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ELEMENTARY SCIENCE TEACHER EDUCATION

Possibilities and Limits of Integrating Science and Diversity Education in Preservice Elementary Teacher Preparation

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Abstract In this paper we present findings from a project that documented the development of preservice teachers' beliefs and practices in delivering science instruction that considers issues of language and culture. Teacher candidates in the intervention group ($n = 65$) received a science methods course and teaching practicum experience that provided guidance in teaching science in culturally and linguistically responsive ways. Comparisons between a control group of preservice teachers ($n = 45$) and those involved in the intervention yielded stronger beliefs about the efficacy in promoting collaboration in science teaching than the intervention group. Observations of these preservice teachers during their teaching practicum revealed differences in favor of the intervention group in: (a) implementing science instruction that addressed the language and literacy involved in science; (b) using questions that elicited higher order thinking and; (c) providing scaffolds (e.g., purposeful feedback, probing student background knowledge) when confronting abstract scientific concepts. Implications for preservice teacher education are addressed.

Keywords Science · Diversity · Pre-service teacher · Language · Literacy · Culture

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Introduction

The primary goal of science education reform is to improve student science learning by making rigorous science content accessible and holding all students to high standards and expectations, particularly students from non-dominant groups, whose achievement has persistently lagged behind that of majority culture students such as low-income students, African American and Hispanic students (American Association for the Advancement of Science, 1989, 1993; National Academy of Sciences [NAS], 2011; National Research Council, 1996). Such students typically have limited access to science education in elementary school and subsequently lower achievement in science.

Unfortunately, although present reform agendas emphasize “science for all”, they do not provide a coherent conception of equity or strategies for achieving it (Eisenhart, Finkel, & Marion, 1996; Lee & Fradd, 1999; Lynch, 2000; Rodriguez, 1997). Rodriguez (1997) documented wide gaps between ethnic groups in his analysis of trends in science achievement using national databases, including the National Assessment of Educational Progress, National Education Longitudinal Study, American College Test, Scholastic Aptitude Test, and Advanced Placement exams. For example, Latino and African American students consistently score in the lowest quartiles. By 2020, it is projected that Hispanic student enrollment in public schools will increase by 25 %, Asian/Pacific Islander student enrollment will increase by 35 % and American Indian/Alaskan Native student enrollment will increase by 17 % nationally (National Center for Education Statistics, 2011). Yet, the fastest growing demographic groups in the general population are the ones that are most under-represented in science and engineering fields. Currently <3 % of all Hispanic/Latino, African American, and Native American/Alaska Native who are 24 years old have earned a university degree in the natural sciences or engineering (NAS, 2011).

Fundamental to this problem is the limited knowledge base on how to teach science to culturally and linguistically diverse (CLD) students and how to better prepare the teachers that serve them (Lee, 2005; Stoddart, Pinal, Latzke, & Canaday, 2002). In this paper, we present results from a study focused on preparing novice practitioners to deliver science instruction that leverages students’ language and culture in the service of science learning. We utilize the research-based pedagogy set forth by the Center for Research on Education Diversity and Excellence (CREDE), referred to as the CREDE Five Standards for Effective Pedagogy (CFSEP) (Goldenberg, 1992; Tharp, 2005) as the building block for the intervention. The framework draws on culturally responsive pedagogy, the leveraging of experiences of students from diverse backgrounds to enhance student learning (Garcia, 2001; Gay, 2000, Moll, Amanti, Neff & González, 1992). In particular, the “funds of knowledge” construct (Moll et al. 1992), helped refine our understandings of the sources of knowledge in the personal, home and community contexts available to CLD students. In this paper, we investigate if preservice teachers that experienced the CFSEP model in their science methods course and teaching practicum demonstrate stronger beliefs and practices in culturally responsive science pedagogy than a comparison group of preservice teachers.

Science and Diversity Education

Subject matter education reformers tend to view equity and diversity issues as beyond the scope of their disciplinary work and assume that others will address these socio-cultural topics in the broader educational reform arena (Darling-Hammond, 2006; Lee, 2005; Secada, 1996). The equity and diversity research community, on the other hand, primarily attends to issues related to culturally responsive teaching, often overlooking subject matter, including science. As long as these two research agendas continue to operate independently, improving science achievement for all students will remain an elusive goal.

