Teaching English Learners through Science-Language Integration: Linking a Conceptual Framework to Secondary Teacher Preparation, Symposium presented at the annual meeting or the Na...

Conference Paper · April 2015

4 authors, including:

Edward G. Lyon
Sonoma State University

Trish Stoddart
University of California, Santa Cruz

Sara Tolbert
University of Canterbury

Teaching English Learners through Science-Language Integration: Linking a Conceptual Framework to Secondary Teacher Preparation

Edward G. Lyon[1], Trish Stoddart[2], Jorge Solis[3], Sara Tolbert[4], George C. Bunch[2], Barry Roth[4], Ivan Salinas[5], Corey Knox[4], Joanne Couling[2], Malcolm Butler[6]

[1]*California State University, Sonoma*, [2] *University of California, Santa Cruz University,*

[3]*University of Texas, San Antonio*, [4]*University of Arizona*, [5]*Universidad de Chile*

[6]*University of Central Florida*

Symposium presented at the 2016 annual meeting of the National Association for Research on Science Teaching. Baltimore, MD

Author Note

Funded by the National Science Foundation DR K-12 grant #1316834. Portions of this paper have been adapted from the forthcoming book, *Secondary Science Teaching for English Learners: Developing Supportive and Responsive Learning Contexts for Sense-Making and Language Development* (Lyon, E. G., Tolbert, S., Solis, J., Stoddart, T., & Bunch, G. C., Eds)

Correspondence to Edward G. Lyon Email: lyone@sonoma.edu

Mailing address: School of Education, 1801 East Cotati Avenue, Rohnert Park, CA 94928-3609

Abstract

We discuss a secondary science teacher preparation intervention (namely, redesigned science method courses and professional development for mentor teachers across four institutions) that developed a set of instructional practices (referred to as SSTELLA Project Practices), centered on the integration of science, language, and literacy, to prepare secondary pre-service science teachers (PSTs) to teach science in classrooms with English Learners (ELs). In addition to discussing how the SSTELLA Project Practices were embedded within pre-service teacher preparation, we report on three analyses from a quasi-experimental research design (with a baseline control group) to show preliminary findings related to (1) PST implementation of the practices during student teaching, (2) PST knowledge/beliefs in teaching science to ELs, and (3) the relationship between science method instructor teaching and PST practice. Analyses reveal that PSTs participating in the redesigned method course and SSTELLA-informed mentoring implemented the four (out of nine) sub-practices at a statistically significant higher level than those receiving a business as usual method course and mentorship: contextualizing science activities through ***framing*** and ***adapting/applying*** and providing more opportunities for ***student interaction*** and ***science talk***. Analyses also reveal a tentative relationship between more explicit pedagogical development of these practices in the method course and treatment participant's practice. Finally, preliminary analysis of interviews has resulted in a coding scheme to link teacher beliefs around SSTELLA Project practices and implementation of them. The analyses collectively provide preliminary evidence that will guide continued work linking a conceptual framework of science-language-literacy integration to the secondary science teacher preparation.

Keywords: Secondary science, pre-service education, English learners, language and literacy development

Teaching English Learners through Science-Language Integration: Linking a Conceptual Framework to Secondary Teacher Preparation

The work reported in the paper provides a much-needed response in science education to the challenge novice secondary science teachers face when attempting to increase opportunities for their English Learners (ELs) to learn science and develop proficiency in English. Almost two decades ago, August & Hakuta (1997) argued that extending existing theories and methodologies of content area learning and second-language literacy should be the highest research priorities for improving schooling for language minority children. One reason cited is that schools often foreground language instruction over content learning for ELs (August & Hakuta, 1997; Echevarria et al., 2011). Since then, research finds that when integrated with language and literacy development, inquiry-based science provides an ideal context for all students, including ELs to improve science learning (Cervetti, Pearson, Barber, Hiebert & Bravo, 2007; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; Rivet & Kracjik, 2008; Stoddart et al., 2002). We discuss how this research on science-language-literacy integration led us to develop a set of interrelated instructional practices as part of the Secondary Science Teaching with English Language and Literacy Acquisition (or SSTELLA) Project funded by the National Science Foundation. These instructional practices were embedded in two critical pieces of university teacher preparation programs across four sites: the secondary science method course and mentoring of pre-service teachers (PSTs) during their student teaching. Through three specific analyses, we provide preliminary evidence and analytic approaches to guide continued analysis to link the use of a conceptual framework of science-language-literacy integration to the preparation of secondary science teachers to teach science to ELs.

The Challenges for English Learners

English Learners (EL) in the United States face significant challenges while learning academic subjects because they must learn the subject matter content and discourse and develop English proficiency simultaneously. Even in schools recognized for working effectively with ELs, it can take 3 to 5 years to develop English oral proficiency and 4 to 7 years to develop academic English proficiency (Hakuta et al., 2000). As ELs are developing their English proficiency, a widening gap continues between ELs and native English speakers.

This challenge is exacerbated by the separation between teaching subject matter and teaching language and literacy to ELs. Many ELs are denied access to rigorous subject matter instruction and relegated to remedial instructional programs because it is assumed that they must first be proficient in English *before* learning content (Garcia, 1993; Garrison & Mora, 1999; Lee, 2005). Consequently, the majority of ELs do not have opportunities to develop the disciplinary specific language needed to understand, conceptualize, symbolize, discuss, read, and write about topics in academic subjects (LaCelle-Peterson & Rivera 1994; McGroaty, 1992; Minicucci & Olsen, 1992; Oakes, 1990; Pease-Alvarez & Hakuta, 1992). In most English Language Development (ELD) classes, ELs acquire basic social communication skills but less readily acquire the complex subject-specific language skills required for academic success. It comes to no surprise that the academic progress of ELs is significantly behind that of their native English-speaking peers. The most recently published National Association for Educational Progress (NAEP) report shows that in mathematics, science, and reading the scores of Latino students are on average 20 points below those of White students. Gaps in achievement actually increase from elementary school to secondary school (NCES, 2011).

Moreover, ELs performed well below their English-speaking peers under each state's prior standards (Goldenberg, 2013).

The Challenge for Preparing New Teachers to Teach Science to English Learners

The work in this paper directly responds to a second challenge: how to translate the knowledge base of effective secondary science teaching for ELs into a program of teacher preparation that would allow even novice science teachers to develop the dispositions and practices necessary to support ELs' science learning and language and literacy development. Unfortunately, teacher preparation content method courses typically do not give explicit attention to how linguistic and cultural resources of the students being served can be used to further content learning (Godley, Sweetland, Wheeler, Minnici, & Carpenter, 2005; Trent, Kea, & Oh, 2008). Issues related to linguistic and cultural diversity, when taught, are often presented in separate courses emphasizing social conditions and not discipline-specific pedagogy (Trent et al., 2008). What is needed are opportunities within teacher education programs to show PSTs the how and why of integrating the development of disciplinary-language and literacy into the teaching of rigorous science content.

Theoretical Foundations: The Reciprocal and Synergistic Relationship between Secondary Science Learning and Language Development

Language and Subject Matter

The acquisition and use of disciplinary language and literacy is fundamental to the learning of school subjects. Each subject matter has its own norms and patterns of language use essential to the practice of the discipline (Halliday, 1978). To acquire disciplinary knowledge, a student must, therefore, learn to read, write and speak the language of the subject domain. In essence, each science student must become multilingual. In any given day, a student in a science classroom is required to speak science with a teacher fluent in that disciplinary language but who do not view him or herself as a teacher of a second language. The majority of secondary school teachers view their responsibility as presenting the subject matter content and covering the set curriculum, not teaching language and literacy (Stoddart et al., 2002). They assume these skills have been taught in the elementary school grades or in a different class.

The language and literacy practices necessary to learn secondary school subjects differ greatly from the basic reading and writing skills taught in grades K-6. As the content gets more specialized and advanced in the transition from elementary to secondary school, the language and literacy demands for students also increase related to the acquisition of new academic genres (Abreu, Bishop, & Presmeg, 2002; Queen, 2002). It is important for teachers to understand the many types of language that a student uses inside and outside the classroom, how these language forms influence their learning and how they are developed (Bunch, 2013). K-12 students use social, everyday language daily – the language, for example, from the home, street, bus, or popular culture – to communicate and interact socially with others in their environment. Simultaneously, students need to become proficient in the language of the education system, which is used for formal academic learning.

