Teachers' Knowledge and Beliefs About English Learners and Their Impact on STEM Learning

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Reform documents in STEM (science, technology, engineering, and mathematics) education call for the transformation of content and instruction so that all students, including English learners, can excel in these disciplines (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; National Research Council, 2012; NGSS Lead States, 2013). English learners (ELs) currently constitute 4.6 million or 9.4% of students enrolled in U.S. K-12 public school classrooms (National Center for Education Statistics, 2016). ELs include both students who were born outside of the U.S. and students who have a home language other than English. Despite the uniformity of their label, EL students are diverse in their language and literacy backgrounds, including home language and number of and proficiency in languages spoken; levels and quality of their prior schooling; country of origin, ethnicity, and culture; personal history; gender identity; sexual orientation; and socioeconomic status (National Academies of Sciences, Engineering, and Medicine, 2017). Like all students, they bring resources to STEM classrooms that should be valued, elicited, and built on during instruction (Rosebery & Warren, 2008).

Teachers are considered essential to ensuring ELs learn STEM disciplinary concepts and practices as envisioned in reform documents. Teachers must "purposefully enact opportunities for the development of language and literacy in and through teaching . . . core curricular content, understandings, and activities" if they are to interest, engage, and challenge their EL students (Bunch, 2013, p. 298). Their efforts to construct safe classroom communities and effectively implement reform-based strategies have been found to impact both ELs' views of themselves as learners and their mathematics and science achievement (Carlone, Haun-Frank, & Webb, 2011; Lewis et al., 2012; Llosa et al., 2016). Given, then, that "teachers are both on the front line and responsible for the bottom line" in providing ELs with the knowledge, practices, and habits of mind needed to excel in and affiliate with STEM disciplines, it is important to understand their views and experiences (Gandarà, Maxwell-Jolly, & Driscoll, 2005, p. 2). This review of literature focuses on teachers' knowledge and beliefs about ELs and effective ways to teach them: It attempts to trace mis/connections across teachers' knowledge and beliefs, their instructional practices, and the implications for EL student learning.

Method

This literature review examines empirical studies of STEM teachers' knowledge and beliefs about ELs conducted in the U.S. since 2000. The three constructs of (1) STEM teachers, (2) knowledge and beliefs, and (3) ELs are broadly defined. STEM teachers include content-area, ESL (English as a second language), and bilingual teachers at the elementary and secondary levels who teach mathematics, science, and/or engineering; they are studied alone or with teachers of other disciplines. The phrase knowledge and beliefs encompasses teachers' ideas,

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reasoning, and sense-making about their students, discipline, instruction, and/or larger school and community contexts. Studies reviewed in this paper investigate not only teachers' knowledge or beliefs (see Pajares, 1992, for a discussion of the two constructs), but disposition (Burant, Chubbuck, & Whipp, 2007), positioning (Harré & van Langenhove, 1999), and noticing (Sherin, Jacobs, & Philipp, 2011) as well. Finally, the term ELs includes English learners, bilingual students, and linguistically diverse students.

I employed three methods to identify relevant articles, book chapters, and books. One, I searched the Education Resources Information Center (ERIC) and Web of Science indexes using the terms of teacher; mathematics, science, or engineering; and English language learner, English learner, language learner, or linguistically diverse (student). Two, I reviewed the reference lists of relevant publications for related work. And three, I solicited recommendations from experts in the fields of second language acquisition, English language development (ELD), mathematics education, science education, and engineering education. Only articles, book chapters, or books that reported empirical findings were included. No studies specifically about engineering were identified. All told, approximately 80 publications were reviewed.

Teachers' Knowledge and Beliefs About ELs in the Research Literature

Findings from relevant literature about STEM teachers' knowledge and beliefs are presented across seven themes: (1) ELs; (2) ELs' parents and communities; (3) the nature and content of STEM disciplines; (4) the intersection of STEM content and ELD, including first and second language (L1 and L2) acquisition; (5) reform-based instructional strategies; (6) school, district, state, and federal contexts and policies; and (7) effective professional development focused on ELs. It is important to note that the vast majority of studies speak to two or more of these seven themes.

Theme 1: EL Students

The first theme of EL students serves as the foundation for the six other themes examined here. As one might expect, a long list of studies speak to teachers' knowledge and beliefs about their EL students. Findings were organized into two areas: (1) teachers' asset-based views of ELs, and (2) teachers' deficit-based views. I identified no clear patterns separating practicing from preservice teachers, or mathematics from science disciplines.

Asset-based views of ELs. Researchers examine a wide range of teachers' knowledge and beliefs about the resources, interests, and strengths of their EL students both within and across studies. A substantial number of studies make clear that at least some teacher hold high expectations for their EL students (Buxton, 2005; Buxton, Carlone, & Carlone, 2005; Cahnmann & Remillard, 2002; Jackson & Roberts, 2017; Johnson & Bolshakova, 2015; Johnson, Bolshakova, & Waldron, 2016). A substantial number also find that at least some teachers view their ELs as *willing* and *able* to learn both STEM content and English – as eager and capable learners (Buck, Mast, Ehlers, & Franklin, 2005; Chval, Pinnow, & Thomas, 2015; de Araujo, I, Smith, & Sakow, 2015; Dong, 2002; Estapa, Pinnow, & Chval, 2016; Fernandes, 2012; Gandarà et al., 2005; Jackson & Roberts, 2017; Johnson et al., 2016; Kang & Zinger, 2017; Karabenick &

Noda, 2004; Ortega, Luft, & Wong, 2013; Suriel & Atwater, 2012; Zwiep, Straits, Stone, Beltran, & Furtado, 2016). Other studies present at least some teachers as recognizing EL students as a diverse rather homogeneous group, in terms of their background, interests, and/or English proficiency levels (Bartell et al., 2010; Bianchini & Brenner, 2010; Buck et al., 2005; Estapa et al., 2016; Fernandes, 2012; Gandarà et al., 2005; Harper & de Jong, 2009; Nasir & Heineke, 2014; Petit, 2013; Smetana & Heineke, 2017; Sowa, 2009; Vomvoridi-Ivanović & Razfar, 2013). Still other studies note that at least some teachers see their ELs as bringing valuable knowledge and experiences to the STEM classroom that should be elicited and built on (Dong, 2002; Chval & Pinnow, 2010; Harper & de Jong, 2009; Jackson & Roberts; 2017; Moore, 2008; Ortega et al., 2013; Patchen & Cox-Petersen, 2008; Rivera Malucci, 2009; Roberts, Bianchini, Lee, Hough, & Carpenter, 2017). Additional aspects of teachers' knowledge and beliefs identified by at least two sets of researchers include the following: Viewing ELs as entitled to rich learning opportunities and adequate scaffolds and supports (Chval et al., 2015; de Araujo, et al., 2015; Jackson & Roberts, 2017; Kang & Zinger, 2017); as enriching the classroom for all students (Buck et al., 2005; Polat & Mahalingappa, 2013; Sowa, 2009); as engaged in disciplinary meaning-making (Chval et al., 2015; Estapa et al., 2016; Vomvoridi-Ivanović & Razfar, 2013); as potential scientists (Carlone et al., 2011; Rivera Malucci, 2009; Tolbert & Knox, 2016); and as constrained by institutional and economic forces (Battey et al., 2013; Ganchorre & Tomanek, 2012).

Studies conducted by Chval, Pinnow, and colleagues (Chval et al., 2015; Estapa et al., 2016) provide examples of teachers' asset-based views of EL students. In one of these studies, Estapa et al. (2016) investigated two beginning 3rd-grade teachers engaged in a long-term professional development project. Researchers found that one of their teacher participants, Laura, shifted her knowledge, beliefs, and practices over time: She realized that she had been ignoring the ELs who quietly sat in the back of her classroom, came to see them as willing and able to engage in mathematics sense-making, and began to make connections between her ELs' mathematics sense-making and her practices as a teacher. Similarly, the second teacher participant, Sara, began to attend to her ELs' mathematics sense-making. She came to recognize that there was a great deal that her ELs knew, but that they could not always express their ideas in English. Further, both teachers came to see ELs as diverse, noticing the behavior and mathematical thinking of specific ELs. In a second study by Chval et al. (2015), Courtney, another 3rd grade teacher participating in professional development, learned to approach her lesson preparation from the perspective of her ELs: She came to see her ELs as eager to engage in and capable of making sense of mathematics, to understand the challenges that particular contextual situations and mathematics curriculum materials posed for these learners, and to recognize the kinds of adjustments she needed to make to promote equitable access to mathematics content and academic language for all her students.