The CREDE model provides a conceptual framework for integrating research on subject matter and diversity education (Doherty & Pinal, 2002; Hilberg, Tharp, & DeGeest, 2000; Tharp & Gallimore, 1988). Researchers working through the CREDE center identified a set of practices that were associated with strong academic achievement of students from culturally and linguistically diverse backgrounds across subject areas. The five standards of effective pedagogy included promoting collaboration among students, instructional attention to the language and literacy involved within and across disciplines, connecting school curriculum to students' prior experiences from home and/or community, teacher's use of questions that elicit higher order thinking and maintaining academically challenging experiences with appropriate scaffolds. Doherty, Hilberg, Pinal and Tharp (2002) tested the efficacy of these practices with Latino students. In this quasi-experimental design study, Doherty et al. found students whose teacher's used the standards with fidelity, showed greater gains in comprehension, language development, and vocabulary on the Stanford achievement Test (SAT-9). The efficacy of these practices have been tested and met the evidence standards adopted by the What Works Clearinghouse (WWC), U.S. Department of Education Institute of Education Sciences (2006). Of 73 studies reviewed, the CREDE model was one of twelve quasi-experimental studies that showed improvement in reading and language development for CLD students. WWC standards of evidence strictly consider randomized control trials and quasi-experimental design studies.

Similarly, Lee & Fradd (1998) propose a framework—*Instructional Congruence*—to explain the possibilities of not only recognizing but also leveraging the language and culture of students from diverse cultural and linguistic backgrounds to facilitate science learning. A set of promising studies have taken place to better understand this perspective and specifically, how science instruction might be made relevant and accessible to all students by considering the role of students' language and culture (Adamson, Secada, Maerten-Rivera & Lee, 2011; Stoddart, Tolbert, Solis, & Bravo, 2010; Hart & Lee, 2003; Lee, Deaktor, Hart, Cuevas & Enders, 2005; Moje, Collazo, Carrillo, & Marx, 2001). Moje et al. (2001) examined the potential of project-based pedagogy for engaging CLD middle school students in science learning, with a particular focus on the discursive demands associated with this approach. Researchers analyzed the discourse practices in a science classroom and found that multiple, often competing, practices coexisted in the classroom, including the discourses offered by the teacher and those brought to the classroom by CLD students. Moje et al. found that, in spite of the teacher's efforts to bring the discourses into alignment, students and teacher often talked "across" each other (p. 478). Many students were left out of the classroom discourse due to misinterpretations of the discourse practices and texts. For example, some students were consistently unfamiliar with notational codes used by the teacher during science time —"N" representing "record in notebook" and "J" referencing "recording in journal." Moje et al. suggest using the ruptured discourse practice as a "third space" to expand students' knowledge beyond their own immediate experiences while using those experiences as a sound foundation for appropriating new knowledge. They provide an example for the possible bridging of prior student experiences and science learning expectations where a teacher draws on student experiences from the Dominican Republic who had lived through a hurricane in their native country to understand the natural disasters experienced in the United States.

To test the effectiveness of language and culture considerations in science teaching, Lee et al. (2008) implemented a five-year project that included inquiry-based curriculum units, hands-on science material, and professional development for teachers. The professional development for participating teachers included attention to the language and literacy needs of diverse learners, in particular, instructional supports to promote the understanding of key science concepts by using such visual tools as drawings of experimental setups and Venn diagrams. Teachers were also encouraged to engage students in a variety of group formations familiar to students from home experiences to promote communication. On a researcher-developed science assessment administered before and after a yearlong intervention, CLD students in the seven intervention classrooms outperformed students in the eight comparison classrooms in science achievement.

Also critical to consider as interventions are crafted to impact teacher learning is the stances science teachers take and how these stances mediate teacher learning. For example, Cochran-Smith et al. (2009) found preservice teachers had varied understandings of what it meant to have a social justice commitment—*maximizing student learning with the goal of improving life opportunities by challenging school and societal inequalities*—as a result of their teacher education program. Interview data revealed distinct interpretations as to how social justice addresses the learning needs of students of color. Several preservice teachers viewed the social justice focus of their teacher education program as simply providing quality teaching, while others saw a need and place for students' language and culture, still others equated social justice to providing students with basic skills. Mediating factors for preservice teacher learning included their teaching placement (Rivera Maulucci, 2011) and identity as a science teacher (Moore, 2008).

While the viability of preparing in-service teachers to teach science using the instructional models described above have been well documented (Lucas & Villegas, 2010; Teemant, Wink, & Tyra, 2011), understanding how to prepare preservice teachers to consider these instructional supports during science teaching requires further probing.

Method

Study Overview

We compare changes in post-baccalaureate preservice teachers' beliefs (pre/post survey) and practice (science teaching observation) across two conditions. One condition includes preservice teachers that received support in integrating science and diversity education using the CREDE five standards of effective pedagogy (CFSEP) model. The control condition received course work that addressed issues of cultural and linguistic diversity in a separate course and not integrated, as did the intervention group.

This study is guided by the following research questions:

1. Do intervention group preservice teachers demonstrate stronger beliefs in culturally responsive science pedagogy than control group preservice teachers?
2. Do intervention group preservice teachers implement these practices more fully in their teaching practicum than control group preservice teachers?