Connection to Next Generation Science Standards and Common Core

The fundamental relationship between subject matter and language is embedded in the new standards. The Next Generation Science Standards (NGSS) based upon the *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core ideas* (National Research Council, 2012) identify core science ideas and cross cutting themes that students would learn in cognitively more complex ways as they progress through their K-12 science education. NGSS views science activities (reflected in scientific and engineering practices) as *language intensive* practices. This recognition of the role of academic language and literacy in content learning is echoed in the Common Core for English Language Arts, Mathematics, and Literacy in Social Studies, Science, and Technical Subjects (Common Core State Standards [CCSS], 2010). In the NGSS, science content and language intersect as students, for example, construct oral and written explanations and engage in argument from evidence (Cheuk, 2012; Lee et al., 2013), two practices echoing CCSS for English Language Arts. Concurrently, the ELA literacy standards for science and technical subjects require that students engage with technical (e.g., lab reports, scientific research articles) and non-technical (e.g., newspaper articles, letters to the editor) texts that are discipline specific by writing arguments, translating written information into visual forms (e.g., tables, graphs), and comparing/contrasting findings presented in various sources. These new standards require that all teachers of all school subjects must also be teachers of disciplinary language. These new standards offer an unprecedented opportunity to improve the development of K-12 students' understanding of subject matter in general but in particular create the means to begin to close the achievement gap between English learners and native English speakers.

SSTELLA Instructional Practices

We translated the research on integration science and language pedagogy into a set of four interrelated instructional practices that collectively form a coherent framework to inform critical elements of secondary science teacher preparation, as shown in Figure 1.

Contextualized science activity. A key aspect of supporting ELs in learning academic content is the strategic and collaborative incorporation of students' cultural and linguistic backgrounds into classroom learning experiences. This practice focuses on how science teachers ***frame*** instruction through meaningful and relevant science, such as explaining natural phenomenon or solving real world problems that are connect to students' home, community, local environment, or socio-scientific issues. Additionally, the practice promotes continuously eliciting and leveraging the funds of knowledge brought from the students, their home and community, referred to as ***adapting/applying*** (Moll et al., 1992).

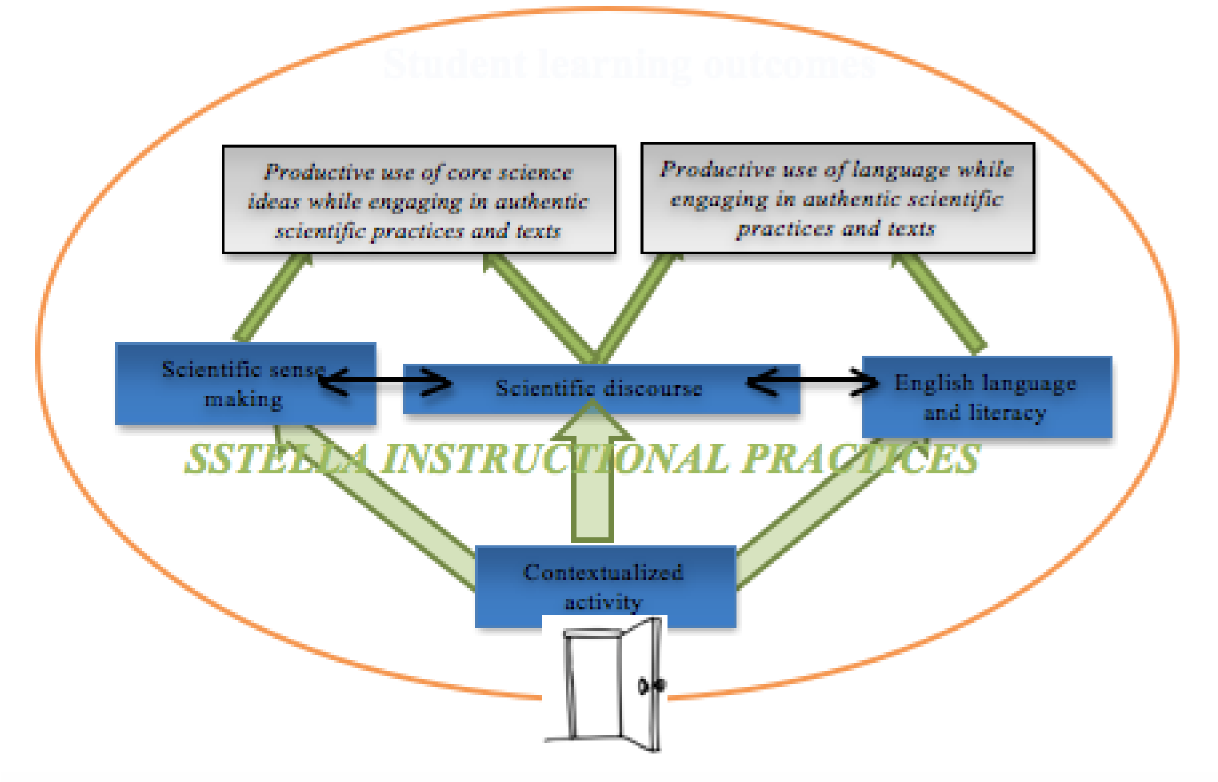


Figure 1. *SSTELLA Framework*

Scientific sense-making. In this practice, teachers assist students in negotiating everyday and scientific ways of knowing, centered on communicating and making sense of "***big ideas***" in science by engaging students in ***scientific/engineering practices***, such as developing scientific models and solving authentic problems. Throughout instruction, teachers maintain rigorous classroom rigor for ELs through appropriate supports and sustained scaffolding (Walqui & van Lier, 2010).

Scientific discourse. This practice focuses on helping students understand and use specific discourse tools expected in scientific communities, such as ***explaining and arguing*** from evidence. Through ***productive student talk***, teachers expose students to disciplinary specific discourses, such as communicating scientific explanations and arguments, which can help students make sense of both science concepts and develop language (Kelly, 2007). At the same time, teachers leverage EL students' sense-making in relation to familiar socio-cultural practices inclusive of hybrid spaces (Gonzalez et al., 2005) in the classroom, ensuring all students' discursive contributions are resources for knowledge production in the science classroom.

Language and disciplinary literacy development. Finally, this practices focuses on promoting opportunities for ELs to use and share, and receive assistance on, a range of language and ***literacy tasks*** in the service of scientific and engineering practices, such as reading accounts of how science was done or writing explanations to account for data collected through inquiry (Rodriguez, 2010) and ***using vocabulary*** to engage in scientific practices. Throughout teachers provide supportive contexts for ELs to ***interact*** and participate with other students.

In summary, SSTELLA's conceptual framework, a set of interrelated instructional practices, views the relationship among the practices as reciprocal and synergistic. Contextualized science activity serves as the gateway through which ELs can come to understand relationships between school science learning and their lived experiences outside of schools, and use these relationships to enhance science learning. Teachers promote scientific sense-making, scientific discourse, and English language and literacy development through these contextualized learning experiences and make use of strategic supports so that students use core ideas in science and disciplinary language in authentic science tasks and texts.

Research Design and Questions

The SSTELLA Project employs a quasi-experimental design in which a control group of pre-service science teachers are studied under normal conditions during their teacher preparation program and into their first two years of full time science teaching. This group is compared to pre-service teachers who complete their program at the same institutions the following year and who received an intervention: namely a redesigned secondary science method course and mentorship during their student teaching from cooperating teachers and university supervisors who attended SSTELLA-informed workshops. SSTELLA is investigating the following questions, which will be addressed in three subsequent analyses.

1) Do SSTELLA treatment teachers show a significant change in instructional practices used to teach secondary science to ELs during student teaching when compared to a baseline control group?
2) Do SSTELLA treatment teachers show a significant change in knowledge and beliefs of teaching secondary science to ELs before and after their teacher education program? Is this change significant when compared to a baseline control group?
3) What is the relationship between Science Methods instructors' fidelity of implementation (FOI) of SSTELLA practices and PST implementation of the practices?

We are also exploring relationships with K-12 student learning outcomes. These data are currently still being collected. Instruments, procedures, and analytical approach will be discussed later through the three report analyses.

Setting and Participants

The research was carried out at four institutions across three states in the western United States serving communities with high EL populations. As displayed in Table 1, these sites represent a range of teacher education contexts, include undergraduate and graduate programs, cohort vs. non-cohort models, as well as Next Generation Science Standards (NGSS) vs. non-NGSS adopted states (as of 2016).

