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'They might know a lot of things that I don't know': investigating differences in preservice teachers' ideas about contextualizing science instruction in multilingual classrooms

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ABSTRACT

This paper describes the results from a qualitative study of 72 preservice teachers' initial ideas about contextualizing science instruction with language minority students. Participants drew primarily on local ecological and multicultural contexts as resources for contextualizing instruction. However, preservice teachers enrolled in the bilingual certification program articulated more asset-oriented and less stereotypical ideas than those not seeking bilingual certification. Results can inform teacher education programs that aim to prepare graduates for teaching science in multilingual classrooms.

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Changing demographics and immigration patterns worldwide merit increased attention to how content area learning can be supported for students in multilingual science classrooms. In the U.S.A, for example, it is expected that the population of students who are learning the dominant language of instruction as a second language (i.e. English in the U.S.A) will have increased by 45% from 2005 to 2020 (Fry, 2008; cited in Kern, Roehrig, & Wattam, 2012). Additionally, educating new generations of individuals who are proficient in science, technologically, engineering, and mathematics is an issue of global concern (Fensham, 2009). Research in language acquisition and science education has highlighted contextual relevance, that is, instruction embedded in relevant contexts beyond the classroom, as an essential element of both language and science learning (Stoddart, Solis, Tolbert, & Bravo, 2010; Lee & Luykx, 2006). Situating science instruction within more meaningful contexts in linguistically diverse classrooms can lead to improved student outcomes, including increased participation and engagement in science, improved science understandings, more positive attitudes toward science, and increased consideration of science as a career goal. These patterns have been observed in formal and informal learning settings, as well as in rural and urban communities across the globe (e.g. Kasanda et al., 2005; Lee & Luykx, 2006; Molyneux & Tyler, 2014; Nashon & Anderson, 2013; Rivet & Krajcik, 2008; Stoddart et al., 2010).

A key challenge is that both novice and experienced teachers often struggle to design and implement science lessons that are socially and culturally contextualized (Bryan &

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Atwater, 2002; Lee, 2004; Lee, Luykx, Buxton, & Shaver, 2007; Patchen & Cox-Peterson, 2008). Part of the problem is that preservice teachers rarely receive instruction on how to contextualize science instruction during their teacher education programs. Courses on social context, language, and culture are typically offered separately from science methods courses, and science methods courses infrequently incorporate issues of student diversity (Bryan & Atwater, 2002; Rodriguez, 1998). Research indicates, however, that teachers who are prepared through bilingual teacher preparation programs may be better qualified to build on language minority students' lived experiences than those who are not prepared through bilingual teacher preparation programs (Hopkins, 2013), and that bilingual preservice teachers bring unique contributions to teacher education (Evans, Arnot-Hopffer, & Jurich, 2005; Hopkins, 2013).

Still, few to no studies have explored differences between teachers certified for bilingual instruction versus those not seeking bilingual certification, with regard to science teaching. The purpose of this paper is to explore those differences, with a focus on preservice teachers' initial ideas about contextualization in science. Two groups serve as the basis for comparison in this study: those enrolled in a bilingual certification program versus those who are enrolled in a non-bilingual, or traditional, certification program.

Conceptual framework

In the sections that follow, we present a brief overview of how contextualization is conceptualized in both science education and language acquisition. Then, we draw from related research on contextualization in both fields to present a framework for categorizing the multiple approaches to contextualization teachers might use to increase the relevance of science instruction in linguistically diverse classrooms. Finally, we consider how teachers in bilingual teacher education programs are differently prepared to address the needs of language minority students in science classrooms.

Contextualization in science and language learning

Language minority students have often been excluded from science instruction due to the misconception that English proficiency (or dominant language proficiency) is a necessary prerequisite for science learning (Lee & Luykx, 2006; Stoddart, Pinal, Latzke, & Canaday, 2002). Research on language acquisition, however, has demonstrated that language minority students who are learning a second language benefit from concrete, physical representations of content vocabulary as well as opportunities to use language in authentic tasks (Echevarria, Short, & Vogt, 2012; Shaw, Lyon, Stoddart, Mosqueda, & Menon, 2014; Tharp & Gallimore, 1988; Wong Fillmore, 1991). Students need opportunities to use language while engaging in hands-on activities, where language is connected to a physical experience, which makes inquiry science an ideal context for language acquisition (Stoddart et al., 2002). Furthermore, a bilingual student's first language proficiency often equips them with an additional resource for understanding science language (Bravo, Hiebert, & Pearson, 2007), and the metalinguistic awareness of bilingual students can be useful in learning an additional register, such as the language of science (García, 2009; Kearsey & Turner, 1999). A related approach to contextualization found in both science education and language acquisition research is the use of simulations or hypothetical scenarios to facilitate a more concrete language/content learning experience (e.g., Fan & Geelan, 2013).

Language minority students are infrequently exposed to scientists from underrepresented backgrounds or the science of non-dominant knowledge systems, such as traditional ecological knowledge, and are rarely provided with school science learning experiences that build on their lived experiences and/or household and community practices (Hammond, 2001; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). A more contextually authentic approach to science instruction also requires a more inclusive and responsive approach, such that language minority students' experiences and ways of knowing are valued in science classrooms. For example, Warren et al. (2001) reveal how language minority students explore ways to design an ant habitat after conducting longitudinal observations of ant behavior. One student temporarily 'becomes' the ant, trying to imagine himself as the ant living in the proposed habitat. Using a combination of his longitudinal observations as well as this anthropomorphological reasoning framework, he constructs a proposal for a sophisticated ant habitat design.