Intervention

The intervention CFSEP Elementary Teacher Education Program contained two components that include a CFSEP science teaching methods course and practicum placement with an experienced elementary classroom teacher who was provided with professional development in mentoring the preservice teacher on the CFSEP model. The model promotes teaching as a cultural practice, and attempts to address instructional ruptures with the goal of promoting social justice through education (Cochran-Smith, 2004).

CFSEP Science Methods Course

The curriculum in the intervention science methods course integrated the CFSEP in both content and delivery. The course included readings about and activities exemplifying each of the Five Standards for Effective Pedagogy, as outlined, validated and tested by CREDE (Doherty, Hilberg Epaloose, & Tharp, 2002). Delivery of the CFSEP included meta-pedagogical discussions of the practices. These discussions were moments when the methods instructors stepped out of the role of K-8 teacher and into role of teacher educator to underscore a practice, detailing the theoretical origins, research support and how to enact a particular practice.

The practices the teacher educators modeled in their courses included:

Standard I: Joint productive activity (JPA)
Standard II: Language and literacy development (L&L)
Standard III: Contextualization (CX)
Standard IV: Challenging activities (CA)
Standard V: Instructional conversation (IC)

Teacher and students producing together (Standard I) requires promoting Joint Productive Activity in classrooms where the teacher facilitates learning through purposeful interaction between the teacher and students and between students. JPA is more than making allowances for group work, the teacher promotes shared authority with students in the service of solving authentic problems. This was exemplified in the science methods course as a practice that is germane to the scientific enterprise, as scientists often work with other scientists and leverage each other's expertise to solve problems. Preservice teachers in the intervention course worked collaboratively to co-construct a science investigation that they presented to classmates and that pulled from their own expertise in relation to the science topic. Discussions of differing cultural knowledge (e.g., medicinal plant use, meaning of weather patterns) in collaboration were discussed and scaffolds to assure full participation by all students were offered (e.g., creating varied grouping structures).

Standard II supports language use as both a tool for learning and as part of science practices. Effective science classroom contexts are those where learners have opportunities to use academic language and genres for reasoning, speaking, reading, and writing in science. The methods course used science reference books, science discourse circles as examples for how the language of science can be explicitly taught. For example, Spanish/English cognates was discussed in the course, particularly the existence of cognates that are high frequency words in Spanish (e.g., *luna, sol*) yet academic science words in English (e.g., *lunar, solar*).

Contextualized teaching (Standard III) refers to acknowledging students' everyday, familiar knowledge and experiences and bridging this to lesson objectives. For example, in the science methods classroom, the instructor allowed students to make connections to understanding the phases of the moon by probing students' folk understanding of this concept that had roots in home and community knowledge. Such foundational knowledge was linked to the way scientists study the phases of the moon. While contextualizing instruction holds great promise (Moore, 2008) we also recognize it requires substantial support to implement.

Teaching through the use of Challenging Activities (Standard IV) refers to teacher moves that promote complex understanding of key concepts by monitoring student understanding, providing purposeful feedback, asking substantive questions, and giving assistance when necessary. The methods instructors displayed these through meta-pedagogical discussions as they provided grade-level material with the appropriate scaffolds to assure student success. The scaffolds included models of science reasoning, constructing explanations and opportunities for students to reflect on what they learned.

Instructional Conversations (Standard V) refers to the opportunities the teacher structures during a science lesson where he/she can directly model academic discourse patterns and evaluate students' comprehension of academic topics and tasks through dialogue. Teachers engage students in dialogue by initiating discussions, probing student ideas and re-voicing student contributions. The revoicing ensures student responses do not carry tag-questions (e.g., isopods, *isn't it?, erosion?*), responses formulated in question format that positions response as unsure and requiring confirmation, common among students from culturally and linguistically diverse backgrounds. The methods instructor provided transcripts of common teacher interactions (Initiation-Response-Evaluate, Mehan, 1979) and proposed other productive interaction patterns (e.g., Think-Pair-Share, Science Discourse Circle).

These CFSEP aligned practices were instantiated in assignments (e.g., conducting investigations and writing scientific reports), readings that included both science and culturally responsive pedagogy topics (e.g., *Ring my Bell: Contextualizing*

Home and School in an African American Community by Foster and Peele (2001); *Return of the King of Trees* by Wright (2004)) course activities (e.g., instructional conversations about readings). In year one, these practices were piloted in one science methods course and revisions to overall activities were made in year two. Data presented in this paper constitute the experiences candidates had with the revised science methods course.