Table 1

University Site Contexts

	Site 1	Site 2	Site 3	Site 4
Program length/	1 year, credential + M.A.	4 year B.A. + credential	1 year, credential + M.A.	4 year B.A. OR 1 year + M.A. + credential
Secondary science method course	10 week course (Jan – March) proceeding a science education research/practice course	15 week course (August – December OR January-May) Only science education course	15 week course (August – December) Only science education course	15 week course August – December) B.A.: Often proceeding a discpline-specific method course M.A.: Proceeding an introductory science method course
Standards adoption (as of 2016)	NGSS and CCSS adopted state	No adoption of NGSS or CCSS	NGSS adoption pending; CCSS repealed	NGSS adoption pending; CCSS repealed

Pre-service teachers who were enrolled in the participating secondary science method course at each site during 2013-2014 (baseline control cohort) and 2014-2015 (Treatment cohort) were invited to participate in the study. Table 2 displays the sample size and background/demographic information on each cohort for those individuals who provided informed consent and took at least the first survey. This information reveals some variation across sites (highlighted cells indicate 10% or higher difference from the cohort average, but when aggregating the baseline control and treatment groups, the groups are comparable except for one category. The baseline control group appears to have a significantly higher proportion of PSTs (78.4% vs. 58.5%) who took grade 6-12 classes with peers who were predominately of color or mixed race/ethnicities.

Table 2

Participant Background Information

	Baseline control cohort (2013-2014)					Treatment cohort (2014-2015)				
Site	1	2	3	4	T	1	2	3	4	T
N	9	13	15	37	**74**	9	14	15	27	**65**
Average Age	26.3	26.4	30.3	25	26.1	22.7	27.9	32.5	23.3	26.7
% Female	55.6	53.8	73.3	59.5	**60.8**	77.8	57.1	66.7	55.6	**61.5**
% Non-white	44.4	76.9	33.3	18.9	**35.1**	66.7	42.9	20	37	**38.5**
% Non-native English speakers	11.1	15.4	13.3	10.8	**12.2**	11.1	0	6.7	18.5	**10.8**
% Advance/fluent non-English language proficiency	11.1	23.1	20	24.3	**21.6**	22.2	21.4	33.3	18.5	**23.1**
% non-white grade 6-12 peers	77.8	61.5	86.7	81.1	**78.4**	44.4	64.3	66.7	55.6	**58.5**

The Science Teacher Preparation Intervention

The SSTELLA Project's intervention consisted of two major components of a secondary science teacher preparation program across the four university sites:

- a secondary science method course taken by participating Pre-service Teachers (PSTs) that was redesigned to more explicitly address SSTELLA Project practices and
- mentoring of PSTs explicitly around SSTELLA Project practices by mentors (i.e., cooperating teachers and university supervisors) who attended a SSTELLA Project workshop.

Redesigned Secondary Science Method Course

During project year 1, secondary science method instructors (SMIs) from each of four university sites met over a series of face-to-face and virtual meetings to (1) share current instructional approaches, (2) learn from project PIs about the integration of science learning with language development for ELs (through the SSTELLA instructional practices), and then (3) develop a set of common tools to be used to help PSTs experience, analyze, and approximate the practices. Tools include four multi-day science lessons (called learning segments) that exemplify the integration of language, literacy, and science through different scientific practices (developing models, arguing from evidence, constructing explanations, planning and carrying out investigations) and different content areas (8th grade physical science, high school earth/space science, high school life science). SMIs established a set of common readings and shared other activities, such as engaging pre-service teachers in carrying out a "science talk" in their field placement.

An additional project goal was to develop a series of video cases that can help pre-service teachers notice and analyze particular features of SSTELLA practices verses more traditional, didactic science instruction. Finally, all SMIs would provide a space for pre-service teachers to develop lesson plans that articulate connections with the SSTELLA practices and carry out the lesson in the method course. Throughout the course, PSTs used the SSTELLA Practices Progression, a modified version of an observation protocol that will be discussed in Analysis 1, as a tool to plan and reflect on learning segments, video cases, and their own teaching. A strength of the developed tools was the consistent alignment with the SSTELLA practices. Collectively, the tools would allow pre-service teachers to experience, noticing/analyze and approximate the instructional practices with the populations they are being prepared to teach (Roth, Garnier, Chen, Lemmens, Schwille, & Wickler 2011; Sherin, 2004).

Professional Development for PST Mentors

The second component consisted of mentoring around PST implementation of SSTELLA practices during student teaching. Research is clear that practicum experiences and mentors in the field can potentially have more of an impact on novice teachers' beliefs and practices than university coursework, and that cooperating teachers are rarely professionally prepared for the type of supervision and mentoring which teacher educators often expect of them (Clarke, Triggs, Nielsen, 2014). Mentors were viewed in the project, therefore, as valued partners in increasing coherence between university coursework and field experiences.

Both university supervisors (who meet and observe pre-service teachers throughout the student teaching experience) and cooperating teachers (who oversee and observe pre-service teachers in their own classroom) participated in a 1.5 day workshop in which they became familiar with SSTELLA's conceptual framework and associated instructional practices by (1) experiencing and deconstructing one of the SMI developed learning segments, and by (2) engaging in discussion and actual role-playing around using educative and culturally responsive mentoring practices (from video-recorded classroom observations developed by project researchers). Mentors were also given the SSTELLA Practices Progression to note PST teacher implementation of SSTELLA practices and to guide debriefs with PSTs to promote self-reflection and next steps for teaching.

Overall, 34 cooperating teachers and 8 university supervisors participated in the professional development and mentored at least one SSTELLA PST. Results from independent evaluator observations and participant feedback showed that the PD workshops achieved their goal of familiarizing cooperating teachers and university supervisors with the SSTELLA Framework in general, and that the vast majority of mentors felt confident they could use the SSTELLA Practices Progression as a tool for coaching PSTs who are part of the project intervention cohort. The PD set the stage for a consistent understanding of the SSTELLA practices with those who will most closely work with the PSTs.

Analysis 1: Pre-service teachers' Implementation of SSTELLA Practices

Analysis 1 addresses the first research question: *Do SSTELLA treatment teachers show a significant change in instructional practices used to teach secondary science to ELs during student teaching when compared to a baseline control group?* The SSTELLA Classroom Observation Rubric (or SCOR) was developed to capture levels of implementation across the various practices and sub practices. The SCOR was adapted from observation instruments developed in precursor projects, such as the Effective Science Teaching for English Learners (ESTELL) Project's *Dialogic Activity in Science Instrument* (or EDAISI) to examine teacher practice. Project PIs and key collaborators engaged in an iterative process of watching video clips from various sources (new and experiences science teachers across regions) and developing and refining indicators for various practices. The final SCOR captured four implementation levels (not presented, introducing, implementing, and elaborating) as summarized in Figure 2, which stem from literature around teaching expertise (Bransford et al., 2000; Dreyfus & Dreyfus, 1986) and science-language and integrated domains (Stoddart et al., 2002).

Not present (Rule based, inflexible)	Present		
	Introducing (global understanding)	Implementing (organized plan)	Elaborating (Flexible, responsive to context)

PROVIDE NO OPPORTUNITY TO ENGAGE STUDENTS IN THE **INTELLECTUAL ACTIVITY**	PROVIDES OPPORTUNITY TO ENGAGE STUDENTS IN THE **INTELLECTUAL ACTIVITY**, ALTHOUGH SUPPLANTS "**AUTHENTIC USE**" AND INCLUDES ONLY **MOMENTARY SUPPORTS**	PROVIDES A CLEAR PLAN FOR SUPPORTING STUDENTS IN **AUTHENTIC USE OF THE INTELLECTUAL ACTIVITY** WITH **APPROPRIATE SUPPORT**	PROVIDES A CLEAR PLAN FOR SUPPORTING STUDENTS IN **AUTHENTIC USE OF THE INTELLECTUAL ACTIVITY** WITH **APPROPRIATE SUPPORT**. RESPONDS TO THE **CONTEXTUALIZED NATURE OF THE INTELLECTUAL ACTIVITY WITH TARGETED FEEDBACK**

Figure 2. *Implementation Levels for Observing Teacher Practice*

Figure 3 summarizes the observation criteria for each instructional practice across implementation levels. The full rubric used by observers included more explicit criteria and divided each instructional practice into two or three sub-practices (nine sub-practices in total).