Contextualization of science instruction also encompasses the ways in which students draw from multiple perspectives to understand and critically evaluate current and historical socioscientific issues. For example, students might explore how the media differently addresses infectious diseases originating from African countries versus the spread of infectious diseases through decreasing vaccination rates in developed countries, or the role of governmental agencies in constructing science-related policies and regulations (Schindel Dimick & Tolbert, in press). Exploring science concepts through culturally meaningful socioscientific issues can help create rich and relevant context for language and science learning.

The relationship between context, language, and science: a sociocultural perspective

For language minority students in particular, the 'language, values, and personal identity that affect an individual's participation in science activities' are necessary considerations in science teaching and learning, but often go unacknowledged in science classrooms (p. 702; Buxton, 2006). Integrating the sociocultural perspectives on language acquisition and science education described above, the first author (Sara Tolbert) developed a framework for contextualization to identify and understand how teachers can increase the relevance of science instruction in diverse classrooms (Tolbert, 2009, 2011). This framework includes nine categories of contextualization: Multicultural, Local–Ecological, Linguistic, Community Engagement, Critical–Feminist, Physical–Kinesthetic, Universal–Everyday, Hypothetical–Simulative, Historical. These categories are described in detail below.

(1) *Multicultural* – Instruction is culturally responsive (Gay, 2010) and tied to the funds of knowledge of students and families (Moll, Amanti, Neff, & Gonzalez, 1992). Attention is given to the contributions of scientists from non-dominant backgrounds as well as contributions to science from non-Western cultures – past and present. Non-dominant ways of knowing and multicultural contexts are valued and acknowledged as resources for science learning.
(2) *Local–Ecological* – Instruction is tied to the local physical and ecological environments. Local/ecological contextualization includes the discussion of concepts

related to local scientific phenomena, for example, understanding local weather patterns, investigating pond ecology on school grounds, and so on (Buxton, 2006; Rosebery, Warren, & Conant, 1992). Local/ecological contextualization may engage students in extending their understandings of local environmental concerns to global sustainability science issues (Barton & Tan, 2010).

(3) *Linguistic* – Students are encouraged to learn and use formal discourses of science, but students' own home discourse patterns and native languages are viewed as equally important sense-making resources for doing science (Brown, 2006; Warren et al., 2001). Translanguaging practices, or the fluid and dynamic practices through which bilingual/multilingual learners draw on a variety of linguistic resources for sense-making and communication, are supported (García, 2009).
(4) *Community Engagement* – Students learn to use science knowledge for socio-political engagement and/or participation in the community (Barton & Tan, 2010; Bouillion & Gomez, 2001; Buxton, 2010; Hodson, 1999; Roth & Lee, 2004). Students work with community members to establish and/or participate in 'public science' projects, such as gardening, water quality testing, environmental health, raising public awareness, and so on. Family and community members are invited to participate as experts in the science classroom, expanding the borders of what it means to 'do science' beyond only those with formal degrees in science.
(5) *Critical/feminist* – Students evaluate issues of objectivity and subjectivity in science. Students investigate how science has been used to privilege or marginalize individuals or groups of people. Students recognize science as both a social and material practice, and that the scope of objectivity must always be expanded to include the material, social, historical, and cultural location of the scientist(s) and the research question (s) (Barad, 2007; Mayberry, 1998; Norman, 1998).
(6) *Physical/kinesthetic* – Learning is constructivist and tied to physical hands-on activities and manipulatives, concrete investigations, total physical response, and so on, in order to enhance science learning for second language learners (Stoddart et al., 2002).
(7) *Universal/everyday* – Science activities are designed around interests considered universal to the human experience (e.g. cooking and food science) or to the interests of students in a particular age group, for example, skateboarding, riding bicycles (Rivet & Krajcik, 2008).
(8) *Hypothetical/simulative* – Students learn science through the use of kits or simulations, Internet resources, science fiction, and so on, or through a teacher- or student-constructed hypothetical scenario or simulation (e.g. Hsu & Zembal-Saul, 2004).
(9) *Historical* – Science learning is historically contextualized, such that students learn about the trajectories of science and scientists and/or social and historical conditions that led to a particular discovery, development of a theory, and so on (Matthews, 1994).

Teacher preparation for contextualizing science instruction in linguistically diverse classrooms

Although there are a variety of approaches to contextualizing science instruction in diverse classrooms, enhancing the contextual authenticity of instruction requires that teachers be knowledgeable about students' experiences, interests, and backgrounds (Buxton, 2006). However, knowledge of students alone is not enough. Teachers must be prepared to use knowledge of students, science, and language development in practice to *facilitate meaningful connections* between school science and relevant social and cultural contexts (Lee, 2004; Lee et al., 2007; Rodriguez & Berryman, 2002). Contextualizing instruction has presented challenges for teachers across all subject areas, not just within science (Teemant, Wink, & Tyra, 2011). However, these challenges are compounded in science, given that science has often been presented in classrooms as 'objective' and 'culture free' (Buxton, 2006). Often, teachers' own cultural and linguistic experiences as well as more traditional experiences as students of science inadequately prepare them for the type of overhaul in instructional approaches that contextualization requires (Bryan & Atwater, 2002). However, teacher education programs that integrate both content and diversity education across coursework and field experiences for preservice teachers have demonstrated that novice teachers can learn to be more culturally responsive educators (Gay, 2010; Lee & Luykx, 2006; Rodriguez, 1998; Sleeter, 2008; Stoddart et al., 2010). Still, further investigations must help illuminate 'how to design teacher education programs that enable preservice and practicing teachers to articulate the relation of science disciplines with students' linguistic and cultural practices' (p. 133; Lee & Luykx, 2006).