Deficit-based views of ELs. Teachers' deficit-based views about ELs are also numerous; many are in direct contrast to asset-based views discussed above. Several studies document the low expectations some teachers hold for their EL students' success **(**Buxton, 2005; Chval & Pinnow, 2010; de Araujo, Smith, & Sakow, 2016; Rodriguez & Berryman, 2002; Sharkey & Layzer, 2000). Several present at least some teachers as believing ELs are homogeneously low in language proficiency and STEM and as conflating English language proficiency with STEM content understanding (Battey et al., 2013; Bunch et al., 2009; Cho & McDonnough, 2009; de

Araujo, 2017; de Araujo et al., 2016; Harklau, 2000; Lee et al., 2009; Wilson, Sztajn, Edgington, Webb, & Myers, 2017). Others describe at least some teachers as holding stereotypes of ELs grounded in their first language, ethnicity, and/or country of origin (Bartell et al., 2010; Chval & Pinnow, 2010; de Araujo, 2017). Still others describe teachers as viewing ELs as lacking relevant prior knowledge, experiences, and/or language (Deaton, Deaton, & Koballa, 2014; de Araujo et al., 2016; Lee, Maerten-Rivera, Buxton, Penfield, & Secada, 2009). Further, a number of studies note that at least some teachers see their ELs as unable or unwilling to communicate with teachers and/or with their non-EL peers (de Araujo et al., 2016; Deaton et al., 2014; Durgunoğlu & Hughes, 2010; Karabenick & Noda, 2004; Sharkey & Layzer, 2000; Swars & Chestnutt, 2016). Additional examples of teachers' deficit-based knowledge and beliefs identified by at least two sets of researchers include the following: Teachers assume that ELs are motivated and hard-working rather than intelligent (Hansen-Thomas & Cavagnetto, 2010; Harklau, 2000; Sharkey & Layzer, 2000); have access to the same cultural knowledge as non-EL students (Cahnmann & Remillard, 2002; Coady et al., 2016); require more time to have their needs met than their non-EL peers (Bianchini & Brenner, 2010; Karabenick & Noda, 2004; Petit, 2013; Polat & Mahalingappa, 2013; Reeves. 2006); and experience fundamental inequities in their lives that teachers and schools should not be expected to address (Bianchini & Brenner, 2010; Suriel & Atwater, 2012).

De Araujo et al. (2016) provided an example of teachers' deficit thinking: Researchers investigated one preservice elementary teacher, Kimberly, enrolled in an elementary methods course and required to conduct a series of interviews on mathematics tasks with one EL student, a 5th grader from Korea. Kimberly held several deficit views of ELs: that they are homogenous in their language proficiencies, unable to communicate with teachers given their lack of language proficiency, average in their abilities, and likely to struggle with tasks in mathematics simply because they are ELs. She also failed to consider how ELs' own experiences and languages might provide a supportive context for learning. When Kimberly determined her 5th-grade EL was indeed gifted in mathematics, her plans changed from a focus on supporting his learning of language and mathematics to challenging him. However, because she made the language rather than the mathematics in the tasks more complex, she served to position herself as the authority and her EL student as in need, doing little to further his mathematical understanding. In sum, in Kimberly's case, the implications of her deficit views and the positioning of her EL student in deficit ways led to the selection and modification of tasks that focused on complex language rather than on demanding mathematical practices.

Theme 2: EL Students' Families and Communities

Studies of EL students' families and communities were organized into three areas: Teachers' knowledge and beliefs about (1) EL students' families, (2) their communities, and (3) their cultures more broadly. As with EL students themselves, findings present some teachers as holding asset-based views and others, deficit-based ones. Again, I identified no clear patterns separating practicing from preservice teachers, or mathematics from science disciplines.

EL students' families. Collectively, studies of teachers' knowledge and beliefs about EL students' families span asset- to deficit-based views. Few studies identify only asset-based views teachers hold about ELs' families (Durgunoğlu & Hughes, 2010; Sowa, 2009). More common are

studies that present some teacher participants as welcoming and valuing EL students' parents and others as holding deficit views of parents' contributions (Bunch, Aguirre, & Téllez, 2009; Deaton et al., 2014; Fernandes, 2012; Karabenick & Noda, 2004; Lee et al., 2007; Tolbert & Knox, 2016). Several additional studies document challenges that remain even when teachers value EL parents and encourage their participation (Gandarà et al., 2005; Hammond, 2001; Turner et al., 2012). For example, Hammond (2001) examined both practicing and preservice elementary teachers engaged in a bilingual and crosscultural professional development project at a school in California attended by students from Southeast Asian refugee families (Mien and Hmong) as well as Central Asian, Mexican, and transient English-speaking families. Hammond found that teachers came to view parents as experts in traditional knowledge. However, some teachers assumed that parents wanted greater decision-making power at the school while parents simply wanted their traditional knowledge to be recorded and maintained. European American teachers also thought ethnic minority teachers were being passive and irresponsible because they did not encourage parents to speak up. Hammond concluded that cultural conflict is an essential part of building intercultural understanding – as long as it is carefully mediated and thoughtfully understood. Finally, a few studies identify only deficit-based views held by teachers about ELs' parents, for example, perceiving parents as a barrier to ELs' learning or as valuing education less than non-EL parents (Lee et al., 2007; Lee et al., 2009; McLeman & Fernandes, 2012).

EL students' communities. There are many fewer studies that include examination of EL students' communities. Several studies note that teachers learn to recognize the importance of drawing on students' local communities and contexts as part of their teacher education or professional development experiences (Chval et al., 2015; Deaton et al., 2014; Koballa, 2014; Lee, 2004). Four studies examine teachers in relation to EL students' communities in greater detail, identifying both strengths and limitations in their knowledge, beliefs, and practices (Bartell et al., 2010; Ganchorre & Tomanek, 2012; Tolbert & Knox, 2016; Turner et al., 2012). In a study conducted by Bartell et al. (2010), for example, researchers investigated 200 preK-8 preservice mathematics teachers' work on a community mathematics exploration module as part of their mathematics methods course. The purpose of this instructional module, along with other modules, was to support preservice teacher participants in designing and implementing effective instruction that builds on and integrates diverse students' mathematical knowledge bases. Researchers found that preservice teachers entered the course with the belief that connecting to students' mathematics funds of knowledge was a valued teaching practice but had little concrete understanding of how to do so. By the end, all preservice teachers were able to develop mathematics problems that built on their students' multiple funds of knowledge, although some struggled with the mathematics involved or with knowing how to connect the community to instruction. In addition, at the beginning of the course, some preservice teachers reported avoiding certain communities because of their negative reputations. By the end, they came to feel more comfortable about engaging with students' communities and identifying community contexts as resources.

EL students' cultures more broadly. As with the area of families discussed above, studies of teachers' knowledge and beliefs about EL students' cultures span asset- to deficit-based views. Several studies report only on teacher participants' asset-based (Dong, 2002; Rivera

Malucci, 2009; Smetana & Heineke, 2014; Sowa, 2009) or deficit-based (Battey et al., 2013) views of students' cultures. In several other studies, researchers document how some of their teacher participants value and use students' culture as a foundation, resource, or bridge to STEM learning while others view students' culture through a deficit lens (Buxton, 2005; Johnson & Bolshakova, 2015; McLeman & Fernandes, 2012). Still others emphasize that at least some teachers understand their students to come from diverse home cultures, recognizing the need not to overgeneralize or stereotype (Lee, 2004; Nasir & Heineke, 2014). And still others examine the nuances or contradictions in teachers' views and beliefs about ELs' cultural backgrounds (Aguirre, Zavala, & Katanyoutanant, 2012; Cahnmann & Remillard, 2002; Coady, Harper & de Jong, 2016; Harper & de Jong, 2009; Johnson et al., 2016; Patchen & Cox-Petersen, 2008). In Cahnmann and Remillard's (2002) study of two 3rd-grade teachers involved in professional development opportunities, for example, researchers found that both teachers were committed to making mathematics accessible and meaningful to their diverse students. Ms. Arieto worked to create a bridge between her students' home language and culture and the academic expectations of the school. She empathized with her students' life experiences and provided nurturing transitions from home to school, chose activities and tools that she believed would motivate students and connect to their culture and language, and used Spanish to introduce new mathematics concepts and re-enforce learning in English. However, she emphasized making mathematics fun and engaging at the expense of implementing lessons that were rich in learning and accurate in content. In contrast, Ms. Kitcher consistently engaged her students in reform-based mathematics, emphasizing mathematics concepts and explanations. She wanted her students to enjoy mathematics, see it as relevant, and see themselves as competent. However, she avoided making specific references to class and culture; conflated racism, class, and school performance; and assumed academic language was universal rather than specific to the dominant culture. Researchers concluded their study by recommending teachers move to using both a mathematical and a cultural perspective in their teaching of diverse students, or what they called culturally contextualized instruction.