	Implementation Level (Bransford et al., 2000; Dreyfus & Dreyfus, 1986)			
Instructional Practice	**Not present**	**Introducing**	**Implementing**	**Elaborating**
Scientific Sense-making	Classroom activity focuses on recalling science concepts w/o communicating a "big idea."	Classroom activity incorporates some S&E practices, but heavily T led w/ implicit communication of a "big idea."	Classroom activity incorporates S&E practices through open-ended inquiry w/ explicit reference to a "big idea" and appropriate scaffolding.	Classroom activity framed around a partial model or puzzling phenomenon that Ss refine while reflecting on learning goals. T provides appropriate feedback and scaffolding.
Scientific Discourse	Does not engage Ss in scientific discourse nor productive student talk.	Engages Ss in some scientific discourse, but only brief probing to expand on science ideas.	Presses S use of scientific discourse in authentic tasks w/ substantive probing and scaffolding to expand on science ideas.	Presses S use of scientific discourse collaboratively in authentic tasks, w/ substantive probing, scaffolding, and feedback to expand science ideas.
English Language and Literacy Develop-ment	Uses science vocabulary, but no opportunity for Ss to develop English language or literacy.	Has Ss define science vocabulary and read/write scientific texts, but in inauthentic and unsupported tasks.	Presses for Ss authentic use of science vocabulary and scientific texts w/ scaffolding.	Presses for Ss authentic use of science vocabulary and scientific texts w/ scaffolding, feedback, and revision.
Context-ualized Science Activity	No attempt at relating activities to students' home/culture or the local/global environment	Momentarily relates activities to students' home/culture or local/global environment	Makes clear connections between activities and students' home/culture or the local/global environment	Makes informed and sustained connections between activities and students'' home/culture or the local/global environment

Note: S&E – "Scientific and Engineering;" T – Teacher; Ss – "Students"

Figure 3. *Abbreviated SCOR*

Project observers (1-2 per site) were first trained on the SCOR through an initial orientation to SSTELLA practices, led by Project PIs which also included practice viewing and scoring the same video excerpts initially reviewed by the PIs. Independent scoring tests were conducted to ensure acceptable inter-rater reliability for each sub-practice. Reliability calibration meetings were conducted in subsequent years. In addition, Project PIs rescored a sub-sample (5%) of baseline observations to check for inconsistencies in scoring.

Analysis 1 focuses on classroom visits from Sites 1, 3, and 4, while data from site 2 is still being analyzed due to pre-service teachers just finishing their student teaching in Fall 2015 at this site. For the three sites, project observers made a total of 260 classroom visits across 55 baseline control participants and 50 experimental treatment participants (including visits during participant's student teaching and first and second year of full time teaching if a position was secured). This analysis focuses on the 95 baseline control classroom visits and the 74 experimental treatment classroom visits. Pre-service teachers were visited twice during their semester long student teaching placement, typically in the third and fourth of their placement. Visits occurred 2-4 weeks apart, except a few occasions in which only one visit occurred. During each visit, the Project observer directly observed classroom interactions and took field notes while videotaping the lesson. After each lesson, observers also conducted a 15-20 minute debrief with the PST to garner further context about the lesson to assist in scoring. Observation scores with the SCOR were determined using this direct observation, relevant information from the debrief and lesson plan/artifacts, and by re-watching video recordings. For a minority of the participants, the observer could not schedule a direct observation, thus the observer relayed on videotape and debrief alone.

Findings

Findings focus on three parts of the analysis: (1) descriptive and inferential statistics to compare baseline control and treatment groups across all sub-practices, (2) disaggregation of scores by site, and (3) examination of histograms to unpack practices that improved from control to treatment years.

Mean and standard deviation scores were calculated across all baseline control and experimental treatment visits. Unpaired t-tests were used to determine statistical difference of scores between conditions. On average, baseline control PST scores ranged from .41 (4b: contextualized science activity – adapting and applying) to 1.59 (3b: vocabulary development); while experimental PST scores ranged from .78 (also adapting and applying) to 1.74 (3a - student interaction). Descriptively, experimental PSTs on average scored higher than baseline control PSTs in 7 of the 9 sub-practices, while Baseline Control teachers actually scored higher in 1a (big idea) and 2b (explanation/argumentation). Figure 4 displays these comparative trends across the nine sub-practices in the form of a spider web.

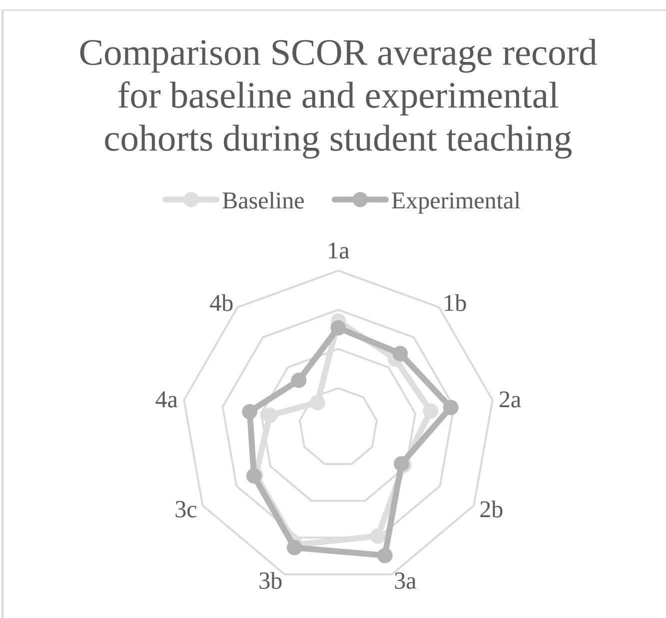


Figure 4 *Spider web comparison for baseline and experimental cohorts during student teaching*

Experimental PST implementation of four sub-practices was statistically higher (α = .05) than the baseline control: *Productive student talk* (t = 2.939, p = .0038), *student interaction* (t = 2.4179, p = .0144); *framing* (t = 2.692, p = .0078) and *adapting and applying* (t = 3.1505, p = .0019). Table 3 displays the mean, standard deviation, and inferential statistics across all practices. For all remaining five sub-practices, there was no statistically significant difference between baseline control and treatment.

Table 3

Descriptive and Inferential Statistics Between Conditions and Across Sub-practices

		1a	1b	2a	2b	3a	3b	3c	4a	4b
Baseline	Mean	1.36	1.14	1.20	0.97	1.48	1.59	1.22	0.89	0.41
	SD	0.73	0.64	0.54	0.68	0.63	0.70	0.53	0.66	0.71
	n	95	96	96	94	96	96	96	96	95
Experimental	Mean	1.27	1.23	1.46	0.93	1.74	1.64	1.24	1.15	0.78
	SD	0.69	0.67	0.62	0.67	0.76	0.73	0.64	0.59	0.83
	n	74	74	74	74	74	74	74	74	74
Unpaired t-test p-value (two-tailed)		0.428	0.3542	0.0038	0.7339	0.0144	0.71	0.7851	0.0078	0.0019
t-value		0.7946	0.929	2.939	0.3405	2.4719	0.3725	0.2731	2.6922	3.1505
df		167	168	168	166	168	168	168	168	167

Table 4 disaggregates the scores by site to determine any variation across site that might contribute to the aggregate averages. When looking across the three sites at the baseline cohort, some sites scored higher at certain sub-practices than others, but no site consistently scored higher or lower. For the experimental cohort, Site 1 PSTs scored the highest on 5 of the 9 sub-practices. For each site, teachers improved the most in the same four significantly different sub-practices. Site 4 also had gains in 3b (vocabulary development).

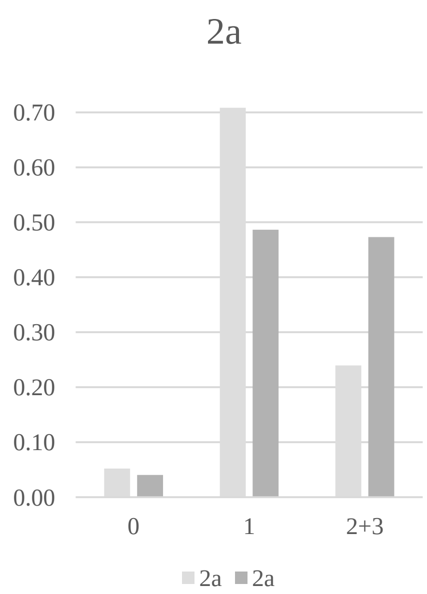
Table 4

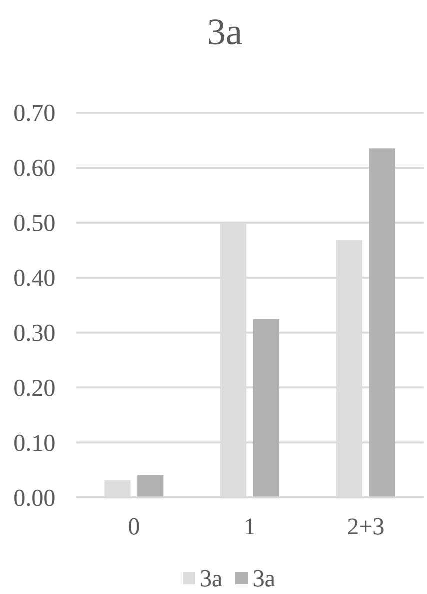
Descriptive and Inferential Statistics Between Conditions and Across Sub-practices