Differences between bilingual and traditionally certified teachers

Rarely, if at all, has research in science teacher education compared or investigated differences between preservice teachers seeking bilingual certification versus those seeking traditional certification. Typically in science education research, effectiveness of instruction has been largely measured by teachers' understanding of the nature of science, commitment to reform-based teaching, science background, and pedagogical content knowledge (Abell & Lederman, 2007). Given the increasing cultural and linguistic diversity in today's classrooms, more attention is being given to teachers' abilities to teach science effectively in multilingual/multicultural classrooms. While there is growing research on characteristics or dispositions of effective science teachers in diverse classrooms, few to no studies have investigated differences between bilingually certified teachers versus traditionally certified teachers with regard to science instruction.

Hopkins (2013) conducted a mixed-methods study to explore relationships between bilingual educators' self-reported use of culturally and linguistically responsive practices in bilingual classrooms, compared with teachers who were teaching similar populations of students (i.e. language minority students) in monolingual (i.e. English only) classrooms. Researchers administered surveys to 474 bilingually certified teachers and traditionally certified teachers of linguistic minority students in Arizona, California, and Texas, from which 19 were interviewed. Hopkins (2013) found that bilingual educators' bilingualism and bilingual certification predicted teachers' self-reported use of culturally and linguistically responsive practices. While holding a bilingual certification was a significant predictor for use of some of the practices (i.e. building on prior knowledge, experiences, and cultural resources), teacher bilingualism (versus bilingual certification) itself was a significant predictor for others (i.e. cross-linguistic practices such as leveraging students' native language, facilitating code-switching, etc.). This study supports prior research indicating that bilingually certified educators, particularly those whose cultural and linguistic backgrounds are similar to those of their students, offer important pedagogical dimensions to instruction in diverse classrooms (Dilworth & Brown, 2008; Hopkins, 2013).

Methods

The primary goals of this qualitative study were to investigate entering elementary preservice teachers' initial ideas about contextualization in science instruction (CSK), and to identify differences, if any, in contextualization knowledge between participants enrolled in the bilingual teacher education program versus those enrolled in the traditional program. Specifically, we sought to investigate the following research questions:

(1) What are preservice teachers' initial ideas about contextualization in science? How can preservice teachers' initial ideas about contextualization in science inform our understanding of the type of support they need in teacher education?
(2) Are there differences between the two groups' (bilingual versus traditional) initial ideas about contextualization in science? How could these findings inform our understanding of differences between preservice teachers enrolled in bilingual versus traditional teacher education programs, and the types of individual support they may need in teacher education?

Research participants and setting

The study described in this paper was part of a larger multi-site study investigating the impact of a culturally and linguistically responsive model of elementary science teacher education, developed in collaboration with the Center for Research on Education, Diversity, & Excellence (CREDE). In the study that is the subject of this paper, we investigated 72 preservice teachers' initial ideas about contextualizing science instruction. The preservice teachers include participants of the larger multi-site study who were enrolled in one of two full-time university-based post-baccalaureate teacher education programs in California pursuing either the Bilingual, Cross-cultural, Language, and Academic Development (BCLAD) teaching credential ($n = 41$) or the Cross-cultural, Language, and Academic Development (CLAD) teaching credential ($n = 31$). As with any bilingual certification program, preservice teachers who enroll in the bilingual certification (BCLAD) program were required to demonstrate proficiency in one additional language, in this case, Spanish or Chinese (i.e. Cantonese). Participants in the CLAD program may also be bilingual, but may choose not to participate in the BCLAD program for a variety of reasons (e.g. do not want to teach in a bilingual classroom, do not demonstrate the required additional language proficiency, do not want to take additional coursework, etc.). Generally speaking, however, while all of the preservice teachers enrolled in the BCLAD program are fluent in a language other than English, few in the CLAD program are fluent in an additional language. The primary differences between the two programs (CLAD versus BCLAD) are that BCLAD programs give increased attention to language learning/acquisition, and faculty members who teach in BCLAD programs are generally bi-/multilingual themselves and well versed in the theory and practice of bilingual education.

The research settings at both participating universities are ideal for studying contextualization in multi-ethnic settings; each is characterized by culturally, linguistically, and economically diverse communities with a high population of English Language Learners. Of the 72 preservice teacher participants, 15 are male, 57 female, 4 Asian American, 37 Latino/a, 5 mixed race, 1 Pacific Islander, and 25 Anglo European. Seventy-six percent of participants seeking bilingual certification are from racially/ethnically minoritized backgrounds (i.e. Latino/a, Asian American). Nineteen percent of the participants seeking traditional certification are from racially/ethnically minoritized backgrounds (i.e. Latino/a, Asian American, Pacific Islander). At both sites, for CLAD and BCLAD teachers, preservice teachers enrolled in the science methods course after having completed at least one year of coursework in their teacher education program. The science methods course took place just before the final spring student teaching semester.