Theme 3: The Nature and Content of STEM Disciplines

Research on teachers' knowledge and beliefs about the nature and content of STEM disciplines was organized into three areas: (1) their views of STEM as cultural production, (2) their understanding of the centrality of language in STEM disciplinary concepts and practices, and (3) their knowledge of STEM subject matter. The first of these areas resonates with the findings about students' culture discussed above; the second, with the mis/connections between learning STEM content and developing English language proficiency discussed below.

STEM as cultural production. Studies that provide insight into teachers' knowledge and beliefs about the cultural aspects of STEM disciplines focus on the teaching and learning of science at the elementary school level (Hammond, 2001; Lee, 2004; Lee, Luykx, Buxton, & Shaver, 2007; Tolbert & Knox, 2016). They have little in common beyond their context. As one example, Tolbert and Knox (2016) investigated 72 preservice elementary teachers' initial ideas about contextualizing science instruction for EL students in California. Of the nine ways to contextualize lessons identified, the two most tightly tied to the culture of science – historical (the

trajectories of science and scientists and/or the social and historical conditions that led to a particular discovery or theory) and critical-feminist (the evaluation of issues of objectivity and subjectivity in science and how science has been used to privilege or marginalize individuals or groups of people) – were rarely employed. In the latter case, using a critical feminist perspective could help students see science as an important tool for social justice and social change in their marginalized communities. As a second example, in Lee's (2004) study of six bilingual, Hispanic 4th-grade teachers involved in a professional development project in a large urban district in the Southeast, teachers understood the cultures of science and of students to sometimes be in conflict; such conflicts generally involved cultural values and practices related to the epistemology of science. Teachers identified three incompatibilities: (1) the questioning and inquiry central to science might not be encouraged in some cultures; (2) the autonomy needed to engage in inquiry might be in conflict with some cultures' respect for teacher authority; and (3) the movement between collaboration and independence in science might conflict with some cultures' preference for group decision-making. As such, teachers in Lee's study found establishing instructional congruence a gradual and demanding process. Further, in their implications, Lee et al. (2007) noted that science is often portrayed as objective and acultural. They suggested this might explain why some of their practicing elementary teacher participants felt conflicted, indifferent, or resistant to integrating culture and language into their science instruction even though both were integral to the professional development project.

The centrality of language in STEM disciplinary concepts and practices. A few of the studies that inform the second area, teachers' knowledge and beliefs about the centrality of language in STEM disciplines, suggest that practicing and preservice teachers conceive of language as integral to the nature of mathematics or science (Bunch et al., 2009; Swanson, Bianchini, & Lee, 2014). As one example, Swanson, Bianchini, and Lee (2014) found that a high school teacher, Ms. H, conceived of science as including both practices and discourse. She defined science discourse as generating and evaluating arguments from evidence, sharing ideas and understandings with others in public forums, and using precise language. As such, Ms. H provided her EL students with multiple, scaffolded opportunities to articulate their ideas about natural phenomena; engage in the process of developing arguments from evidence; and read, interpret, and evaluate scientific information. As a second example, Bunch et al. (2009) examined eight preservice elementary teachers' written reflections about mathematics lessons submitted for PACT (a performance-based assessment administered to preservice teachers in California). They found that the majority of their participants viewed language – using specific vocabulary and engaging in other discourse practices – as integral to mathematics. A minority, however, thought mathematics focused on numbers and, thus, viewed the language demands of mathematics, including vocabulary, as minimal.

Additional studies of practicing and preservice teachers in mathematics echo the findings of the minority of participants in Bunch et al.'s study: Mathematics teachers often fail to see language as integral to the nature, concepts, and practices of mathematics (Battey et al., 2013; Estapa et al., 2016; Fernandes, 2012; Hansen-Thomas & Cavagnetto, 2010; McLeman & Fernandes, 2012). In Battey et al.'s study (2013) of practicing elementary teachers involved in a mathematics professional development project focused on Cognitively Guided Instruction in Arizona, five of the seven teachers interviewed conceived of mathematics as a universal language

comprised of numbers. Similarly, Fernandes (2012) found that an assignment given to preservice middle school mathematics teachers in his course, interviewing EL students about a series of mathematics tasks, seemed to reinforce prior beliefs that some preservice teachers held about mathematics being universal. This belief emerged when EL students successfully solved a task with minimal assistance; having such a belief ignores the additional cognitive load EL students face because of the centrality of language in mathematics. Further, McLeman and Fernandes (2012) found that the majority of the 330 preservice K-12 teachers from 12 different states they surveyed thought mathematics ideal for beginning ELs to transition into learning English; preservice teachers most likely viewed mathematics as devoid of language and symbolic in nature. However, the majority of preservice teachers who intended to teach high school and who had exposure to learning a second language provided responses aligned with research on the complex discourse of mathematics.

STEM content knowledge. Studies that speak to the third area, teachers' knowledge about STEM content, focus on practicing and preservice elementary teachers in mathematics and science (Cahnmann & Remillard, 2002; de Araujo et al., 2016; Lee, 2004; Lee et al., 2016; McLeman & Fernandes, 2012; Santau, Secada, Maerten-Rivera, Cone, & Lee, 2010; Stoddart, Pinal, Latzke, & Canaday, 2002). I identified two trends across these studies. One, elementary teachers often express concern about their lack of STEM subject matter knowledge, at least initially if involved in teacher education or professional development. For example, in Stoddart et al.'s (2002) study of a professional development project to encourage elementary teachers in rural California to focus on inquiry and language acquisition, researchers found that, initially, the majority of their 24 participants felt themselves well prepared to teach either science or language but not both. After the professional development, however, the majority of teachers believed they had improved in their weak domain. (See also Cahnmann & Remillard, 2002; de Araujo et al., 2016; Lee et al., 2016.) Two, the depth of teachers' subject matter knowledge increases as one progresses up grade levels. For example, in a study conducted by Santau et al. (2010), at the end their first year of a professional development opportunity, practicing elementary teachers reported that they were fairly knowledgeable about the science content at their grade level. In observations of their science lessons, teachers' science knowledge was found to be generally accurate, although teachers' knowledge tended to increase in higher grades and all teachers' knowledge and practices fell short of reform-oriented goals. (See again McLeman & Fernandes, 2012.)

Theme 4: The Intersection of STEM Content and English Language Development

Studies that investigate teachers' knowledge and beliefs about the mis/connections between STEM content and ELD were organized into two areas: (1) first and second language (L1 and L2) acquisition, and (2) the teaching and learning of STEM content and English language more broadly. Studies cut across practicing and preservice teachers as well as the disciplines of mathematics and science. Collectively, they provide insight into the ways teachers' knowledge, beliefs, and practices align with or diverge from research as well as the ways knowledge, beliefs, and practices of teacher groups are similar to and different from one another.

First and second language acquisition. Some studies on teachers' knowledge and beliefs about L1 and L2 acquisition, the first area identified above, find that teachers are supportive of L1 use; others, that teachers hold misconceptions about L1 and L2 learning (Rios-Aguilar, Gonzalez Canche, & Moll, 2012; Rivera Malucci, 2009; Song & Samimy, 2015; Swanson et al., 2014; Reeves, 2006). Song and Samimy (2015), for example, investigated 31 secondary content teachers involved in a year-long TESOL teacher education program in Ohio. Most had taught ELs in their classrooms but had limited or no prior EL-training. Researchers found teacher participants' understanding of the importance of language development grew over time: Beliefs moved away from viewing language learning through a behavioral lens, L1 as negatively influencing L2 acquisition, and the role of age in L2 learning as important. Changes in beliefs led to improvement in classroom practices for ELs as well: There was a substantial increase in teacher participants' use of teaching strategies that allowed ELs to use their L1s as a mediation tool for L2 acquisition. Teacher participants attributed changes in their beliefs to their teacher education coursework, action research projects with ELs, and peer coaching. In contrast, from surveys administered to 279 high school teachers in Nebraska, Reeves (2006) found that most participants (83%) would support legislation making English the official language of the U.S. Many (72%) also agreed that EL students should be able to acquire English within two years. Teachers were more split on whether ELs should continue use of their L1s at school: Thirty-nine percent thought that ELs should not speak their L1s at school while 58% thought students' L1 use should continue. It is important to note that the vast majority of teachers (90%) who participated in Reeves' study had received no prior training in how to work with language-minority or EL students.