	1a	1b	2a	2b	3a	3b	3c	4a	4b
Site 1 (baseline n = 18; experimental n = 14)									
Baseline	1.39	1.06	1.22	1.06	1.89	2.00	1.28	0.89	0.72
SD	0.61	0.64	0.55	0.54	0.68	0.77	0.46	0.68	0.96
Experimental	1.14	1.43	1.64	1.00	2.21	1.79	1.43	1.07	0.86
SD	0.53	0.65	0.63	0.96	0.58	0.89	0.65	0.73	0.86
Site 3 (baseline n = 29; experimental n = 24)									
Baseline	1.28	1.21	1.17	0.90	1.48	1.86	1.10	0.83	0.34
SD	0.75	0.73	0.54	0.72	0.57	0.44	0.41	0.54	0.61
Experimental	1.25	1.29	1.50	0.67	1.88	1.67	1.21	1.33	0.71
SD	0.85	0.69	0.59	0.48	0.68	0.76	0.88	0.70	1.00
Site 4 (baseline n = 41; experimental n = 36)									
Baseline	1.49	1.17	1.22	0.95	1.32	1.24	1.29	0.95	0.24
SD	0.68	0.59	0.57	0.74	0.57	0.62	0.64	0.77	0.58
Experimental	1.33	1.11	1.36	1.08	1.47	1.56	1.19	1.06	0.81
SD	0.63	0.67	0.64	0.60	0.77	0.65	0.40	0.41	0.71

To unpack statistically significant differences, we examined the distribution of scores for four aforementioned sub practices: Productive student talk (2a), Student interaction (3a), Framing (4a) and Adapting/applying (4b). Since teachers rarely scored a 3 (elaborating level), scores for a “2” or “3” were combined in the histograms.

For productive student talk, we find nearly equal proportion of control and experimental teachers not involving students in anything more than closed ended question, only about 5% of each group. However, we see a shift in the proportion of teachers in the experimental group who demonstrate high implementation (implementing or elaborating level), nearly double the percent. Although the shift is not as dramatic, higher proportion of teachers in the experimental group also demonstrate high implementation (implementing or elaborating level) for involving widespread interaction of students. The picture is different for contextualization, since the average scores were lower for both. For Framing, the proportion of PSTs demonstrating some implementation is similar between control and experimental (around 60%). However, only 10% of experimental teachers do not make reference to a local, home-community, real world, or other context, compares to around 26% of Control PSTs. We see, therefore, around two times the percentage of Experimental teachers demonstrating high implementation, although still relatively low compared to those demonstrating some implementation. A similar trend for adapting/applying, although there are around triple the percentage of Experimental teachers demonstrating high implementation.





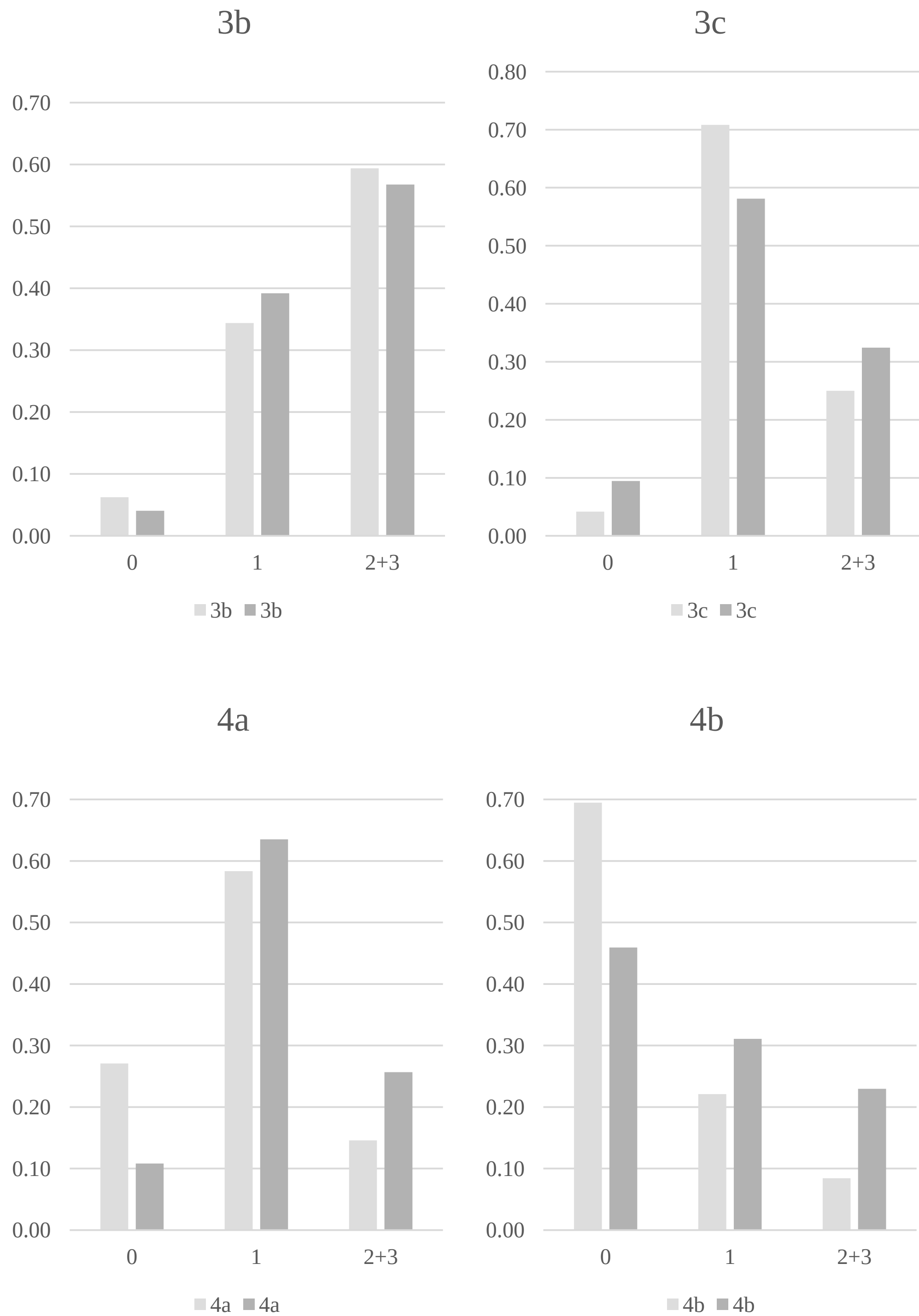


Figure 5. SCOR distributions

Discussion and Next Steps

The patterns found reflect the very challenges facing new science teachers during teacher preparation and consistent with other projects looking at teacher implementation of effective practices for ELs. For one, contextualized science instruction and promoting more student interaction and talk is consistently found to challenging for teachers of science to implement. Science talk, student interaction, and contextualization all revolve around the notion of eliciting students' ideas (about science and their lives outside of school) and building on these ideas. In essence, teachers shift authority toward students and recognize and value student contribution. It may be that these practices between conditions changed as a result of differences in how they perceived and understood what ELs and all learners can do and how best to provide a supportive context for the sharing and leveraging of student ideas.

Future analyses will examine teacher practice over time as they were observed into their first and second year of teaching. We will also look for variation in rater scoring and contextual factors that might explain variation. These variables could then be used for linear regression analyses. Finally, analyses described next can support and help explain some of the reasons we might see these differences in teacher practice. Furthermore, inferential statistics will be reported during the symposium to make stronger arguments about the found differences.

Analysis 2: Pre-service Science Teachers' Beliefs Toward Teaching Science to ELs

Design/procedure

Analysis 2 addresses the research question*: Do SSTELLA treatment teachers show significant changes in knowledge and beliefs toward teaching secondary science to ELs? Is this change significant when compared to a baseline control group*?

Data for analysis 2 came from PST interviews using a developed semi-structured interview protocol drawing on previous projects that also elicited views about teaching science to ELs. The protocol was divided into 5 parts:

- Background questions (e.g., how/why did you decide to become a science teacher?)
- Conceptions of science teaching (e.g., Is it the responsibility of the secondary science teacher to teach reading and writing?)
- Conceptions of learners (e.g., Is it important for all students to take advanced high school science courses beyond general science?)
- Conceptions of effective practices for ELs (e.g., What challenges do ELs face in mainstream [clarify term if needed] science classes?)
- Teacher preparation program experiences (e.g., Did your teacher education instructors model effective science teaching practices? Were any practices particularly effective for ELs? [Interview #2 only]

Participating pre-service teachers were interviewed with the protocol before beginning their secondary science method course as well as at the end of their teacher preparation program. Interviews ranged in duration from 30 to 55 minutes in length. Interviews were conducted one-on-one with trained researchers. Interviews were audio-recorded and transcribed.