Master Teacher Professional Development

The master teacher has the role of scaffolding preservice teachers' experience by modeling, providing feedback on practice and discussing such topics as curricular materials and student assessment results. The master teachers of preservice teachers in the intervention condition also received support in modeling, scaffolding, and providing feedback using the CFSEP model. Three visits by a research team member for 1.5 h per visit included calibration on the observation rubric, models for providing feedback that detailed strengths and needs of the candidate, and examples of expected lessons outlined in the science methods course. Follow up meetings (20 min) took place after the preservice teacher was observed to share observation notes of the practices needing support and consider instructional models to share with the preservice teacher. A video of the CFSEP practices, as implemented in other classrooms, was also shared with the master teacher as a point of reference. Master teachers in the control condition met with our researchers as well, but did not receive support with the CFSEP model. Instead they were informed about supporting the preservice teacher with feedback on their pedagogy as well as approaches to address classroom management, which is the typical professional development support for master teachers working with preservice teachers.

Given master teachers are assigned to preservice teachers according to geographic preference of the preservice teacher, master teachers were not selected to work specifically with the preservice teacher on the CFSEP model. Master teachers in either condition did not have prior experience with the CFSEP model according to our recruitment survey. Each master teacher was assigned one preservice teacher and the range of grade levels was Kindergarten (K) through fifth grade. There was no imbalance in grade placement between the conditions.

Site Descriptions

Sites include two California elementary teacher education programs of comparable size and teacher education focus. Both focus on developing teachers in bilingual and cross-cultural, language and academic language credentials. Over 40 % of the population is from a cultural/linguistic minority group. Both programs graduate over 200 teachers each year.

A requirement of both programs includes practicum placement of preservice teachers in Kindergarten-8th grade schools that are culturally and linguistically diverse. While data of the demographic information of each school where preservice teachers taught is not available, the two school districts where preservice teachers were placed is provided below. The ethnic representation of one school district included 33 % Chinese; 10 % African American; 11 % White; 23 % Latino; 6 % Filipino with 27 % of students designated as English language learners and 61 % of students on free and reduced lunch. The second school district is also culturally and linguistically diverse with 61.7 % Hispanic; 29.9 % White; 2.2 % African American; 3.1 % Asian. A total of 36 % of students were designated as English language learners and 72 % of students were on free or reduced lunch.

Participants

The preservice teacher education programs under study follow a cohort model. That is, all teacher candidates within a cohort take the same courses with the same classmates and are grouped into a set number of schools to conduct their teaching practicum. Of the five cohorts, in each teacher preparation program two were randomly selected to be in the intervention group and two were selected for the control group.

While over half of the participating preservice teachers where white (53 %), Latino preservice teachers comprised about one-third of the sample (32 %), with 10 % Asian and 5 % multiracial participants. Over 70 % of the participants' ages ranged between 20 and 30 years of age. The gender makeup of the sample was 81 % female, and 19 % male (See Table 1 below).

Notably, only three participants majored in a science related fields, while the majority (81 %) majored in Education, Humanities, Liberal Studies, and Social Science (See Table 2 below). Participants were enrolled in a one-calendar year teacher preparation program. Summer course work involved educational foundation courses that dealt with language acquisition and social and cultural considerations in teaching. Fall course work entails a developmental teaching and learning course, reading methods, science methods and candidates teaching practicum experience. In

Table 1 Pre-service teacher demographic characteristics by condition (n = 110)

	Intervention		Control	
	n	Percent	n	Percent
Race-ethnicity				
Asian/Asian American	7	10.8	4	8.9
Black	1	1.5	0	0
Hispanic/latino	33	50.8	2	4.4
Multiracial	2	3.1	3	6.7
White, non-hispanic	22	33.8	36	80
Age range				
20–24	28	43.1	20	44.4
25–29	21	32.3	17	37.8
30–39	9	13.8	3	6.6
40+	7	10.8	5	11.1
Gender				
Female	52	80	37	82.2
Male	13	20	8	17.8

Table 2 Credential program type and undergraduate major (n = 110)

	Intervention		Control	
	n	Percent	n	Percent
Undergraduate major				
Education	32	49.2	11	24.4
Humanities	10	15.4	9	20
Liberal studies	6	9.2	8	17.8
Social Sciences	9	13.8	12	26.7
Natural or physical sciences	2	3.1	1	2.2
Other	6	9.2	4	8.8

spring, candidates enroll in math methods, reading in upper grade courses and the teaching practicum experience. The course work where normally issues of culture and language are dealt with take place in the summer before candidates are in their teaching practicum and it is these courses that best align with the CFSEP model. This is different from the experience the intervention group received, where their science methods course infused those issues of culture and language into the methods course rather than experiencing at the onset of their program and not deal with them again.

A subset of preservice teachers (n = 56) were observed teaching science during their practicum experience. Table 3 provides demographic information of this subset of teachers.