Several studies compare teachers' knowledge and beliefs about L1 and L2 acquisition by differences in attitudes, experiences, and/or training (Coady et al., 2016; Karabenick & Noda, 2004; Karathanos, 2010; Lee & Oxelson, 2006; Polat & Mahalingappa, 2013). As one example, in their investigation of 69 practicing K-12 teachers in California, Lee and Oxelson (2006) found that teachers who held an ESL and/or BCLAD credential were more likely than their colleagues without these credentials to believe that maintaining their students' L1s promoted academic achievement, to report implementing practices in their classrooms that affirmed students' L1s and cultures, and to think that schools should play a role in L1 maintenance. Teachers who spoke at least two languages were more likely to implement practices that encouraged and affirmed students' L1s and cultures, and felt more strongly that schools should take an active role in supporting L1 maintenance than their monolingual, English-speaking colleagues. Further, teachers who had not received training as language educators thought that learning English should be a priority and that more time and greater exposure to English lead to faster and better English language acquisition. As a second example, Karathanos (2010) investigated 227 K-12 practicing teachers enrolled in an ESL-endorsement distance education program in Kansas. She divided teacher participants into two groups: those with no ESL coursework and those who had completed at least three such courses. Teachers who had completed at least three ESL courses reported implementing a number of instructional practices to a noticeably greater extent than teachers without such preparation: allowing students to use their L1s in the classroom, encouraging ELs to use their L1s in answering questions or writing assignments, pairing or grouping ELs with the same L1s but differing levels of English proficiency, and using L1 instructional resources. However, both groups of teachers identified similar challenges in promoting use of students' L1s

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in their classrooms: Teachers did not feel they had enough time and resources to include students' L1s; expressed concerns about asking EL students to translate for one another and about ELs speaking off-task in their L1s; thought their own lack of proficiency in the L1s of their EL students was an obstacle to communicating with them and involving them in class activities; and were more comfortable supporting certain L1s in their multilingual classes, for example, Spanish over Farsi. Karathanos concluded that many of the perceived barriers identified by teacher participants might be a reflection of their underlying ideological beliefs about teacher-student power relations and/or might be attributed to a lack of knowledge or misconceptions about second language acquisition and effective EL instruction.

Successes and challenges in balancing content and language. Looking at the second area of teaching STEM content learning with English language development more broadly, a long list of studies document teachers' successes in achieving content and language integration (Chval & Chavez, 2011; Deaton et al., 2014; Dong, 2002; Estapa et al., 2016; Fernandes, 2012; Lee, 2004; Moore, 2008; Nasir & Heineke, 2014; Ortega, Luft, & Wong, 2013; Petit, 2013; Smetana & Heineke, 2017; Sowa, 2009; Von Esch & Kavanagh, 2017; Zwiep et al., 2011). As one example, Zwiep et al. (2011) examined 60 elementary teachers who were engaged in a long-term professional development project at three schools in a large urban district in California. Initially, teachers lacked science content knowledge and were uncomfortable with the idea of teaching science. However, by developing and implementing lessons that integrated science inquiry with ELD, they came to see science as integral to language development. Teachers learned to consider the depth and breadth of their EL students' understanding in both content and language. They also learned to make appropriate decisions about which terms and language functions should be front-loaded or scaffolded, without removing the inquiry from their lessons; to see sentence frames as essential but limited scaffolds that failed to display the depth of students' content understanding; and to explore additional measures of student understanding that were not as language dependent, such as assessments that included graphic organizers, pictures, and hands-on activities. Changes in science instruction led to changes in their EL students: Students became excited about and looked forward to science lessons, increased both their oral and written English production in science lessons, and increased their use of English in other content areas and in non-classroom settings as well. As a second example, Von Esch and Kavanagh (2017) studied four preservice elementary teachers' planning, implementation, reflection, revision, and re-teaching of lessons to support the mathematics and language learning of culturally and linguistically diverse students within a teacher residency program. Researchers found that preservice teacher participants learned to identify ways in which mathematics and everyday language intersected with student understanding of the mathematics content of the lesson, made key distinctions between EL students' understanding of the content versus being able to use the language to explain their thinking, planned and implemented instruction to address academic language demands both visually and in teacher talk, and adjusted their use of language in the moment to scaffold their EL students' comprehension.

A long list of studies also document teachers' struggles to integrate STEM content and ELD. Studies of teachers' knowledge and beliefs about the perceived separation of mathematics and language were already introduced in the section on The Nature and Content of STEM Disciplines above (Battey et al., 2013; Bunch et al., 2009; Estapa et al., 2016; Fernandes, 2012;

Hansen-Thomas & Cavagnetto, 2010; McLeman & Fernandes, 2012). As yet another example, Turkan (2016) studied 10 practicing secondary mathematics teachers who had at least five years of experience teaching in schools with a high percentage of ELs. Seven of the 10 conceived of mathematics and language as separate entities. As such, these seven consistently conceived of ELs as needing linguistic support in the form of either linguistic simplification or removal of language demands specific to mathematics altogether.

For those teachers who accept the need to integrate content and language, additional struggles are identified (Coady et al., 2016; de Araujo, 2017; de Araujo et al., 2016; de Araujo, et al., 2015; Gandarà et al., 2005; Harper & de Jong, 2009; Johnson et al., 2016; Lee et al., 2009; Roberts et al., 2017). Coady et al. (2016), for example, found that while their two elementary teacher participants had been trained in and recognized the need to integrate content and language learning, they continued to value content learning over language learning. As such, in their teaching of mathematics (as well as reading), both relied on mere exposure to English and Euro-American cultural experiences rather than explicit instruction in linguistic and cultural norms to meet the needs of their EL students. Both also did little to plan for ELs' linguistic development and cultural learning through differentiated instruction or assessment. Along similar lines but with reverse emphasis, a series of studies conducted by de Araujo and colleagues (de Araujo, 2017; de Araujo et al., 2016; de Araujo, et al., 2015) found that practicing and preservice mathematics teachers prioritized their support of students' language over their mathematical thinking; their focus on their students' label of language learners overshadowed their focus on students as mathematics learners. As a result, teachers constrained their ELs' opportunities to think deeply about mathematical concepts and practices. Additional examples of perceived challenges in integrating language and content include struggles to find enough time both to teach ELs subject matter and ELD, and to address the needs of both ELs and other students (Gandarà et al., 2005); difficulties in differentiating misunderstandings grounded in content versus those grounded in language (Roberts et al., 2017); and failures to consistently use ESL strategies to promote ELD in STEM lessons (Lee et al., 2009).

Before moving on, it is important to note that teachers do not uniformly equate language learning with vocabulary learning (Battey et al., 2013; Brown, Lemmio, Wild, & Zummo, 2017; Bunch et al., 2009; Coady et al., 2016; de Araujo, 2017; Richardson Bruna, Vann, & Escudero, 2007; Smetana & Heineke, 2017; Vomvoridi-Ivanović & Razfar, 2013). Some studies find teachers focus exclusively on the teaching of STEM vocabulary. For example, Richardson Bruna et al. (2007) examined one teacher teaching an English Learner Science course primarily to Latinas/os at a high school in Iowa. Because she focused her instruction on the teaching of vocabulary, she tightly constrained classroom discourse, preventing ELs not only from talking like scientists but thinking like scientists as well. She also did not provide the kinds of explicit instruction in semantic relationships and the opportunities to use linguistic resources students needed for conceptual understanding. In brief, the teacher's simplified understanding of academic language instruction led to simplified science talk in the classroom, which resulted in simplified science learning by her EL students. However, in other studies, STEM teachers move beyond vocabulary to focus on the levels of syntax and discourse as well. For example, Vomvoridi-Ivanović and Razfar (2013) found that the vast majority of their 129 preservice elementary teacher participants moved from a discrete vocabulary orientation for the language used in teaching mathematics towards an embedded discourse approach. A discrete vocabulary

orientation treats mathematics terms as decontextualized entities; an embedded discourse approach frames mathematics terms as nested within activity systems mediated by cultural rules and concrete goals. By participating in an activity that used the context of baseball to highlight the complexities of mathematics discourse, most participants came to realize that using language in real communicative situations focused on meaning-making and problem-solving was more powerful than reviewing vocabulary and having definitions of terms available.