Instruments

Data from two instruments were used to investigate the research questions. (1) We asked all 72 participants to respond in writing to the following open-ended question: 'Describe one to three activities that a teacher could use to relate science concepts to students' social and cultural backgrounds.' (2) Ten percent of participants (i.e. 7 participants) were selected through stratified random sampling to proportionally represent the diversity of the two cohorts (i.e. by gender, ethnicity, BCLAD versus CLAD). These seven preservice teachers participated in a semi-structured interview that explored participants' understandings of the connections between students' out-of-school experiences and science. Data from both instruments were collected from students at the beginning (within the first two weeks) of their science methods course. Of the seven interview participants, four were BCLAD and three were CLAD. Qualitative data from interview questions were used to triangulate the open-ended question analysis and to explore in greater depth respondents' initial ideas about contextualization in science. The researchers (including the first author, Sara Tolbert) conducting the interviews did not participate in any aspects of the instruction, and were unaffiliated with the teacher education programs in which the preservice teachers were enrolled. Interview questions (listed below) were designed to explore participants' understandings regarding potential connections between students' out-of-school experiences and science instruction:

(1) Do you think your students' home/community experiences influence their science learning? If so, in what ways?
(2) What are the sources of students' science knowledge?
(3) Does the cultural background of your students influence your science teaching? If so, how?
(4) Describe activities that a teacher could use to relate science concepts to students' social and cultural backgrounds.

Analysis and findings

Open-ended question analysis

A coding tool, the Contextualization in Science Instruction – Knowledge (CSI-K), developed from an extensive review of the literature, was used to categorize participants' pedagogical knowledge about contextualizing science instruction (Tolbert, 2009, 2011). The CSI-K categories correspond to the nine categories of contextualization described at the beginning of this article. They are: Multicultural, Linguistic, Critical–Feminist, Community Engagement, Local–Ecological, Physical–Kinesthetic, Universal–Everyday, Hypothetical–Simulative, Historical. In a content analysis of the open-ended survey question, a process of structural coding (Saldaña, 2013) was used to assign a single code from the CSI-K coding scheme. Once inter-rater agreement was achieved (90%) between the two authors, codes were assigned to all of the open-ended question data. Frequency counts by both participant and activity were conducted in order to determine the frequency of CSI-K categories, as they appeared in the open-ended survey question data. In order to minimize the influence of researcher bias or preconceptions, participant data were disaggregated by credentialing type only after CSI-K codes had been assigned.

Open-ended question findings

A wide range of contextualized science activities were identified from participant responses to the open-ended survey question (*Describe one to three activities that a teacher could use to relate science concepts to students' social and cultural backgrounds*). Frequency counts by participant were calculated to determine the number of respondents who described at least one of three possible activities in the open-ended survey question on contextualization related to each of the nine categories. Of the 72 participants, the most frequent type of example was Multicultural. Forty-five respondents (62%) described at least one activity that was coded as Multicultural, followed by Local–Ecological (26%), Universal–Everyday (22%), Community Engagement (17%), Physical/Kinesthetic (11%), and Historical (6%). The categories with the corresponding frequencies and percentages are listed in Table 1.

Table 2 is designed to qualitatively display data related to the overall types of contextualized science activities that participating preservice teachers articulated in the open-ended survey question. Therefore, some participant responses have been collapsed and paraphrased for the sake of data reduction. For example, the responses 'activities kids do like skateboarding, paintball, riding bikes – pose questions about how these things work' and 'use playground play – momentum and acceleration on the bars' were collapsed into 'Investigate science in activities children do/incorporate play activities' under the Universal/Everyday category of contextualization. When there was only one single response

Table 1. Contextualization type (*N* = Number of respondents who listed one or more for each category).

Type	*N* *N* = 72	% total (CLAD and BCLAD)	BCLAD *N* = 41	% total BCLAD	CLAD *N* = 31	% total CLAD
Multicultural	45	62	23	56	22	71
Local–Ecological	19	26	14	34	5	16
Universal	16	22	9	22	7	23
Community Engagement	12	17	9	22	3	14
Physical–Kinesthetic	8	11	6	15	2	6
Historical	4	6	3	7	1	3
Simulative	2	3	2	5	1	3
Critical–Feminist	2	3	1	2	1	3
Linguistic	0	0	0	0	0	0

Table 2. Preservice elementary teachers' initial understandings about contextualization in science.

Category	Examples
Multicultural	Discuss scientific contributions from various cultures; have students research a scientist from their own background
	Use cultural products to introduce/study science concepts (i.e. Horchata – solubility; making tortillas – states of matter; the making of traditional meals, soap, dyes, spices, ancestral time-telling)
	Incorporate cultural beliefs/artifacts in science teaching/discuss difference in cultural perceptions of science (i.e. astronomy connected to cultural beliefs in different parts of the world, beliefs about reusing/reducing waste, flowers used in cultural celebrations; animals common to a particular culture; cultural dances/music/foods)
	Engage students in virtual tours of different countries
	Compare/contrast environment, health, human ecology, ecology, geography, climate, agricultural practices in countries around the world, particularly students' country of origin
	Study contributions among non-Western scientists throughout history (i.e. preservation of artifacts)
	Examples of cultures that reuse and reduce waste
Local–Ecological	Analyze relationships between natural features/climate/agricultural practices and evaluate human impact on the environment (current and historical)
	Take students outside
	Discuss current global environmental issues (global warming, pollution) and how to contribute locally to their solutions
	Study concepts related to the community in which you teach (i.e. in a farming community – weather's impact on agricultural workers)
	Take field trips to local sites (i.e. natural history museum)
	Discuss regional weather, natural phenomena and geographical features relevant to region (i.e. earthquakes, Yosemite)
	Earth science connected to local geography – geology, rivers, irrigation, soil
	Study science and its relationship to humans in the community (i.e. weather's impact on agricultural workers, condition of soil in California)
	Agricultural science
	Composting
	Native leaf/plant collection
	Reusing material and resources
	Learn about local environmental issues
Universal–Everyday	Cooking and food science, food origins
	Genetic history, genetic differences
	Investigate science in activities children do/incorporate student play activities (i.e. skateboarding, paintball, riding bikes, playground play)
	Experiments with everyday objects (Mentos/soda)
	How is science used in everyday lives
	Weather
	Study of the human body
Community Engagement	Interview parents/neighbors about their science learning experiences
	Collect genetic history info from parents to be shared with class
	Have parents come in as guest speakers (i.e. field workers to talk about plant care)
	Community investigations – Collect/analyze data on environmental justice issues relevant to community (e.g. water quality, effects of pesticide use on farm workers, air pollution analysis in community)
	Conduct environmental projects in the community (e.g. energy conservation, recycling, community garden)
Physical–Kinesthetic	Bring in physical materials, visuals, for students to investigate
	Plant a school garden
	Use hands-on activities
	Collect leaves
	Grow individual plants in class
Historical	Gold rush – CA (minerals)
	Biography of scientists (i.e. author of periodic table)
Hypothetical–Simulative	Virtual tours of different countries to evaluate environmental and seasonal differences
Critical–Feminist	Make a hypothesis about a social stereotype, collect data and present
	Discuss cultural perceptions of science
Linguistic	n/a