Instruments

We used two researcher-created instruments to capture the impact of the intervention on novice teachers:

- The Science and Diversity Pedagogy Survey
- The Dialogic Activity in Science Instruction (DAISI) Observation Protocol

Science and Diversity Pedagogy Survey

The survey gauges teacher beliefs, in particular how they value certain pedagogies. The survey included Likert scale items clustered around each of the CFSEP practices. The instrument scales are *Strongly Agree, Agree, Unsure, Disagree, Strongly Disagree.* Following are number and examples of each construct: (a) JPA (12 items; *To promote effective science learning, the teacher should always control classroom activities* [*negatively worded*]); (b) L&L (12 items; *Songs and poems about science are not as important as writing science reports and reading science informational books*); (c) CX (13 items; *To promote science learning, the teacher should build on the knowledge students bring with them from their homes and communities*); (d) CA (12 items; *Figuring something out for yourself is more important than knowing the facts*) and; (e) IC (13 items; *Talking about science is as important as doing science*).

Table 3 Observed preservice teacher demographic characteristics by condition (n = 56)

	Intervention		Control	
	n	Percent	n	Percent
Race-ethnicity				
Asian/Asian American	1	3.3	–	–
Black	1	3.3	–	–
Latino/hispanic	17	56.7	2	3.8
Multiracial	1	3.3	1	7.7
White, non-hispanic	10	33.4	23	88.5
Age range				
20–24	15	50.0	11	42.3
25–29	8	26.7	11	42.3
30–39	2	6.7	1	3.8
40+	5	16.7	3	11.5
Gender				
Female	25	73.3	22	56.4
Male	5	16.7	4	12.8
Undergraduate major				
Education	5	16.7	8	30.8
Humanities	6	20.0	11	42.3
Liberal studies	2	6.7	2	7.7
Social Sciences	12	40.0	3	11.5
Natural or physical sciences	1	3.3	1	3.8
Other	4	13.3	1	3.8

Cronbach's alpha was calculated to gauge the internal consistency (reliability) of this instrument and found to be within an acceptable range for all five constructs ($\alpha = 0.73$). Items within each construct detailed teacher beliefs about the importance of each construct in scaffolding learning for CLD students (for additional details regarding the content validity of this instrument, please see Stoddart, Bravo, Mosqueda, & Solis, 2013). The survey was administered within 2 weeks of the program commencing and at the end of the program that coincided with the end of their practicum.

Dialogic Activity in Science Instruction (DAISI) Observation Protocol

The DAISI is a classroom observation instrument designed to capture the range of teaching practices in the classroom related to science teaching using the CFSEP. Five total rubrics comprise the instrument (Doherty, Hilberg, Epaloose, & Tharp, 2002), each scale from *not present (0), introducing (1), implementing (2),* and *elaborating (3).* Five graduate student researchers (GSR) gained inter-rater reliability (above 89 %) based on five video-recorded science lessons using this instrument. Only the GSR were involved in the observations. The reliability score included two additional checks conducted midway and toward the end of the data collection cycle (85 %).

DAISI scoring occurs every 15 min of a lesson, up to 1 h in duration. This observation protocol also captures teachers' talk, as lessons are also audio-recorded. Ethnographic fieldnotes accompany each observation as well. Cronbach's alpha was calculated on each of the subscales and found all to be above the acceptable range ($\alpha = 0.70$). The lesson topics are selected by the preservice teacher and aligned with curriculum and standards for the grade level where they are conducting their clinical experience.

The observations took place the subsequent semester from when the preservice teachers were enrolled in their science methods course. Three separate observations were conducted for each participant over the course of their practicum experience, a pre-observation took place within the start (2 weeks) of the second semester of their teacher preparation program and the second between the 15 and 10 week and final observation during the last 2 weeks of the 15-week semester. Due to variability in the timing of when the second observation took place across the sample, we only report on the pre and post observations in this paper. Moreover, only a subset of preservice teachers were observed ($n = 56$) due to placement issues with some preservice teachers who had not completed all the teacher credential program requirements. Observations averaged 45 min in length.

Data Analysis

We analyzed survey responses and observation scores between participants in the intervention condition in comparison to the control group teachers. We used ordinary least squares (OLS) regression for this analysis. Since other factors can influence the implementation of the CFSEP, we also tested whether or not the impact of the intervention was moderated by other contextual factors such as teacher demographic characteristics (ethnicity, gender, age) and schooling information (undergraduate major in college, and credentialing institution).

