for students to learn from each other, and there is a reduction in the reliance of traditional text for learning. In more traditional science instructional settings, this reliance on text often results in reduced achievement for ELs who are still coping with learning academic language.

3. Builds thinking skills: ELs can access both languages more often in this setting. In more traditional text-driven classrooms, they are more likely to be restricted to the use of English. By accessing both languages, often as they work with peers, they do not have to expend so much energy on language and can place a greater focus on the concepts or ideas being explored and learned.
4. Cooperative learning (Rosebury, Warren, & Conant, 1992): As students work in pairs or small groups, they use a greater level of language because discussion is encouraged. This helps to develop their expressive skills and builds their vocabulary. Of benefit also is the interaction with peers as activities are conducted. That is, students may feel a greater level of comfort as they have peers walk them through a procedure during a hands-on activity rather than having a teacher guiding every aspect of a lesson. Students often hesitate to stop and ask questions of a teacher during a lesson but mostly feel free to ask questions more often of their peers. Peers can also at times serve to translate from one language to another, making the learning process a team effort, thereby not placing a single student in the "hot seat" of having to know the "right" answer or not or being able to explain their thinking in English.
5. Comfort level: In this environment, students are more apt to feel comfortable when they do not know the answer to a question or a problem. First, they learn that through the process of exploration, their ideas are as valuable as anyone else's because ideas tend to be viewed as hypotheses. Secondly, there is not always one right answer but possible multiple answers.
6. Creating positive attitudes toward learning: Students are encouraged to learn by "figuring it out" with some prompting and guidance from the teacher. When a student realizes that s/he has had some success in discovering something, there is an attitude developed where the student believes that there is no reason why the next thing cannot be figured out as well. One step into success leads to the next, creating a positive attitude and leaving students wanting to do and learn more.

Limitations and Questions for Future Study

While results from this study are encouraging, it is important to note that data were collected from one point in time. Further study on the achievement of these students is necessary to determine the level of sustainability of progress over time. As the program continues, there should also be a larger pool of students from which data can be collected. Future studies will also shed more light on the relationship between instruction in inquiry-based science and language development in the areas of reading, language arts and writing. For example, studies already underway examine the relationship between teacher training in the writing of science notebooks and student development of proficiency in the writing of various genres. Another will examine the level of development in reading achievement as it correlates to the inclusion of trade books in science education.

Summary

The report discussed here studied the impact of an inquiry, kit-based science program for ELs. Results indicated that the achievement of English learners increased in relation to the number of years they participated in the project. Specifically, the results showed a positive correlation between the number of years students participated in the program and student achievement in science, reading, writing, and mathematics.

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