such that it could not be collapsed with multiple responses into one category, it was included as a stand-alone response (i.e. 'Gold rush – CA' or 'biography of scientists who wrote the periodic table').

Differences by credentialing type

Differences in the data were revealed when disaggregated by credentialing type (i.e. bilingual versus traditional). Preservice teachers seeking bilingual (BCLAD) certification were more likely to articulate understandings of contextualization in science that leveraged the local ecological environment or engage family/community resources than were preservice teachers seeking traditional (CLAD) certification, as illustrated in Table 1: Thirty-four percent of preservice teachers enrolled in the BCLAD programs described at least one Local–Ecological activity, compared to 16% of those enrolled in CLAD; 22% of BCLAD preservice teachers described at least one Community Engagement activity, compared to 14% of CLAD candidates. CLAD candidates, however, were more likely to describe Multicultural activities (71%) than were BCLAD candidates (56%).

Summary of findings from the open-ended question analysis

The most frequent type of example was Multicultural, with over half of respondents naming at least one activity that was categorized as Multicultural. The second most frequent type of activity named was Local–Ecological. The least mentioned types of contextualization were Hypothetical–Simulative, Critical–Feminist, and Linguistic. Differences in the data were revealed when disaggregated by credentialing type. Bilingual credentialing candidates were more likely to articulate Local–Ecological and Community Engagement examples than mainstream credentialing candidates. Mainstream credentialing candidates were more likely to articulate Multicultural activities than bilingual candidates.

Findings: interview analysis

Similarities between the two groups (CLAD and BCLAD) were consistent with those revealed in the open-ended survey question analysis (see Instruments section for interview questions). Among both groups, there was a particular focus on Multicultural and Local–Ecological contextualization as compared to the other types of contextualization.

Preservice teachers enrolled in the traditional (CLAD) program

Interview responses from preservice teachers enrolled in the traditional program revealed simplistic understandings of culture and its relationship to science learning and difficulties in connecting cultural experiences with science instruction. These preservice teachers appeared to focus more on what students lacked rather than resources they brought to science learning:

> *(In response to a question about students' sources of science knowledge)* I would say it [science learning] probably … for most of them [students] it is probably going to start with what is being done in the classroom.

Preservice teachers enrolled in CLAD programs also were more likely to make generalizations about students' backgrounds and reveal static notions of culture (e.g. piñatas):

> If you personally had a um significant cultural background where it's a huge part of your life, and you take that food, and you make a piñata out of it, so you like take a balloon, and shape it into whatever food like fruit, vegetable, whatever you wanted and they could learn how the water and the glue or the water and the flour made a paste, so that could be one scientific experiment along with art and culture.

Note that the preservice teacher equates 'significant cultural background' with piñatas, that is, 'significant cultural background' refers to Mexican culture.

Preservice teachers in the traditional program did, however, acknowledge the value of integrating students' out-of-school experiences via connections to universal–everyday experiences, particularly as a way of helping students to understand or apply scientific concepts:

> Hopefully, with an understanding of what science is [in the classroom] there can be some relationship tied back to the family, the home or the community in terms of some of the principles that you would apply in science you are doing at home you know in the home environment that could be as simple as cooking a meal or baking a cake. Uh, you know flipping on a light switch there are aspects of science that you are using or doing within your family or community … it could be something as simple as the creation of a dam on a river, what's the impact on a particular habitat and you might be able to relate that back to an example [from the local environment].

Those preservice teachers not seeking bilingual certification also shared challenges they perceived in attempting to connect science instruction with students' cultural practices:

> I'm thinking about ways you could incorporate different types of lesson plans or different types of activities that would incorporate their culture, I'm just not quite sure of specific activities. I can't think of any … I think considering we have so many different ones, it'd be hard to get the several different types, maybe – not types, but several different cultures. To get them incorporated into the classroom … I wouldn't want one student's culture to be neglected and have them feel, oh I'm not important. Mine's not important. I think that would be the real challenge … .

In summary, interview findings revealed that traditional (CLAD) credentialing candidates felt that connecting science with students' social and cultural backgrounds was important but were not familiar with meaningful ways to do so. Their responses also indicate that they saw connections between school science and students' home-community contexts as unidirectional – in other words, school science knowledge can be applied to home–community contexts, but there was little evidence that traditional (CLAD) candidates viewed students' families and communities as sources of scientific practices and/or knowledge.