In order to address the possibility of bias on post survey and post-observation outcome measures, we included pre test measures as independent variables in our OLS regression models. This covariate adjustment technique allows us to represent the amount of change on the post assessment measures while accounting for each participant's pre test score. With the pre test scores controlled for in the model, any differences detected in this analysis reflect assessment performance beyond what is already measured on the pre test. Also, only matched pre post survey and observation data were included. The observation data includes a subset of preservice teachers from the full sample because not all participants initiated their clinical teaching experience the semester after they were enrolled in the science methods course.

Results

Survey

The results in Table 4 show that the intervention preservice teachers held stronger beliefs about the efficacy of the practices than the control group regarding one of the five practices—*Joint Productive Activity*.

Table 4 Survey descriptive statistics of beliefs toward the CFSEP (n = 110)

	Intervention		Control	
	M	*SD*	*M*	*SD*
Pre-beliefs survey				
JPA	3.06	0.29	3.22	0.30
L&L	3.14	0.22	3.13	0.25
CX	3.36	0.29	3.44	0.31
IC	2.93	0.27	3.11	0.27
CA	3.06	0.28	3.20	0.37
Post-beliefs survey				
JPA	3.14	0.32	3.10	0.27
L&L	3.17	0.28	3.16	0.22
CX	3.35	0.34	3.32	0.30
IC	3.20	0.33	3.21	0.23
CA	3.27	0.32	3.29	0.30

The intervention mean post score of beliefs on the *Joint Productive Activity* domain was slightly higher 3.14 ($SD = 0.32$) than the control mean post survey score of 3.10 ($SD = 0.27$), and these mean differences were statistically significant ($\beta = 0.15$, $p < .05$), controlling for pre survey scores, demographic, and schooling background measures. The descriptive statistics in Table 5 show that while the post survey response differences for this domain are small, the gains from pre- to post-survey are more pronounced since the intervention group mean was 3.06 ($SD = 0.29$), compared to the much higher control group pre-survey mean of 3.22 ($SD = 0.29$).

As illustrated in Table 5, no statistically significant differences were found between conditions for the other four domains. On these four domains, all preservice teachers' beliefs about the importance for implementing these practices during science hovered near a mean score of three, indicating strong beliefs about the efficacy of the practices.

Practices

Table 6 displays the pre and post mean observation scores for both groups across the five practices. Analysis of observation scores of preservice teachers revealed statistically significant differences on mean observation scores between conditions on three of the five practices (Table 6).

These differences were statistically significant and higher for the intervention group than the control in the *Language and Literacy* ($\beta = 0.42$, $p < .05$), *Instructional Conversation* ($\beta = 0.58$, $p < .01$), and *Challenging Activities* ($\beta = 0.46$, $p < .05$) domains.

The regression analysis in Table 7 illustrates statistically significant findings in favor of the intervention group relative to the control group. In the *Language and Literacy* domain, preservice teachers in the intervention group were associated with a 0.42 higher score relative to control group participants. Similarly, the CFSEP

Table 5 OLS regression analysis of survey results (n = 110)

	JPA Coef./(SE)	L&L Coef./(SE)	CX Coef./(SE)	IC Coef./(SE)	CA Coef./(SE)
Intercept	1.540***	1.011***	1.627***	1.605***	1.666***
	(0.305)	(0.282)	(0.331)	(0.323)	(0.282)
Condition					
Intervention (control omitted)	0.145**	0.041	0.047	0.071	0.086
	(0.068)	(0.049)	(0.067)	(0.064)	(0.064)
Pre-survey	0.487***	0.663***	0.498***	0.498***	0.497***
	(0.092)	(0.087)	(0.094)	(0.099)	(0.082)
Demographics					
Female (male is omitted)	0.025	0.091 ~	0.035	0.023	0.066
	(0.070)	(0.051)	(0.070)	(0.066)	(0.066)
Race-ethnicity					
Latino	−0.091	−0.017	0	−0.005	−0.084
	(0.070)	(0.051)	(0.070)	(0.067)	(0.067)
Asian (white omitted)	0.039	−0.086	0.198	0.196*	−0.050
	(0.102)	(0.075)	(0.102)	(0.098)	(0.097)
Age group					
Age (20–25)	−0.018	0.009	0.101	0.108	0.076
	(0.069)	(0.051)	(0.071)	(0.065)	(0.066)
Age (26–30) (age 31 + omitted)	0.071	0.018	0.018	0.032	−0.005
	(0.074)	(0.054)	(0.074)	(0.070)	(0.070)
Undergrad. major					
Education major (all other majors omitted)	−0.028	−0.055	−0.122	−0.008	−0.028
	(0.064)	(0.047)	(0.064)	(0.062)	(0.061)
Cred. institution					
Program 1 (program 2 omitted)	−0.074	−0.008	−0.161	−0.069	−0.091
	(0.063)	(0.045)	(0.063)	(0.060)	(0.061)
R^2	0.25	0.42	0.33	0.28	0.35