Preliminary Analysis of Language and Literacy

Preliminary analysis of baseline interviews using a grounded coding approach identified several direct and indirect themes emerge from sample transcripts. Preliminary analysis of teacher interviews indicates several patterns of responses. For example:

- Pattern 1: secondary science teacher candidates have restricted and narrow conceptions of the role of language and literacy in science teaching and how to support ELs in accessing science content.
- Pattern 2: secondary science teacher candidates have limited and broadly optimistic conceptions of the role of language and literacy in science teaching and how to support ELs in accessing science content.
- Pattern 3: While participants commonly reported feeling underprepared to teach ELs in their classrooms, they also reported feeling that they possessed some strategies.

In some instances, secondary science teachers used a mix of distancing stances related to language and literacy knowledge to both acknowledge their lack of preparation in teaching ELs and also to note the low likelihood (plausibility) of acquiring what they believed was a desired language and literacy pedagogy. For example, a secondary science teacher candidate reported that he should be "given a linguistics course or just some sort of a background in that" and another reported "I don't have a linguistics background so I don't know how people learn languages… I'm a science teacher." Yet other examples demonstrate that participants understood the critical role of language in science learning. The following is an example of how some secondary science teacher candidates understood language learning as a common or universal point of departure for all students. The following response is given to a question about challenges and possibilities of ELs learning science in their classrooms.

- "I feel that is something that is a universal language you know, they can see what is happening in front of them. And science is fun. It can be fun."

- "I think that might be a hurdle but that could also be seen as actually a tool because you're all approaching this new language together. It's not just as though English native speakers already know..."

Code Development

Yet, this preliminary analysis led the research team to identify several procedural and conceptual coding questions arising from the data. A more focused analysis plan was needed to address both the basic research questions and ensure fidelity of coding. The SSTELLA research team needed to develop coding analysis approach that focused more directly on locating focal research questions using a systematic scoring approach. An interview codebook is now being developed to analyze interviews using theory-driven and data-driven qualitative constructs following previous methodological work on the development of interview codebooks (DeCuir-Gunby, Marshall and McCulloch, 2011; Saldaña, 2013). Analysis of interviews draws in part from theory and grounded themes in the field related to the preparation of mainstream teachers for diverse classroom contexts. A computer-assisted qualitative data analysis software program (i.e., Dedoose) was used as a tool for coding teacher interviews along a scale of agreement with respect to project practices. Researchers formed expert panels to develop integrated attitudes and beliefs scales (Luft and Roehrig, 2007; Stoddart et al., 2002) for analyzing interviews aligned with other measures used in the study including the observation rubric from Analysis 1. This particular analysis focuses on the development of that scoring scaled used for coding interview responses and examples that could be used for coding the rest of the data corpus.

The development of a scoring scale to be used across SSTELLA practices has identified three levels of agreement and/or responses within each category. Below are samples of two scoring dimensions being explored addressing SSTELLA practices. While the expert panels have coordinated in creating a three-point scoring scale that directly addresses the focal SSTELLA practices, there are some emerging differences across SSTELLA practices in terms of indicators or layers of distinction between Level 1, Level 2, and Level 3 scores. These differences are still being tested with sample transcripts. Tables 5 and 6 describe some differences across some of the practices as well as broad levels of agreement between levels.

Table 5

Sense-making: Communicating the Big Idea

	Level 1 Recognizes the theme	Level 2 Recognizes teacher's roles	Level 3 Identifies strategies examples
A. belief	Indicates that science teaching should address specific science ideas/topics	Indicates that science teaching should **address specific science ideas/topic**	Indicates that science teaching should address specific science ideas/topics **and communicate these ideas through an anchoring event/puzzling phenomenon, real world problem etc.**
B. rationale		**and elaborates on** the importance of teaching specific science ideas/topics (e.g., how it helps connects to other ideas, part of larger core ideas, communicates the nature of science)	**and elaborates on** the importance of teaching specific science ideas/topics (e.g., how it helps connects to other ideas, part of larger core ideas, communicates the nature of science)
C. Practice	Examples just list science ideas/topics (e.g., Newton's Laws, climate change, photosynthesis)	**OR** Examples describe how students might come to understand the importance of big ideas or understanding learning	**OR** Examples describe how to communicate science ideas **through an anchoring event/puzzling phenomenon, real world**

	goals/expectations around the idea	**problem etc.** communicate big ideas

Table 6

Scientific discourse: Facilitating Productive Talk

Level 1 Recognizes the theme	Level 2 Recognizes teacher's roles	Level 3 Identifies strategies examples
Indicates that science teaching should **address student opportunities** for productive student talk.	Indicates that science teacher **should promote student talk and that the teacher should support them in talking & that there are strategies to do that.**	Indicates that science teaching should address students opportunities for student talk **where specific types of suppor**t is given by the teacher and/or **has tried them.**

The research team has gone back to the data to score sample transcripts using initial codebook scheme and examples in Dedoose. The following are some examples used in the codebook.

Table 7 and 8 describe excerpts taken from transcribed interview of participants responding to interview questions. Additional coding and scoring is needed to reach locate new patterns of teacher beliefs and knowledge related to SSTELLA practices and teaching science to ELs.

Table 7

Productive student talk excerpts

Facilitating productive student talk	**Level 1: Recognizes the theme**
	(D1) Respondent: They may be once in a while for a topic like I mean I guess a popular one would be global warming will let the kids decide if they believe in it, if they don't maybe pour it with some facts and just kind of let them voice their opinion not be graded on it, you know.

Facilitating productive student talk	**Level 2: Recognizes teacher's roles**
What about discussions are they important in science class? [0:09:12]	(A1) Respondent: Yes, they I think I have always believed the best way to teach, the best way to learn something is to teach it to someone else. So, if you-I do not understand electro Chemistry I am a Chemist I have struggled with electro Chemistry for my entire life and I while continue to struggle until I have to be a teacher and I have to teach it to someone perfectly and I'm still going to struggle, but I have learned it better through talking to people and talking them through it and having them teach me sand back and forth. More [socioculture] now, I think that works best. You have to have kids discussing concepts and who would understand the [..] reaction or the complex synthesis without talking about it.
Facilitating productive student talk	**Level 3: Identifies strategies/ examples**
you wrote about climate change as a topic that is innately connected, just by itself. How do you, did you think that this sort of, this debate would bring out this connection of cultural connections to students? What was your thinking behind it?	(D2) Respondent: I picked climate change because it is a science topic. It's relevant, that's for sure. I thought it was kind of actually hard sometimes to pick topics that might be really relevant to everyone so that's why I picked climate change. There's a lot of research that they could do also on the internet that's easy to find. There's all different levels so I feel like they could actually have a discussion about this in their groups and then present it to the class and it wouldn't be a difficult assignment for any of them to really grasp. That's what I kind of fel

Table 8

Vocabulary excerpts

Vocabulary	**Level 1: Recognizes the theme**
	(C2) They would have to interpret that information themselves, figure out what's true and what's not. I think that would involve a requirement that they use certain vocab in their report. They would have to learn the meaning of that vocab, learn how to use that and apply it. All those things would go into language development.
Vocabulary	**Level 2: Recognizes teacher's roles**

Interviewer: Right. OK. Then that would help them be able to produce some scientific writing that's maybe presenting some data that they've analyzed?	(A2) Respondent:Yes, and I think it would show them how the academic vocabulary applies. What I really want to do that I think would be fun is give them a paper maybe like first month and say, "Read it, break it down, but highlight the words you don't know. Do this. Keep that," because they're going to highlight the entire thing. "Then at the end of the year, give it back." Same thing. Break it down. Tell me what it's about. Then have them walk through that. Then bring out the other one and be like, "This is what you did in the beginning. This is what you did now." Hopefully there's some change. It would be horrible if it was like, "And they're exactly the same."
Vocabulary	**Level 3: Identifies strategies/ examples** (c2) I think the same strategies that would work well for ELLs will also work well for the rest of the students, and should just be incorporated with education anyway. Things like using diagrams, and things like going over vocabulary first thing so that they can apply it throughout the lesson. Things like using videos, and models, and diagrams, and experiments to explain things in other ways, rather than dry, complicated scientific text. I think will help out all students, and will particularly help out ELLs. (d2) Maybe like the visuals or maybe like a work book you know, where it's a visual picture like I think a lot of things in science you can use. Probably like a cell or a plant like you're using pictures, visuals and I think just to start off with vocab, you know, if they get a good understanding of a lot of the vocab that's going to help.
Interviewer: Alright, sounds great. What about uh when a science teacher is developing or choosing a curriculum what should they consider when they have English Language Learners in their class or even the science text? [0:32:05]	(A1) Respondent: Where are the students gonna have issues with the language and with the structure. Where is the um not even where you need to scaffold, but where do they not even need words that they need to have, like pictures, where do they need those glossary definitions, do they need the glossary definition in English or are they going to need it in Spanish as well. Kind of – you have to scaffold you're entire curriculum and finding those points where they're either going to slip up, which would derail them from their education or they're just going to stop and give up, and knowing kind of where to put a boost and where to kind of give them more support, and where to where they just need to work through it and give them that time to just say, " you just-here's a paragraph, it's going to be hard, but I know you can do I, we've been working on this for weeks and this is the point where I'm going to let you loose and fly on your own and you may fall, but here's time."