Preservice teachers enrolled in the bilingual certification (BCLAD) program

Responses to the same interview questions from preservice teachers enrolled in the BCLAD programs reveal contrasts in their understandings of contextualization in science. They were more likely to articulate asset-based views about language minority students, families, and communities:

> It [sources of science knowledge] could be from parents, just you know, if they ask questions or have them go try [things] on their own. Just exploring the outside all the outside is based on science pretty much the environment. They're outside looking at bugs, and that's science, it's kind of everywhere … In the community they're just you know going out and seeing the different jobs and what people make and do.

They articulated asset-based views of children, positioning children as natural scientists:

> I think a lot of children watch TV – even comics like Transformers … There are a lot of cartoons that involve science in them – Bugs Bunny and the alien creature … [these examples can] make children curious and then if they watch them and think 'I know people cannot breathe outside of the earth. That's such a lie.' There's a budding scientist there. They already know something … they are exposed … on a daily basis to science.

Families of Latino students in the region were often from working-class and/or farming communities; BCLAD preservice teachers more often viewed farming practices and non-dominant activities (e.g. auto mechanics) as resources for science learning – recognizing that 'they [bilingual students] might know a lot of things … that I, as an adult, don't know':

> If the child comes from a rural background … the teacher could engage more, for example, in animal farms or in like, plants and their life cycles. They will not feel like they are behind in the classroom. I could ask that child, 'Oh, could you guide us, how do you plant corn, how do you make it grow?' If they know how to do it, why not have them teach the classroom how to do it? This will give that child confidence. Especially, for example, among many Latino children … or, for example, if a child has a father who is a mechanic, they might know a lot of things about a car that I, as an adult, don't know.

The BCLAD candidates appeared to recognize that all students brought resources for science learning from home, and that lower income and working-class families engage in science activities (e.g. agricultural/horticultural activities, mechanics), representing a more bidirectional understanding of connections between school science and home/community contexts. All participants interviewed, whether seeking bilingual or mainstream certification, indicated that connecting science to students' social and cultural backgrounds should be an important part of science teaching and learning.

Discussion

Two key themes have arisen from these findings: (1) preservice teachers generally focused on Multicultural and Local–Ecological connections as resources for CSI and (2) differences emerged between contextualization knowledge demonstrated by participants enrolled in the bilingual versus traditional teacher preparation programs. Overall, the preservice teachers in this study understood contextualizing science instruction as connecting to students' cultural backgrounds, as well as connecting to the local ecological and physical surroundings. Given the predominance of these two types of activities (Multicultural, Local–Ecological) in the open-ended question analysis as well as the interview analysis, regardless of program type, preservice teachers appeared to recognize the value of multicultural and local or ecological contexts as important resources for developing contextualized science activities in linguistically diverse classrooms. On the other hand, whereas preservice teachers in the CLAD program viewed school science as the primary source of language minority students' science knowledge, those in the bilingual (BCLAD) program demonstrated a more asset-based orientation, viewing students, families, and communities as both consumers and producers of science knowledge. This finding supports prior research on bilingual teachers, which has indicated that bilingual teacher candidates more often demonstrate dispositions that are optimal for teaching in culturally and linguistically complex classrooms (Cline & Necochea, 2006; Evans et al., 2005; Hopkins, 2013; Lee, 2004; Nieto, 2000).

Another key difference between the two groups is that preservice teachers in the bilingual programs were more likely to describe Local–Ecological and Community Engagement activities than those preservice teachers enrolled in the traditional programs, and candidates in the traditional programs were more likely to describe Multicultural activities than those in the bilingual programs. One possible explanation is that, drawing from their own experiences as well as from prior experiences in the bilingual program, the preservice teachers in the bilingual programs had developed more nuanced understandings of cultural practices. This tentative explanation is supported by interview findings: Where preservice teachers in the traditional programs made references to stereotypical cultural products, such as piñatas, as resources for contextualizing science instruction, preservice teachers in the bilingual programs were more attentive to finding out about who their students might be, and described how they would draw from relevant local ecological, family, or community contexts to engage students in more meaningful science learning experiences.

It is interesting to note that the least mentioned types of contextualization were Hypothetical–Simulative, Critical–Feminist, and Linguistic. Given that both groups of preservice teachers are being prepared to work in culturally and linguistically diverse classrooms, it would be important to help novice teachers better understand how a critical-feminist perspective can help students see the value of science as an important tool for social justice and social change in marginalized communities (Barton, 1998), and how creating opportunities for hybrid discursivity (Linguistic contextualization) in science classrooms can facilitate contextualized science learning experiences (Gutiérrez, Morales, & Martinez, 2009; Moje et al., 2004).

Implications and conclusions

Given that an overly explicit or prescriptive emphasis on cultural backgrounds can result in preservice teachers' developing or reinforcing fixed notions of culture, teacher educators should encourage preservice teachers to think in terms of building on their students' local places and community funds of knowledge (as cultural practices), as well as students' diverse language practices rather than drawing from stereotypical or superficial representations of culture to contextualize instruction (Lee et al., 2007; Warren et al., 2001). Research on teacher education for students who are emergent bilinguals (commonly referred to as English learners) has indicated that collaborations between bilingual educators and non-bilingual educators have improved the cultural and linguistic responsiveness of practicing teachers not prepared through bilingual teacher education programs (Lucas & Grinberg, 2008). Prior research has also demonstrated that creating these types of hybrid learning communities between the two groups can be beneficial for helping non-bilingual teachers develop cultural awareness and cultural responsiveness (Evans et al., 2005). More research is needed to explore the opportunities and challenges of increasing collaborations between preservice teachers enrolled in bilingual certification programs versus those who are not, as well as the potential effect of these collaborations on preservice teachers' abilities contextualize instruction with language minority students. Also worthy of further exploration is the extent to which bilingualism and/or bilingual certification is a factor in preservice orientations toward culturally responsive science instruction, compared to preservice teachers' experiences with diversity and/or multiculturality in general (see Ganchorre & Tomanek, 2012; Suriel & Atwater, 2012).