Key: ~ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

observation scores for the intervention preservice teachers on the *Instructional Conversation* and *Challenging Activities* domains were 0.58 and 0.46 units higher relative to the mean scores of their respective control group peers, controlling for demographic and institutional characteristics. No statistically significant differences were found between conditions with respect to the other two instructional practices–*Joint Productive Activity, Contextualization.*

Discussion

Preservice teachers in both groups held strong beliefs about the efficacy of all the practices at the onset of the intervention. Both groups averaged a score between 3.06

Table 6 Descriptive statistics of observation results (n = 56)

	Intervention		Control	
	Mean	SD	Mean	SD
Pre-DAISI observations				
JPA	1.63	0.43	1.61	0.49
L&L	1.33	0.52	1.07	0.49
CX	0.99	0.57	0.60	0.44
IC	1.38	0.45	1.31	0.40
CA	1.41	0.57	1.13	0.59
Post-DAISI observation				
JPA	1.78	0.54	1.54	0.57
L&L	1.39	0.70	0.93	0.37
CX	1.09	0.80	0.59	0.60
IC	1.73	0.53	1.31	0.52
CA	1.60	0.62	1.04	0.52

and 3.4 of 4 possible points on the pre-survey. Preservice teachers in the study agreed that the practices enhance and are important for science learning. While students had positive beliefs about the efficacy of these practices at the onset of the study, they were not able to successfully enact these practices as they taught science lessons in their field placement. Both groups averaged an initial observation score between 0.60 and 1.63 and 0.59 to 1.78 for the post observation on the four-point observation rubric.

Pre-Service Teacher Beliefs

The intervention did manage to create positive movement in teacher beliefs about the efficacy of *Joint Productive Activity*. While modest gains from pre to post survey, the intervention group did increase more than the control group in their beliefs about the efficacy of this practice, which includes teacher's use of purposeful grouping and sharing authority with students during science investigations. Survey items probed teacher candidates' beliefs about the efficacy of allowing for group work to take place during science instruction, including how groups were established (e.g., heterogeneously, according to student characteristics) and type of grouping used (e.g., pair work, small group, whole class).

These gains can be attributed to the substantive treatment this practice received on the part of the methods instructors in comparison to the other practices. Both science instructors in the intervention group exemplified this practice through not only what they taught (e.g., readings about cooperative learning in science) but also how they taught the course (e.g., students working in small groups on in class investigations). They revisited this practice constantly because they found it most aligned with their vision of science education. In one faculty's class, he is quoted as saying "*scientists don't sit in lecture halls. Instead, scientists work collaboratively in small groups to draw on everyone's expertise*" (11/6/07).

The other practices also received attention in the science methods course. But these were each unpacked in a single class meeting, with cursory follow up of the practice when assignments were due and students needed to implement the practice in their lesson plans or science report. The instructors' science inquiry inclinations and this alignment with the *Joint Productive Activity* practice translated into sustained treatment of the practice and consequently accounting for the difference between the groups. Such finding suggests efforts to integrate diversity and science pedagogy should consider locating the 'sweet spots', spaces where there is a natural overlay to reap the benefits of integration. Moreover, the data also suggests impacting teacher candidate's beliefs about the efficacy of these practices requires experiences that are sustained throughout the science methods course rather than a single unpacking of the practice in one class meeting and then moving on to the next.

Pre Service Teacher Practice

Of note is the very low incidence of all teacher candidates involving students' 'funds of knowledge' (González, Moll, & Amanti, 2005) in their science lessons. *Contextualization* scores across conditions reached a score of 1.09 on the observation rubric. At best, teacher candidates provided *Contextualization* examples—connections between students' personal, home or community experiences and the science activity under study—yet did not elicit these from students or plan instruction that involved these connections. For example, one intervention teacher candidate in the final observation, taught a science lesson to 2nd grade students about plant structures. In the observation notes, only one example was captured when the teacher candidate alluded to the plants found in the homes of students, and only after one student interrupted the lesson to share about the plants his mother kept for medicinal purposes. This struggle by teachers to capitalize on student experiences is in line with findings from other research efforts (Lucas & Villegas, 2010; Teemant, Wink, & Tyra, 2011).

Coherence between experiences in the science methods course and teacher candidates' placement was a contributing factor for preservice teachers in the intervention group being able to more successfully implement *Language* and *Literacy Development*, *Instructional Conversation*, and *Challenging Activities* teaching practices into their science teaching than the comparison group. Both science methods instructors and the master teachers used a common language in their presentation and feedback provided to the intervention teacher candidates. Such alignment allowed participants to hear a unified voice about how to enact science instruction that supported the learning of the CLD students in their class.