Next Steps

While the findings to date represent a sub-sample of the pre- responses across sites for both treatment and control, a more thorough analysis of a larger subset of the interviews (both pre and post and across both conditions and all sites) will eventually be analyzed. At this stage, the analysis did not attempt to look at differences. In conclusion, results from this analysis provide an important snapshot of how current secondary science teacher candidates view more responses approaches to teaching science to ELs in three states with large numbers of ELs.

Analysis 3: Linking the Instructional Practices of Pre-service Secondary Science Teachers to Science Method Instructor Practice

Design/procedure

Analysis 3 address the project's second research question: What is the relationship between Science Methods instructors' fidelity of implementation (FOI) of Project instructional practices and treatment teachers' practices of teaching science to ELs? To answer this question, observational data was collected on the participating secondary science method instructors (SMIs) during implementation of their science method course, which could then be compared to observational data from the PSTs. Observational data served as a way to monitor fidelity of implementation of the model across intervention sites (Lee, Penfield, and Maerten‐Rivera, 2009).

The Science Methods Course Observation Rubric (or SMOR) was developed to capture features of SMIs instruction during the method course. Much like the SCOR instrument described in Analysis 1, the SMOR aligns directly with implementation of Project practices. However, unlike secondary classroom settings, the science method contexts are replete with pedagogical experiences that involve reflecting about teaching science to children and developing pedagogical orientations for new teachers. For this reason, the SMOR contains two vertical strands for each of the nine project sub-practices outlined in Analysis 1: Science Experiences and Pedagogical Development. Science experiences refer to instruction that allows the pre-service teacher to experience Project practices, whether it be participating in a science lesson modeled by the SMI or another teacher, or watching a video of a teacher teaching. Pedagogical development refers to instances in which pre-service teachers develop a deeper understanding of the practice (theoretical and/or practical) through analysis, discussion, reflection, etc.

To collect data, SMIs were observed three times during the span of their one semester (or quarter) method course by a Project researcher. Observations were coordinated to capture three time points: the initial stages of teaching the course (observation 1), midway through the course (observation 2) and during the final weeks of the semester (observation 3). The observations were also coordinated to capture major activities developed through the SMI collaboration, namely an anchor lesson modeled by the SMI, analysis of exemplar videocases developed by the Project, and PST microteaching in which PSTs develop and enact a science lesson that promotes features of Project practices. Each sub-practice (e.g., big idea, science talk) was scored from 0-3 (Not Present, Introducing, Implementing, and Elaborating) on both the Science Experiences and Pedagogical development stands. Thus each observation recorded a total of 18 sub-scores. Each observation was also video-recorded and additional field notes were taken by the Project researcher on top of the SMOR scoring. Video-recorded observations, in addition to the findings described below, were shared and discussed the summer after implementation as a way for collaborative reflection and refinement for the next course iteration. For more immediate reflection, SMIs also engaged in a written and oral debrief with the a Project researcher after each observation.

Findings

Figure 6 depicts the average SMI score by sub-practice across sites for both strands during the study's implementation (treatment) year.

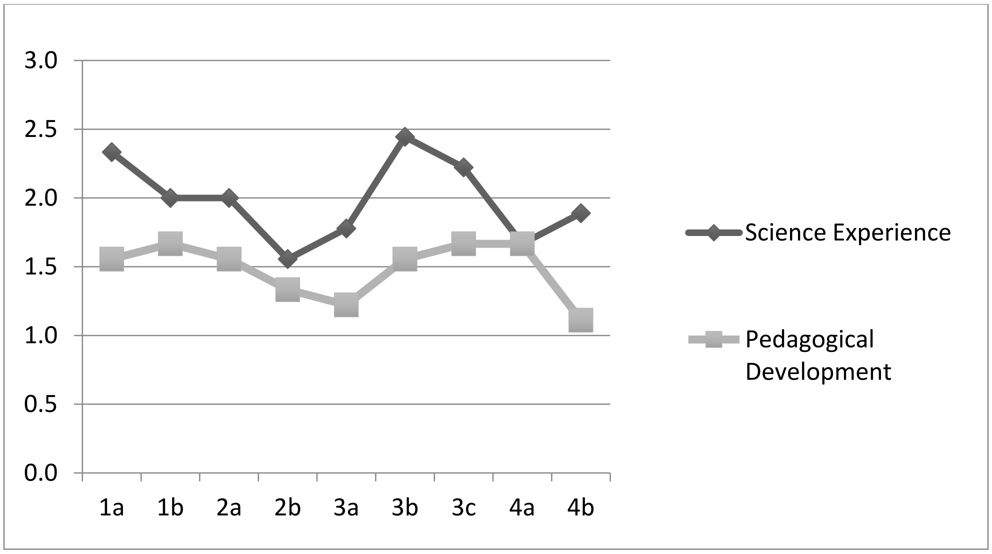


Figure 6. *SMI's Average SMOR score*

The average SMOR scores for the nine sub-practice ranged from 1.0 to 2.5, indicating that on average SMIs addressed the target Project practices within the science methods courses to some extent. However, the scores suggest that practices were addressed through experiencing them more so than through instruction that analyzes, discusses, reflects on the practices, which we refer to as the pedagogical development.

In terms of science experience, SMOR scores indicate more frequent attention to Communicating the Big Idea (1a) Promoting opportunities for English language development for ELs through vocabulary (3b), and Pressing for authentic science literacy tasks (3c), all enacted above the "implementation" level. Much less attention was given to showing or modeling how to contextualize lessons to include student interests or background knowledge (4b) or lessons that

that consider how to promote greater participation in activities (3a) for all students through different types of grouping structures (Tolbert, 2014; Lynch, 2011). These two sub-practices are inherently closely related to addressing issues of equity and diversity in science instruction (Lee, 2005; NSTA, 2009).

Moreover, initial patterns of PST observations (i.e., SCOR results discussed in Analysis 1), within the treatment group suggest some parallel patterns with SMI observations (i.e., SMOR scores). Table 9 compares highest and lowest sub-practice implementation of the method instructors' SMOR scores with the pre-service teachers' SCOR scores.

Table 9

Pre-service scores (SCOR) and science methods scores (SMOR)

SMOR High Scores	SCOR High Scores	SMOR Low Scores	SCOR Low Scores
1a. Communicating the big idea	2a. Science talk	***2b. Explanations/ Argumentation***	***2b. Explanations/ Argumentation***
3b. Vocabulary	***3b.Vocabulary***	***4b. Contextualization, Framing***	***4b.Contextualization, Framing/adapting***
3c. Literacy tasks	3b. Student interaction	3b. Student interaction	

Of particular interest, higher implementation of Vocabulary was found for both SMIs and PSTs, while lower implementation of Explanation/Argument and Contextualization Framing was found for both SMIs and PSTs. Additional analysis will explore the pedagogical developmental differences within instructors enacting the redesigned method courses and what can be considered sufficient exposure to the Project practices to expect similar results with pre-service teachers. This analysis does however suggest that discipline-specific English language development practices like supporting the use of science vocabulary is both readily implemented by science methods courses and in pre-service teaching lessons. This pattern is likely rooted in beliefs surrounding what English learner need to access science content. However, we do not find similar results with high levels of implementation of the reform pedagogy like *Communicating the big idea* and *Pressing for authentic science literacy tasks* when pre-service teachers were observed. With respect to low levels of exposure to the reform pedagogy in the science methods course, we find that pre-service teachers similarly do not implement at a high level some Project practices during student teaching. When SMIs do not model or discuss ways to provide support by contextualizing science learning and pressing for scientific explanations and arguments, pre-service teachers appear to not address these practices in their own teaching..