Theme 5: Effective EL Instruction

A myriad of studies provide insight into teachers' knowledge and beliefs about effective instruction for ELs. Findings are organized into four areas from most broad to most specific: (1) facilitating productive student talk, (2) implementing reform-based instruction, (3) implementing culturally responsive instruction, and (4) providing effective scaffolds and supports. The four areas overlap with each other. Given the importance of addressing both content and language when teaching ELs, they also connect to the discussion above on the integration of STEM content learning with English language development. For each area, examples cut across practicing and preservice teachers, mathematics and science disciplines, and expansive to limited pedagogy.

Facilitating productive student talk. A long list of studies examine teachers' knowledge, beliefs, and practices related to the encouragement and facilitation of productive student talk in STEM classrooms. To begin, at least some teachers believe a welcoming and safe classroom community is needed if ELs are to participate and learn (Chval & Chavez, 2011; Deaton et al., 2014; Fernandes, 2014; Harper & de Jong, 2009; Johnson & Bolshakova, 2015; Johnson et al., 2016; Patchen & Cox-Petersen, 2008). In some studies, teachers recognize the importance of engaging their ELs in mathematics or science talk – of creating discourse-rich classrooms using a variety of participation structures, particularly groupwork (Buck et al., 2005; Bunch et al., 2009; Dong, 2002; Johnson et al., 2016; Lee, 2004; McLeman & Fernandes, 2012; Petit, 2013; Vomvoridi-Ivanović & Razfar, 2013). In several other studies, however, teachers appear to ignore the value of student talk, equating discourse with vocabulary, working with ELs in isolation rather than as part of the whole class, or failing to adequately support groupwork (Chval & Pinnow, 2010; Durgunoğlu & Hughes, 2010; Karathanos, 2010; Richardson Bruna et al., 2007). Still other studies identify misconnections within and across views and practices, either that some teachers value and engage their students in talk while others do not or that teachers' beliefs about the need for disciplinary talk only partially translate into their instructional practices (Chval & Chavez, 2011; Coady et al., 2016; Patchen & Cox-Petersen, 2008; Sharkey & Layzer, 2000; Swanson et al., 2014).

Examples at the two ends of this continuum are presented in greater detail here. In terms of valuing student talk, Chval and Chavez (2011) documented how secondary mathematics teachers changed their beliefs and practices as a result of their participation in a professional development opportunity. Initially, teachers thought it acceptable for ELs to work in isolation or participate as a spectator. They also believed that asking ELs to answer questions or present to the whole class made them feel uncomfortable. However, over time, teachers grew to recognize the need to work strategically to build a classroom community that valued ELs' contributions. They began to carefully select ELs' group members to ensure discussions would be productive, and to

identify opportunities for ELs to present their work to the whole class. In contrast, Durgunoğlu and Hughes (2010) presented a relatively dismal picture of their 62 preservice teachers' efforts to engage ELs in productive classroom talk. Preservice teacher participants held neutral attitudes towards their preparedness and effectiveness regarding EL students and registered low scores on their knowledge of EL issues and strategies. Although the four case study preservice teachers included use of cooperative grouping, they regularly failed to support ELs' participation during small group or whole class discussions; there was an implicit understanding that teachers and ELs would leave each other alone. Their supervising teachers provided no guidance on how to better support ELs. Indeed, peers were the only ones to offer ELs any substantive assistance.

Implementing reform-based instruction. As with facilitating productive student talk, teachers' knowledge, beliefs, and practices related to the vision of mathematics and science education put forth by reform documents vary from expansive to limited pedagogy. Some teachers understand and are able to implement reform-based instruction for their EL students, providing invitations to inquiry, engaging them in argumentation, and/or working to deepen their conceptual understanding (Bravo et al., 2014; Johnson et al., 2016**;** Lee et al., 2016; Swanson et al., 2014; Zwiep et al., 2016). Other teachers are found to make uneven progress toward reform-based instruction, adopting some aspects of effective mathematics or science instruction but not others (Bianchini & Brenner, 2010; Carlone et al., 2011; Kang & Zinger, 2017; Lee, 2004; Lee et al., 2009; Santau et al. 2010; Rillero, Koerner, Jimenez-Silva, Merritt, & Farr, 2017). Only a few studies describe teachers as struggling to implement any aspect of reform (de Araujo, 2017; Rodriguez & Berryman, 2002).

Bravo et al. (2014) made clear the impact teacher training can have on teachers' understanding and implementation of reform-based instruction. Researchers investigated 110 preservice teachers pursuing their elementary teaching credential at one of two California teacher education programs of comparable size and focus. The experimental group at both institutions completed a science methods course and integrated teaching practicum experience that provided guidance in teaching reform-based science to culturally and linguistically diverse groups; the control group received instruction about culturally and linguistically diverse students in a separate summer course before they began field placements. By the close of the program, the experimental group held significantly stronger beliefs than the control group about one of five dimensions of reform-based science instruction for ELs: the efficacy of joint productive activity (sharing authority with students for solving authentic problems). Similarly, by the close of the program, the experimental group implemented three of these five practices significantly more often in their science lessons than the control group: attending to language and literacy involved in science, asking questions to elicit higher order thinking, and providing scaffolds to support the learning of abstract scientific concepts.

Implementing culturally responsive pedagogy. A smaller number of studies examine teachers' knowledge, beliefs, and practices related to culturally responsive pedagogy. The vast majority of studies identified document a mix of teachers' views and practices related to integrating culture into instruction. More clearly, in some studies, a subset of teachers recognizes the importance of culture while others do not, while in other studies, teachers embrace some aspects of culturally responsive instruction while ignoring others (Aguirre et al., 2012; Bartell et

al., 2010; Cahnmann & Remillard, 2002; Carlone et al., 2011; Gann, Moseley, & Bonner, 2016; Johnson & Bolshakova, 2015; Lee, 2004; Patchen & Cox-Petersen, 2008; Suriel & Atwater, 2012; Tolbert & Knox, 2016; Turner et al., 2012).

As an example of the former type of study, Johnson and Bolshakova (2015) investigated five middle school science teachers as part of a three-year professional development project on the role of culture in science pedagogy. Two teacher participants resisted the idea that culture was important to integrate into their science instruction; they held deep-seated views of what teaching should be and thought their Latina/o students must conform to expectations in U.S. schools to be successful. One still integrated inquiry into her instruction; the other did not. The three other teacher participants came to see culture as a way to make students feel more welcomed and the science content more meaningful. They tried to transform their classrooms into safe and engaging places for learning, to build relationships with students, to make their content more culturally relevant, and to change their practice to be more inquiry oriented and collaborative. These teachers identified several professional development experiences that enabled their shift in beliefs regarding culture: home visits, learning conversational Spanish, completing a course on culturally relevant pedagogy, and participating in monthly professional development sessions.

As an example of the latter type of study, Patchen and Cox-Petersen (2008) found that their two elementary teacher participants, well known for their efforts to create constructivist science classrooms, were not always able to translate their beliefs into practice. More concretely, both teachers valued students' cultures, experiences, and languages, seeing them as integral to good instruction. Both thought it important to encourage student participation. They worked to establish relationships with their students, provide a safe classroom environment, encourage native language use, and implement groupwork. Both thought it important to elicit and build on student experiences and understanding as well. However, although teachers assessed their students' understanding, they fell short of building on it: They rarely extended students' contributions in any substantive way beyond merely repeating what they said, and regularly used their own examples or analogies to do the work of knowledge transference rather than their students. Further, both teachers used a variety of teaching methods, including visuals, hands-on activities, cooperative learning, and experiments. However, they avoided implementing inquiry and used direct instruction to scaffold academic material. Finally, encouragement for shifts in authority were at the conceptual (teachers' beliefs) rather than structural (teachers' implementation) level; neither teacher introduced nor addressed teacher-student power relationships as part of her instruction. Overall, then, teachers tended to privilege their own positions, perspectives, and practices. As a result of this mismatch between beliefs and practices, students did not have opportunities to actively construct their own science understanding.