A final outcome of this study has been the development of a framework for analyzing the development of teacher knowledge about contextualizing science activities in diverse elementary classrooms, drawn from literature related to contextualization of science and language instruction. The framework can be used to guide the development of teacher education courses and programs seeking to integrate science, language, and diversity instruction. Future studies should investigate differences between the knowledge *and* practices of both bilingual and non-bilingual preservice teachers as they enact contextualized science activities in multilingual classrooms.

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References

Abell, S., & Lederman, N. (Eds.). (2007). *Handbook of research on science education*. New York, NY: Routledge.

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham, NC: Duke University Press.

Barton, A. C. (1998). *Feminist science education*. New York, NY: Teachers College Press.

Barton, A. C., & Tan, E. (2010). We be burnin! Agency, identity, and science learning. *Journal of the Learning Sciences*, *19*(2), 187–229.

Bouillion, L. M., & Gomez, L. M. (2001). Connecting school and community with science learning: Real world problems and school-community partnerships as contextual scaffolds. *Journal of Research in Science Teaching*, *38*, 878–889.

Bravo, M., Hiebert, E., & Pearson, P. D. (2007). Tapping the linguistic resources of Spanish-English bilinguals: The role of cognates in science. In R. Wagner, A. Muse, & K. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension* (pp. 140–156). New York, NY: The Guilford Press.

Brown, B. (2006). It ain't no slang that can be said about this stuff: Language, identity, and appropriating science discourse. *Journal of Research in Science Teaching*, *43*(1), 96–126.

Bryan, L., & Atwater, M. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education*, *86*(6), 821–839.

Buxton, C. A. (2006). Creating contextually authentic science in a 'low-performing' urban elementary school. *Journal of Research in Science Teaching*, *43*(7), 695–721.
Buxton, C. A. (2010). Social problem solving through science: An approach to critical, place-based teaching and learning. *Equity & Excellence in Education*, *43*(1), 120–135.
Cline, Z., & Necochea, J. (2006, September). Teacher dispositions for effective education in the borderlands. *Educational Forum*, *70*(3), 268–282.
Dilworth, M., & Brown, A. (2008). Teachers of color: Quality and effective teachers one way or another. In M. Cochran-Smith, S. Feiman-Nemser, J. McIntyre, & K. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts* (3rd ed., pp. 424–443). New York, NY and Manassas, VA: Routledge/Taylor & Francis and The Association of Teacher Educators.
Echevarria, J. J., Short, D. J., & Vogt, M. J. (2012). *Making content comprehensible for English learners: The SIOP model* (4th ed.). Sacramento, CA: Pearson.
Evans, C., Arnot-Hopffer, E., & Jurich, D. (2005). Making ends meet: Bringing bilingual education and mainstream students together in preservice teacher education. *Equity & Excellence in Education*, *38*(1), 75–88.
Fan, X., & Geelan, D. (2013). Enhancing students' scientific literacy using interactive simulations: A critical literature review. *Journal of Computers in Science and Mathematics Teaching*, *32*(2), 125–171.
Fensham, P. J. (2009). Real world contexts in PISA science: Implications for context-based science education. *Journal of Research in Science Teaching*, *46*(8), 884–896.
Fry, R. (2008). *The role of schools in the English language learner achievement gap*. Washington, DC: Pew Hispanic Center.
Ganchorre, A. R., & Tomanek, D. (2012). Commitment to teach in under-resourced schools: Prospective science and mathematics teachers' dispositions. *Journal of Science Teacher Education*, *23*(1), 87–110.
García, O. (2009). *Bilingual education in the 21st century: A global perspective*. Malden, MA: Wiley-Blackwell.
Gay, G. (2010). *Culturally responsive teaching: Theory, research, and practice*. New York, NY: Teachers College Press.
Gutiérrez, K. D., Morales, P. Z., & Martinez, D. C. (2009). Re-mediating literacy: Culture, difference, and learning for students from nondominant communities. *Review of Research in Education*, *33*(1), 212–245.
Hammond, L. (2001). Notes from California: An anthropological approach to urban science education for language minority families. *Journal of Research in Science Teaching*, *38*(9), 983–999.
Hodson, D. (1999). Going beyond cultural pluralism: Science education for sociopolitical action. *Science Education*, *83*(6), 775–796.
Hopkins, M. (2013). Building on our teaching assets: The unique pedagogical contributions of bilingual educators. *Bilingual Research Journal*, *36*(3), 350–370.
Hsu, P. S., & Zembal-Saul, C. (2004). A case study of the change process of integrating technology into an elementary science methods course. *Society for Information Technology & Teacher Education International Conference*, *2004*(1), 1190–1196.
Kasanda, C., Lubben, F., Gaoseb, N., Kandjeo-Marenga, U., Kapenda, H., & Campbell, B. (2005). The role of everyday contexts in learner-centered teaching: The practice in Namibian secondary schools. *International Journal of Science Education*, *27*(15), 1805–1823.
Kearsey, J., & Turner, S. (1999). The value of bilingualism in pupils' understanding of scientific language. *International Journal of Science Education*, *21*(10), 1037–1050.
Kern, A. L., Roehrig, G., & Wattam, D. K. (2012). Inside a beginning immigrant science teacher's classroom: An ethnographic study. *Teachers and Teaching*, *18*(4), 469–481.
Lee, O. (2004). Teacher change in beliefs and practice in science and literacy instruction with English language learners. *Journal of Research in Science Teaching*, *41*(1), 65–93.
Lee, O., & Luykx, A. (2006). *Science education and student diversity: Synthesis and research agenda*. New York, NY: Cambridge University Press.