We hypothesize that teacher candidates in the intervention group distinguished themselves from the comparison group in their ability to enact these practices and not *Contextualization* or *Joint Productive Activity* is attributed to contextual factors. Master teachers honed in on providing feedback on practices that supported the academic language development as well as science understandings given that large numbers of their students were English learners and speakers of non-standard English. Teacher candidates in turn ensured the science lessons they taught, more

Table 7 OLS regression analysis of observation scores (n = 56)

	JPA Coef./(SE)	L&L Coef./(SE)	CX Coef./(SE)	IC Coef./(SE)	CA Coef./(SE)
Intercept	0.668	0.261	0.310	0.602	0.340
	(0.383)	(0.334)	(0.348)	(0.344)	(0.360)
Condition					
Intervention (control omitted)	0.368 ~	0.420*	−0.139	0.58**	0.463*
	(0.189)	(0.205)	(0.220)	(0.184)	(0.214)
Pre-survey	0.329*	0.189	0.524**	0.234	0.266 ~
	0.154	(0.166)	(0.166)	(0.172)	(0.149)
Demographics					
Female (male is omitted)	−0.024	0.153	−0.122	0.284	0.188
	(0.186)	(0.199)	(0.215)	(0.182)	(0.214)
Race-ethnicity					
Latino	−0.054	0.193	0.831***	−0.032	0.226
	(0.194)	(0.201)	(0.218)	(0.193)	(0.213)
Asian (white omitted)	0.017	−0.192	0.156	−0.429	−0.253
	(0.382)	(0.396)	(0.432)	(0.372)	(0.422)
Age group					
Age (20–25)	−0.021	−0.119	−0.198	−0.192	0.151
	(0.187)	(0.198)	(0.213)	(0.185)	(0.209)
Age (26–30)	0.097	−0.054	−0.356	−0.043	0.035
(age 31 + omitted)	(0.202)	(0.210)	(0.226)	(0.201)	(0.227)
Undergrad. major					
Education major (all other majors omitted)	−0.011	0.004	0.112	−0.140	−0.199
	(0.223)	(0.229)	(0.247)	(0.214)	(0.242)
Credential institution					
Program 1 (program 2 omitted)	0.453*	0.572	0.301	0.393*	0.269
	(0.187)	(0.200)**	(0.210)	(0.184)	(0.207)
R^2	0.31	0.40	0.50	0.38	0.39

Key: ~ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$

directly addressed practices that would sharpen students' academic language and science understandings.

Limitations

Interpretations of the study results must consider several study limitations. First, the fidelity of implementation of the model was challenging. Instructors gravitated toward practices that resonated with their science teaching dispositions and hence did not implement all the practices in a uniform fashion. We are currently developing an instrument building on the existing observation protocol to capture the fidelity of implementation among instructors and using this data to inform professional development activities for instructors. Second, the sample size was small due to the time-intensive nature of classroom observations and attrition. With a smaller sample size, it was more difficult to detect treatment effects at the acceptable statistical probability (*p* value) levels (Cohen, 1988). Finally, the CFSEP four-point scale on the survey was not nuanced enough to capture the varying beliefs about the efficacy of the practices, suggesting we may need to expand the scale.

Implications for Pre-Service Teacher Education

Positive beliefs about the efficacy of pedagogy is a critical trait for effective science teaching (Lee & Fradd, 1999; Stoddart et al., 2002). Preservice teachers strengthen their beliefs about diversity pedagogy in science when these practices are explicitly labeled, modeled and they receive feedback on their enactment of these practices. Science teacher educators who plan to enhance the manner in which they address the needs of CLD students in their courses must be observant of the need of this level of detail in unpacking these practices, and to craft experiences for preservice teachers that revisit these practices. To facilitate this process, considerations regarding the natural convergence between science and diversity education requires more attention. This may offer science methods instructors approaches to enact the diversity pedagogy in ways that are aligned with the scientific enterprise. For example, presenting ways of talking (*Instructional Conversations)*, reading and writing (*Language and Literacy Development*) as skills practiced by scientists and that support science learning, can provide an authentic rather than contrived reason to address these language domains instructionally in the context of science.

The notion of coherence between what preservice teachers experience in their teacher preparation program and their clinical experience, also shows potential for assisting preservice teachers in enacting practices that support the science learning of CLD students. More conversations between methods instructors and master teachers can create a more lucid experience for preservice teachers. These conversations could help avoid confusions that arise from hearing different language used to explain the same practice.

Integrating diversity pedagogy as defined by the CFSEP and science education with guidance from science methods instructors and support from master teachers shows promise in assisting preservice teachers to enhance their science teaching by considering the cultural and linguistic resources that are present among the students they work with in schools. These efforts can ensure the next generation of educators are making science more accessible to *all* students and hence begin to address the persistent science achievement gap.

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