Effective scaffolds and supports. Studies of teachers' knowledge, beliefs, and practices regarding the implementation of scaffolds and supports for ELs' content and language learning report findings that range from expansive to mixed. Some teachers recognize the need to support their ELs' engagement in cognitively demanding content by implementing different types of scaffolds (Buck et al., 2005; Bunch et al., 2009; Chval et al., 2015; Deaton et al., 2014; Dong, 2002; Fernandes, 2012; Roberts et al., 2017; Smetana & Heineke, 2017). Examples of appropriate scaffolds include word walls and sentence frames, visuals and realia, multiple representations, modeling, hands-on activities, slower and clearer teacher talk, opportunities for

students to speak both their home language and English, differentiation of instruction and assessments, strategies to support reading and writing, checking for understanding, and peer support. Other teachers' knowledge and beliefs are less expansive: Either teachers meet with varying degrees of success in understanding and implementing types of EL support (Coady et al., 2016; de Araujo et al., 2015); view only a limited number of support as acceptable (Polat & Mahalingappa, 2013; Reeves, 2006); or have limited knowledge of the range of effective supports they can implement (Cho & McDonnough, 2009). Buck et al. (2005) underscored that meeting the needs of EL learners through scaffolds and supports is a challenging and complex endeavor, particularly for beginning teachers.

Theme 6: School, District, State, and Federal Contexts and Policies

I identified only a handful of studies where the primary focus of researchers' investigation of teachers' knowledge and beliefs is on school, district, state, and/or federal policies related to ELs. However, a substantial number of additional studies provide some insight into this theme. For this review, studies were divided into two areas: (1) school and district contexts, and (2) state and federal policies. Collectively, these studies identify both perceived and real, positive and negative impacts of policies on teachers' instruction of ELs.

School and district contexts. Studies that examine teachers' knowledge and beliefs about their school and/or district contexts in relation to EL students span mathematics and science, and practicing and preservice teachers. They were organized along three dimensions: school culture, school and district priorities, and school and district resources. At the outset, it is important to recognize that in their study of 419 teachers at 47 elementary schools with high EL enrollment in Ohio, Rader-Brown and Howley (2014) found that the schools in which teacher participants worked did not heavily influence their reported implementation of reform-based practices.

For the first of these context dimensions, several studies document teachers' perceptions of un/supportive school cultures. Some of these studies document the benefits of generative school climates (Flores, Claeys, Gist, Clark, & Villarreal, 2015; Téllez & Manthey, 2015; Zwiep et al., 2016). As one example, Flores et al. (2015) investigated the beliefs of 100 beginning secondary mathematics and science teachers. They found that teachers' efficacy in teaching ELs was, in part, shaped by the campus climate administrators created. Teachers were more likely to remain teaching at a particular school and to report high job satisfaction if they felt supported by the administration. As a second example, in a study of 578 elementary teachers of ELs, Téllez and Manthey (2015) found that strong teacher self-efficacy for ELs was related to collective efficacy (efficacy at the school level) and other school climate measures, even after controlling for the level of ethnic diversity of the school, the percentage of ELs in teachers' classrooms or school, and teachers' years of experience at a specific school. Teachers who worked in schools with a positive climate developed a strong belief in their schools' practices and programs for ELs. Schools with strong collective efficacy tended also to have their EL practices and programs perceived as strong. Discussion around ELD seemed to be related to a school-wide strategy: Many schools asked teachers to engage in professional learning communities where ELD was a primary focus. In short, Téllez and Manthey found that collective efficacy, school culture and

focus, and perceptions of school-wide effective instruction and programs for ELs were associated with one another.

Other studies identify mixed or negative outcomes of school cultures (Buxton, 2005; Harklau, 2000; Kang & Zinger, 2017; Karabenick & Noda, 2004; Lee et al., 2009; Rodriguez & Berryman, 2002). As an example of the former case, in Lee et al.'s (2009) study of 221 elementary teachers from 15 schools in a large urban school district in the Southeast, teachers thought that their principal supported science instruction and that their teacher colleagues collaborated in teaching science; they perceived school personnel as a minor barrier to effective EL instruction. However, teachers also reported infrequently sharing with colleagues teaching materials and activities, assessment tasks, student work, or stories about teaching science. They also rarely discussed inclusion of girls, special education students, EL students, or culturally diversity students. As an example of the latter case, Kang and Zinger, (2017) carefully documented two of six beginning secondary science teachers' struggles to develop reform-based, or what they termed expansive pedagogy, during their first year of teaching. For Mary, the instructional culture, curriculum, and type and nature of colleagues' support at her underresourced school constrained her opportunities to experiment with expansive pedagogy. For Brenda, although she had much more flexibility at her school, she was overwhelmed with planning and had no science teacher colleagues. As such, she neither moved forward with her development of expansive pedagogy nor returned to the school after maternity leave.

For the second dimension of school and district contexts, several studies examine school and district priorities related to the teaching of ELs (Cahnmann & Remillard, 2002; Johnson et al., 2016; Nasir & Heineke, 2014; Ortega et al., 2013). As with studies of school culture, some of these studies focus on how individual teachers perceive such priorities; some, on teachers as a collective. As an example of the former, the beginning science teacher studied by Ortega et al. (2013) shifted to a more teacher-centered orientation for instruction in her second year to accommodate school priorities: She was asked by the principal to prepare her ELs for the upcoming state assessments in reading and writing. In year three, this teacher moved to a new school with different priorities and worked with a supportive colleague. As a result, she shifted back to implementing more inquiry-focused instruction. As an example of the latter, Johnson et al. (2016) investigated a long-term professional development project to transform science teacher quality and its associated impact on science achievement for diverse students. The professional development was conducted with teachers from four middle schools and six elementary schools in a large urban district in the Southwest that served a predominantly Latina/o EL student population. However, real and perceived administrative pressures and district policies to focus instructional time on reading and mathematics constrained elementary teachers' participation in the professional development program. Most of the teachers at three of the six elementary schools limited their science instruction to only one or two days per week.

Finally, STEM teachers thought that insufficient school and district resources negatively impacted their instruction of ELs; this seems an obvious finding (Ganchorre & Tomanek, 2012; Gandarà et al., 2005; Karabenick & Noda, 2004; Lee et al., 2009; Téllez & Manthey, 2015). For example, Karabenick and Noda (2004) surveyed 729 teachers in a suburban district in the Midwest, a district impacted by high numbers of immigrant and refugee ELs. Approximately half of teachers believed that the school and district supported the concept of bilingual and ESL education for EL students, but that bilingual and EL services and resources were insufficient. It is

important to add that the preservice mathematics and science teachers in Ganchorre and Tomanek's (2012) study thought their teaching in underresourced schools would help to re-balance the limited access to material and human resources ELs in these school received. Similarly, practicing teachers in Téllez and Manthey's (2015) study who believed their school promoted effective EL instruction also believed they could successfully work to overcome student and family characteristics beyond their control.

State and federal policies. A substantial number of studies provide insight into STEM teachers' knowledge and beliefs about three dimensions of state and federal policies related to ELs: content standards, language instruction, and assessment and accountability. For content standards, researchers find teachers hold positive and neutral knowledge and beliefs; for language instruction mandates, positive, neutral, and negative knowledge and beliefs; and for assessment and accountability requirements, negative knowledge and beliefs only. Most of these studies speak to the third of these policy dimensions: assessment and accountability. Most focus on practicing teachers.

As suggested above, few studies examine teachers' knowledge and beliefs about content standards in relation to teaching ELs (Coady et al., 2016; Shaver, Cuevas, Lee, & Avalos, 2007; Smetana & Heineke, 2017; Swars & Chestnutt, 2016). Researchers from three studies (Shaver et al., 2007; Smetana & Heineke, 2017; Swars & Chestnutt, 2016) found that practicing and preservice teachers viewed content standards as beneficial and purposeful, as a way to positively influence students' language development and academic achievement. Researchers from a fourth study (Coady et al., 2016) found teachers expressed a neutral view of standards: Teachers acknowledged having a certain degree of flexibility in their classroom instruction as long as their students met the standards set by the Florida Department of Education. No studies were identified where teachers expressed negative views of content standards.

As with content standards, a small number of studies speak to teachers' knowledge and beliefs about language policies (Battey et al., 2013; Rios-Aguilar et al., 2012; Smetana & Heineke, 2017). In one study, Smetana and Heineke (2017) documented preservice teachers' perceptions of positive benefits of language policies: They thought Illinois' policy mandates requiring public schools to document ELs' language proficiency and to provide bilingual support in classrooms helped teachers to discern and address their ELs' language needs. In a second study, Battey et al. (2013) found elementary teachers thought such policies had a neutral effect on their instruction. Although Arizona policy mandates tracking students by English language proficiency and separating English language instruction from subject matter for EL students, teacher participants viewed the impact of these policies on their mathematics instruction as minimal. And in a third study, also set in Arizona, Rios-Aguilar et al. (2012) found that the majority of their teacher participants thought such policies negatively affected their teaching of ELs. Although required to implement a 4-hour ELD block to help ELs become fluent in English in one year, at least 50% of teacher participants considered the block to provide little or no acceleration in English, to inadequately prepare ELs for grade-level academic content, to be less effective than other curricula in preparing ELs academically, and to constrain ELs' learning by separating them from their English-speaking peers, among other concerns.