Conclusion and Next Steps

Our goal through this paper was to report on three analyses that can begin to make the link between the use of a conceptual framework (STELLLA) that interrelates four science teaching practices grounded in science-language-literacy integration ***and*** the preparation of secondary science teachers to teach science to ELs. We examined three primary data sources - pre-service teacher practices during student teaching (using the SSTELLA classroom observation rubric), pre-service teacher knowledge/beliefs (using a semi-structured interview prior to the method course and at the end of the teacher preparation program), and science method instructor practices (using the STELLA method observation rubric). Analysis revealed that PSTs participating in the redesigned method course and SSTELLA-informed mentoring implemented the four (out of nine) sub-practices at a statistically significant higher level than those receiving a business as usual method course and mentorship: contextualizing science activities through ***framing*** and ***adapting/applying*** and providing more opportunities for ***student interaction*** and ***science talk***. The analysis leads to the question of why *these* practices? Although there was an explicit focus, for example, on engaging students in student-centered scientific/engineering practices, particularly the development and use of models, and arguing from evidence, we see no change in teacher practice between the baseline control and experimental group, yet a significant difference in promote student talk. One possibility relates to how teachers were prepared in the method course. Analysis 4 offers some insight that what method instructors do parallels to an extent what PSTs do during students teaching. For example, both method instructors and PSTs scored higher on addressing vocabulary development in their practice, while scoring lower in contextualization – despite the evidence the contextualization was a practice of significant improvement for PSTs compared to the baseline control. What is now needed is to know if the method instructors improved in how they addressed contextualization from baseline to treatment year, and if that change relates to PST improvement. Finally, our approach to analyzing interview data shows possibility for capturing a range of beliefs and knowledge that would conceptually align with our levels of implementation in practices. Thus, we might be able to tease apart the relationship between belief and practice and how that might contribute as compared to other factors such as method instructor practice.

Overall, these analyses warrant further exploration, both quantitatively and qualitatively to how a conceptual framework for science-language-literacy integration is linked to secondary science teacher preparation around teaching science to ELs, and thus promote research-based teacher education reform focused on increasing access to science for ELs at the secondary school level. This is a critical and urgent area for teacher development.

References

Abreu, G., Bishop, A., & Presmeg, N. (2002). Mathematics learners in transition. In *Transitions between contexts of mathematical practices* (pp. 7-21). Springer Netherlands.

August, D., & Hakuta, K. (1997). *Improving schooling for language-minority children: A research agenda*. Washington, DC: National Academies Press.

Bransford, J., Brown, A.L. & Cocking, R. (2000). *How people learn.* Washington, DC: National Academy Press.

Bunch, G. C. (2013). Pedagogical language knowledge preparing mainstream teachers for English learners in the new standards era. *Review of Research in Education*, *37*(1), 298-341.

Cervetti, G.N., Pearson, P. D., Barber, J., Hiebert, E., & Bravo, M. A. (2007). Integrating literacy and science: The research we have, the research we need. In M. Pressley, A. K. Billman, K. Perry, K. Refitt, & J. Reynolds (Eds.), *Shaping literacy achievement*. New York: Guilford.

Cheuk, T. (2012). Relationships and Convergences Found in the Common Core State Standards in Mathematics (practices), Common Core State Standards in ELA/Literacy*(student portraits), and A Framework for K-12 Science Education (science & engineering practices). Unpublished work. Stanford University, Understanding Language Inititative.

Clarke, A., Triggs, V., Nielsen, W. (2014). Cooperating teacher participation in teacher education: A review of the literature. Review of Educational Research, 84, 2, 163-202.

Common Core State Standards Initiative. (2010). Retrieved from http://www.corestandards.org

García, E. (1993). Language, culture and education. *Review of Research in Education*. 51-98.

Garcia, E., Arias, M. B., Harris Murri, N. J., & Serna, C. (2010). Developing responsive teachers: A challenge for a demographic reality. Journal of Teacher Education, 61(1-2), 132-142.

Garrison, L., & Kerper Mora, J. (1999). Adapting Mathematics Instruction for English-Language Learners. *The language-Concept Connection. I L. Ortiz-Franco, NG Hernandez & Y. De La Cruz (red.), Changing the Faces of Mathematics: Perspectives on Latinos*, 35-47.

Goldenberg, C. (2013). Unlocking the Research on English Learners: What We Know--and Don't Yet Know--about Effective Instruction. *American Educator*, *37*(2), 4.

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a codebook for the analysis of interview data: An example from a professional development research project. Field Methods, 23(2), 136-155.

Dreyfus, H., & Dreyfus, S. (1986). *Mind over machine: The power of human intuition and expertise in the era of the computer.* New York, NY: The Free Press.

Echevarria, J., Richards-Tutor, C., Canges, R., & Francis, D. (2011). Using the SIOP model to promote the acquisition of language and science concepts with English learners. *Bilingual Research Journal*, *34*(3), 334-351.

Godley, A. J., Sweetland, J., Wheeler, R. S., Minnici, A., & Carpenter, B. D. (2006). Preparing teachers for dialectally diverse classrooms. *Educational Researcher*, *35*(8), 30-37.

Gonzalez, N., Moll, L., & Amanti, C. (2005). *Funds of knowledge: Theorizing practices in households, communities and classrooms.* Mahwah, NJ: Erlbaum.

Hakuta, K., Butler, Y. G., & Witt, D. (2000). How long does it take English learners to attain proficiency? The University of California Linguistic Minority Research Institute. Policy report 2000-1. *Adolescence*, *40*, 503-512.

Halliday, M. A. (1978) Language as Social Semiotic: The Social Interpretation of Language and Meaning. *London: Arnold*.

Kelly, G. (2007). Discourse in science classrooms. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (2nd ed., pp. 443-470). Mahwah, NJ: Lawrence Erlbaum Associates.

La Celle-Peterson, M. W., & Rivera, C. (1994). Is it real for all kids? A framework for equitable assessment policies for English language learners. *Harvard Educational Review*, *64*(1), 55-76.

Lee, O. (2005). Science education with English Language Learners: Synthesis and research agenda. Review of Educational Research, 75(4), 491-530.

Lee, O., Maerten-Rivera, J., Penfield, R., LeRoy, K., & Secada, W. (2008). Science achievement of English language learners in urban elementary schools: Results of a first-year professional development intervention. *Journal of Research in Science Teaching*, 45(1), 31-52.

Lee, O., Penfield, R., & Maerten-Rivera, J. (2009). Effects of fidelity of implementation on science achievement gains among English language learners. Journal of Research in Science Teaching, 46(7), 836-859.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English Language Learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher* (*42*), 234–249.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. Electronic Journal of Science Education, 1 (2).

McGroaty, M. (1992). The societal context of bilingual education. *Educational Researcher,* 21, 7-10.

Minicucci, C., & Olsen, L. (1992). *Programs for secondary limited English proficient students: A California study* (No. 5). National Clearinghouse for Bilingual Education.

Moll, L. C. (1992). Bilingual classroom studies and community analysis: Some recent trends. *Educational researcher*, *21*(2), 20-24.

National Center for Education Statistics. (2011). *The Nation's Report Card*: Science 2009. Institute of Education Sciences.

National Science Teachers Association (NSTA). 2009. NSTA Position Statement: Science for English Language Learners.

Oakes, J. (1990). Multiplying Inequalities: The Effects of Race, Social Class, and Tracking on Opportunities to Learn Mathematics and Science.

Pease-Alvarez, L., & Hakuta, K. (1992). Enriching our views of bilingualism and bilingual education. *Educational Researcher*, *21*(2), 4-19.

Queen, J. A. (2002). *Student transitions from middle to high school: Improving achievement and creating a safer environment*. Larchmont, N.Y.: Eye On Education.

Rivet, A., & Krajcik, J. (2008). Contextualizing instruction: Leveraging students' prior knowledge and experiences to foster understanding of middle school science. *Journal of Research in Science Teaching, 45*, 79-100.

Rodriguez, A. J. (Ed.). (2010). *Science education as a pathway to teaching language literacy*. Rotterdam, Netherlands: Sense.

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K. & Wickler, N. I.Z. (2011), Videobased lesson analysis: Effective science PD for teacher and student learning. *Journal of Research in Science. Teaching*, *48*: 117–148.

Saldaña, J. (2013). The coding manual for qualitative researchers. London: Sage.

Sherin, M.G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Advances in research on teaching: Using video in teacher education* (Vol. 10, pp. 1–27). New York, NY: Elsevier JAI.

Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. Journal of Research in Science Teaching, 39(8), 664-687.

Tolbert, S., Stoddart, T., Lyon, E. G., & Solís, J. (2014). The next generation science standards, common core state standards, and English language learners: A framework for pre- service secondary science teacher education. *Issues in Teacher Education*, *23*(2), 65-90.

Trent, S.C., Kea, C.D., & Oh, K. (2008). Preparing preservice educators for cultural diversity: How far have we come? *Exceptional Children, 74*, 328–350.