Lee, O., Luykx, A., Buxton, C., & Shaver, A. (2007). The challenge of altering elementary school teachers' beliefs and practices regarding linguistic and cultural diversity in science instruction. *Journal of Research in Science Teaching*, *44*(9), 1269–1291.
Lucas, T., & Grinberg, J. (2008). Responding to the linguistic reality of mainstream classrooms: Preparing all teachers to teach English language learners. In M. Cochran-Smith, S. Feiman-Nemser, J. McIntyre, & K. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts* (3rd ed., pp. 606–636). New York, NY and Manassas, VA: Routledge/Taylor & Francis and The Association of Teacher Educators.
Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. New York, NY: Routledge.
Mayberry, M. (1998). Reproductive and resistant pedagogies: The comparative roles of collaborative learning and feminist pedagogy in science education. *Journal of Research in Science Teaching*, *35*(4), 443–459.
Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly*, *39*(1), 38–70.
Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge: A qualitative approach to developing strategic connection between homes and classrooms. *Theory into Practice*, *31*(2), 132–141.
Molyneux, P., & Tyler, D. (2014). Place-based education and pre-service teachers: A case study from India. *International Journal of Inclusive Education*, *18*(9), 877–887.
Nashon, S. M., & Anderson, D. (2013). Interpreting student views of learning experiences in a contextualized science discourse in Kenya. *Journal of Research in Science Teaching*, *50*(4), 381–407.
Nieto, S. (2000). Placing equity front and center some thoughts on transforming teacher education for a new century. *Journal of Teacher Education*, *51*(3), 180–187.
Norman, O. (1998). Marginalized discourses and scientific literacy. *Journal of Research in Science Teaching*, *35*(4), 365–374.
Patchen, T., & Cox-Peterson, A. (2008). Constructing cultural relevance in science: A case study of two elementary teachers. *Science Education*, *92*, 994–1014.
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*(1), 79–100.
Rodriguez, A. J. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. *Journal of Research in Science Teaching*, *35*(6), 589–622.
Rodriguez, A. J., & Berryman, C. (2002). Using sociotransformative constructivism to teach for understanding in diverse classrooms: A beginning teacher's journey. *American Educational Research Journal*, *39*(4), 1017–1045.
Rosebery, A., Warren, B., & Conant, F. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences*, *2*(1), 61–94.
Roth, W.-M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, *88*(2), 263–291.
Saldaña, J. (2013). *The coding manual for qualitative researchers* (2nd ed.). Thousand Oaks, CA: Sage Publications.
Schindel Dimick, A., & Tolbert, S. (in press). 'I feel like there's a better explanation … ' Ebola, race, & colonization: A case study of othering in science. *Rethinking Schools*.
Shaw, J. M., Lyon, E. G., Stoddart, T., Mosqueda, E., & Menon, P. (2014). Improving science and literacy learning for English language learners: Evidence from a pre-service teacher preparation intervention. *Journal of Science Teacher Education*, *25*(5), 621–643.
Sleeter, C. (2008). Preparing White teachers for diverse students. In M. Cochran-Smith, S. Feiman-Nemser, J. McIntyre, & K. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts* (3rd ed., pp. 559–582). New York, NY and Manassas, VA: Routledge/Taylor & Francis and The Association of Teacher Educators.

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.

Stoddart, T., Solis, J., Tolbert, S., & Bravo, M. (2010). Effective science teaching for English language learners. In D. Sunal & C. Sunal (Eds.), *Teaching science with Hispanic ELLs in K-16 classrooms* (pp. 151–181). Charlotte, NC: Information Age Publishing.

Suriel, R. L., & Atwater, M. M. (2012). From the contribution to the action approach: White teachers' experiences influencing the development of multicultural science curricula. *Journal of Research in Science Teaching*, *49*(10), 1271–1295.

Teemant, A., Wink, J., & Tyra, S. (2011). Effects of coaching on teacher use of sociocultural instructional practices. *Teaching and Teacher Education*, *27*(4), 683–693.

Tharp, R. G., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning, and schooling in social context*. New York, NY: Cambridge University Press.

Tolbert, S. (2009, April). *Cultural food days and growing gardens? Pre-service elementary teacher emerging beliefs and knowledge about contextualizing science instruction in diverse classrooms*. Paper presented at the annual conference of the National Association of Research in Science Teaching, Garden Grove, CA.

Tolbert, S. (2011). *Teaching the content in context: Preparing 'highly qualified' and 'high quality' teachers for instruction in underserved secondary science classrooms*. Ann Arbor, MI: ProQuest LLC.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense making. *Journal of Research in Science Teaching*, *38*, 529–552.

Wong Fillmore, L. (1991). Second-language learning in children: A model of language learning in social context. In E. Bialystok (Ed.), *Language processing in bilingual children* (pp. 49–69). New York, NY: Cambridge University Press.