In contrast, many more studies examine teachers' knowledge and beliefs about assessment and accountability requirements (Bianchini & Brenner, 2010; Brown & Lee, 2012; Cho &

McDonnough, 2009; Gandarà et al., 2005; Harper & de Jong, 2009; Johnson et al., 2016; Lee et al., 2009; Lee & Oxelson, 2006; Shaver et al., 2007). No studies were found where teachers express positive or neutral views of state-mandated tests. I note that a possible positive outcome of state assessments was identified by a group of researchers, rather than teachers. Santau et al. (2010) thought differences in teacher participants' science knowledge and practices between Grades 3 and 5 might be attributed to the administration of a state-wide science assessment; they proposed that 5th-grade teachers might better recognize the importance of knowing science than 3rd-grade teachers because science is tested by the state in 5th grade. In some studies that document teachers' negative views of assessment and accountability pressures, teachers argue that state-mandated tests usurp their power and authority. The teachers in Shaver et al.'s (2007) study, for example, expressed concern that such tests could be used to hold back or promote a student, irrespective of the teacher's recommendation, as well as to grade schools by student performance. In other studies, teachers note that such tests constrain their curricular and instructional practices. The teachers in Harper and de Jong's (2009) study, also from Florida, thought the federal No Child Left Behind Act had both narrowed and homogenized their curriculum and instruction, because they needed to ensure students demonstrated progress on those few content areas tested. In still other studies, teachers view such tests as negatively impacting EL students themselves. The teachers in Gandarà et al.'s (2005) study, for example, thought California's standardized tests failed to adequately assess ELs' academic achievement, and thus, actively discouraged them from succeeding; the tests conveyed to ELs the message that they were far below basic. Finally, in one study conducted by Brown and Lee (2012), three exemplary preK teachers in Texas thought they were able to adequately address their EL students' needs *despite* the high-stakes accountability context.

Theme 7: The Need for Teacher Education and Professional Development Focused on ELs

At the inservice level, a handful of studies examine practicing teachers' knowledge and beliefs about the need for professional development opportunities focused on ELs (Cho & McDonnough, 2009; Gandarà et al. (2005; Reeves, 2006). Those few identified suggest that the majority of teacher participants think it important to receive additional training. Gandarà et al. (2005), for example, surveyed 5,300 practicing K-12 teachers in California. Researchers found that professional development made a difference in how confident teachers felt meeting the challenges of teaching ELs. This was particularly true of inservice presented by or at a college or university. Elementary teachers identified professional development on ELD as most useful and secondary teachers, professional development on cultural issues and strategies for teaching academic subjects. Both groups thought professional development on linguistics too theoretical, and thus, the least useful. Both groups also requested more time to observe and collaborate with their colleagues as a central part of professional development. Over the last five years, however, many teachers had participated in little or no professional EL training and the quality of the training received was uneven. Similarly, but on a much smaller scale, Cho and McDonnough (2009) surveyed 33 practicing science teachers from six ESL-center high schools in Virginia. The majority of teachers in their study selected EL professional development opportunities as the second most important type of support they would like to receive, after bilingual instructional

materials. They rated as important training in EL instructional strategies, second language development, EL learner variables, and cultural understanding.

I found no studies that examine teachers' knowledge and beliefs about the need to learn about ELs as part of their teacher education program. However, in a number of studies on preservice or practicing teachers, researchers compare teachers' knowledge and beliefs by the type of bilingual, ESL, or EL certification they are pursuing or have received as part of their teacher preparation (Gandarà et al., 2005; Karathanos, 2010; Lee & Oxelson, 2006; Rios-Aguilar et al., 2012; Tolbert & Knox, 2016). These studies find that training in bilingual, ESL, or EL instruction has a positive impact on teachers' knowledge and beliefs about teaching ELs. As one example, in the study by Gandarà et al. (2005) discussed several times above, researchers found that the beliefs of teachers with a BCLAD credential differed both from teachers with a CLAD credential and from those with no EL credential. BCLAD teachers rated their abilities to teach ELs in each of six categories significantly higher than teachers without an EL certification and in five of the six categories higher than teachers with a CLAD credential. Teachers with a CLAD credential rated themselves significantly more competent in four of the six areas than those with no EL credential. Indeed, teachers with any professional development that focused on teaching ELs rated themselves significantly more able to teach EL students across all six categories of instruction than teachers with no such training.

The Impact of Teachers' Knowledge and Beliefs on EL Student Outcomes

Many of the studies reviewed here discuss *possible* implications for EL students in light of those aspects of teachers' knowledge and beliefs identified. However, fewer studies present actual data about how teachers' knowledge and beliefs impact EL student outcomes. These latter studies cut across practicing and preservice teachers, and mathematics and science classrooms. Collectively, they speak to teachers' impact on student self-efficacy, interest, and affiliation in mathematics or science; expectations for, tracking into, and cognitively demanding work assigned in courses; interactions with teachers and peers; and gains in learning. It is important to note that no one aspect of teachers' knowledge or beliefs uniformly leads to positive EL student outcomes. For example, teachers' recognition of the importance of high expectations does not always translate into EL STEM learning (e.g., Cahnmann & Remillard, 2002; Buxton, 2005; Rodriguez & Berryman, 2002). As such, studies of teachers' knowledge, beliefs, and practices were clustered into three areas: (1) those that identify positive outcomes for ELs, (2) those that report negative consequences, and (3) those that present mixed results.

Studies of teachers' knowledge and views that led to positive EL student outcomes. Some of the studies reviewed document the translation of teachers' knowledge and beliefs into EL students' successes in mathematics or science classrooms (Chval et al., 2015; Dong, 2002; Hammond, 2001; Johnson et al., 2016; Lewis et al., 2012). As one example, Dong (2002) conducted a yearlong study of three teachers who were recognized as successful with EL students. All three taught sheltered biology courses to EL students, who came from 15 countries and spoke 14 languages, at one of two high schools in New York City. Dong found that these teachers believed in the abilities of their EL students, valued their experiences and cultures, and thought integrating language development with science important. Two major linguistic and

cognitive benefits were identified for EL students as a result: ELs made more connections between science learning in school and in real life, and they reduced their anxiety to speak. As a second example, Johnson et al. (2016) found that, over time, their Grades 4 though 8 teachers changed their beliefs about ELs, the importance of attending to student and classroom cultures, the relationship between science and language, and what counts as effective science instruction as well as made significant improvements in their lesson design, subject matter content, lesson implementation, and classroom culture. In turn, students engaged in more science discourse with peers and reported an increase in their interest in science. Students, particularly EL students, also improved their scores on the state science assessment. As a third example, Lewis et al. (2012) studied almost 1,500 5th and 6th grade Latina/o students in one school district in Southern California. Researchers found that teachers with caring attitudes bolstered students' self-efficacy in mathematics, which positively impacted their test scores. Indeed, teacher caring was more important for ELs than for their English-fluent Latina/o peers: (a) the magnitude between caring and self-efficacy was more pronounced and (b) the impact of caring went beyond impacting self-efficacy to achievement as well.

Studies of teachers' knowledge and views that led to negative EL student outcomes. Other studies document the ways that teachers' knowledge and beliefs limit ELs' opportunities to engage and excel in STEM (Coady et al., 2016; Richardson Bruna et al., 2007; Rodriguez & Berryman, 2002; Sharkey & Layzer, 2000). As one example, Sharkey and Layzer (2000), studied 35 ESL and content-area teachers and their approximately 50 EL students from diverse ethnicities at one public high school in Pennsylvania. Researchers found that teachers valued ELs' hard work and motivation over their mastery of content, which was often neither facilitated nor checked. Teachers' knowledge and beliefs resulted in ELs' placement in lower track classes, limited support for ELs in classroom interactions, and low expectations for ELs' learning of content. As such, ELs were denied access to academic supports and adequate college preparation, even though this denial was cloaked in teachers' well-meaning concern. As a second example, Rodriguez and Berryman (2002) investigated one teacher's efforts to teach against the grain – to hold high expectations for and regularly assign homework and real-world projects to his EL students. This preservice teacher, Chad, taught science to Latina/o ELs at a high school in the Southwest. However, because the other teachers at his school collectively shared low expectations for students, Chad found that his students resisted his attempts to challenge them: They responded with little effort and with strategies to complete the least amount of work possible. Researchers emphasized that school communities must work collectively and consistently to shift both teachers and students' expectations from low to high.

Studies of teachers' knowledge and views that led to mixed EL student outcomes. Still other studies report how teachers' knowledge and beliefs both promote and constrain EL student outcomes (Buck et al., 2005; Buxton, 2005; Cahnmann & Remillard, 2002; Carlone et al., 2011; Harklau, 2000; Swanson et al., 2014). For example, Buxton (2005) investigated a public mathematics and science magnet school located in a major urban center in the Southeast U.S. He identified two groups of teachers and students: those who stayed and those who left (usually within two to three years). Teachers who stayed held high expectations for their culturally and linguistically diverse students, instilling in them the qualities of an educated

person. In turn, students who stayed learned to negotiate shared understandings of achievement and thought themselves adequately prepared to attend college. In contrast, teachers who left were more likely to view students' lives as culturally deficit and expectations for student performance as unrealistically high. Similarly, those students who decided to part ways with the school thought that the teachers were unsympathetic to their personal circumstances, the expectations were unreasonable, the costs of attending outweighed those of their home school, and the science imposed was Western. As a second example, in a study by Buck et al. (2005), three researchers worked with one beginning science teacher to conduct a feminist action research project centered on the teaching and learning of human biology and health. The beginning teacher taught 6th-grade science at a middle school in the Midwest; she had five ELs of diverse backgrounds in her class. The teacher came to see that her EL students could contribute not only rich cultural experiences but rich scientific skills as well. Her EL students' engagement in and understanding of human biology increased as a result. However, differences in learning between EL and non-EL students persisted: At the end of each of three units of study, EL students' understanding neither matched that of their non-EL peers nor the research team and district's expectations for all students. As a third example, this one at the elementary school level, Carlone et al. (2011) investigated two 4th-grade science teachers and their classrooms in one district in the Southeast. Both teachers were widely recognized for their success in teaching culturally and linguistically diverse students reform-based science. However, because the two teachers held different conceptions of what it meant to do science (e.g., emphasizing the importance of providing right answers versus asking thoughtful questions), the diverse students in one teacher's classroom liked and did well in science, but did not affiliate with it.

Limitations

This literature review is limited in a number of ways; three limitations are discussed here. One limitation is that it was challenging to identify definitive findings as there were substantial differences in the knowledge and beliefs held by teacher participants both within a given study and across studies. As one example, although studies of relatively large numbers of teachers using surveys, interviews, and/or written responses find teachers with bilingual and/or ESL credentials to have more positive knowledge, beliefs, and practices compared to other types of teachers (e.g., Gandarà et al., 2005; Lee et al., 2009, Tolbert & Knox, 2016), smaller, more in-depth studies find such teachers can still hold deficit views and constrain opportunities. De Araujo (2017) studied the beliefs and practices of three, ESL-certified teachers who taught a majority of Latina/o ELs at one of two Title I high schools. She found that teachers' unproductive beliefs about ELs – their views of ELs as a homogeneous group with low language and mathematics proficiency – translated into selecting mathematics tasks that were repetitive and procedure-focused, lacked opportunities for communication, and were devoid of context. As such, even though these teachers were ESL-certified, they limited their ELs' opportunities to engage in high-quality, cognitively demanding mathematics. A second example comes from studies that examine the impact of teachers' years of experience on their knowledge and beliefs about ELs. While Gandarà et al. (2005) found that the more years that teachers worked with ELs, the more highly they rated their instructional abilities, Lee and Oxelson (2006) found that teachers' years of experience had no effect on their beliefs about L1 use and maintenance, and

Rader-Brown and Howley (2004), that teachers' years of experience working with ELs negatively impacted their attitudes toward them.

A second limitation is that data presented in a given study can be interpreted differently from that presented by researchers. As one example, in Deaton et al.'s (2014) study of six elementary science teachers, although teachers' deficit thinking pervaded findings, researchers failed to label them as such. Examples of deficit-based knowledge and beliefs presented without comment included a teacher's attempts to value students' participation *while teaching them things they lacked about schooling* and teachers' views of ELs' parents *as lacking the ability to provide homework support, lacking experiences in science, and lacking proficiency in English*. As a second example, none of the studies used in this review to examine teachers' understanding of the positioning of language in the nature of mathematics explicitly identify mathematics' nature as a topic of focus (see again Battey et al., 2013; Bunch et al., 2009; Fernandes, 2012; Hansen-Thomas & Cavagnetto, 2010; McLeman & Fernandes, 2012).

Further, it is important to recognize that a number of scholars question the usefulness of research that examines teachers' knowledge and beliefs absent of what they do in practice. Grossman, Hammerness, and McDonald (2009) argued that teacher educators should move away from a focus on what teachers need to know "to attend to the clinical aspects of practice and experiment with how best to help novices develop skilled practice" (p. 274). Similarly, Ball and Forzani (2009) recommended shifting focus from what teachers know and believe to what they do. "This does not mean that knowledge does not matter," they clarified, "but rather, that the knowledge that counts for practice is that entailed by the work" (p. 503). Over half of the studies cited in this review examine knowledge and beliefs in interaction with teaching tasks or classroom practices.

Conclusion

Clearly, more research on STEM teachers' knowledge and beliefs about ELs is needed. As implied in the Limitations section above, researchers might begin by attempting to reach greater consensus about what counts as productive knowledge, beliefs, and practices for ELs. They should then work to fill the many gaps in the research literature. More studies are needed that trace STEM teachers' knowledge and beliefs through their instructional practices to EL student outcomes. More studies are needed that attempt comparisons – to better determine which aspects of teachers' knowledge and beliefs; school, district, and state policies; and/or teacher education and professional development are most crucial to enacting effective EL instruction. More studies that examine teachers' knowledge and beliefs about ELs at the preK level or in engineering education are needed as well. Given that the number of ELs in U.S. classrooms continues to increase, researchers, teacher educators, policy makers, and teachers themselves need to intensify their efforts if we are to reach the goal of providing all students with a reform-based STEM education.

References

Aguirre, J. M., Zavala, M., & Katanyoutanant, T. (2012). Developing robust forms of pre-service teachers' pedagogical content knowledge through culturally responsive mathematics

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teaching analysis. *Mathematics Teacher Education and Development, 14*(2), 113-136.
Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education, 60*(5), 497–511. doi:10.1177/0022487109348479
Bartell, T. G., Foote, M. Q., Aguirre, J. M., Roth McDuffie, A., Drake, C., & Turner, E. E. (2010). Preparing preK-8 teachers to connect children's mathematical thinking and community based funds of knowledge. In P. Brosnan, D. B. Erchick, & L. Flevares (Eds.). *Proceedings of the 32nd annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1183-1191). Columbus, OH: The Ohio State University.
Battey, D., Llamas-Flores, S., Burke, M., Guerra, P., Kang, H. J., & Kim, S. H. (2013). ELL policy and mathematics professional development colliding: Placing teacher experimentation within a sociopolitical context. *Teachers College Record, 115*(6), 1-44.
Bianchini, J. A., & Brenner, M. E. (2010). The role of induction in learning to teach toward equity: A study of beginning science and mathematics teachers. *Science Education, 94*(1), 164-195.
Bravo, M. A., Mosqueda, E., Solís, J. L., & Stoddart, T. (2014). Possibilities and limits of integrating science and diversity education in preservice elementary teacher preparation. *Journal of Science Teacher Education, 25*(5), 601-619. doi:10.1007/s10972-013-9374-8
Brown, B. A., Lemmio, C., Wild, A., & Zummo, L. (2017). *Understanding beyond the words: How language and ideology impact teachers' understanding of students' knowledge*. Paper presented at the meeting of NARST, San Antonio, TX.
Brown, C. P., & Lee, J. E. (2012). How to teach to the child when the stakes are high: Examples of implementing developmentally appropriate and culturally relevant practices in prekindergarten. *Journal of Early Childhood Teacher Education, 33*(4), 322-348. doi:10.1080/10901027.2012.732665
Buck, G., Mast, C., Ehlers, N., & Franklin, E. (2005). Preparing teachers to create a mainstream science classroom conducive to the needs of English-language learners: A feminist action research project. *Journal of Research in Science Teaching, 42*(9), 1013–1031. doi:10.1002/tea.20085
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. doi:10.3102/0091732X12461772
Bunch, G. C., Aguirre, J. M., & Téllez, K. (2009). Beyond the scores: Using candidate responses on high stakes performance assessment to inform teacher preparation for English learners. *Issues in Teacher Education, 18*(1), 103-128.
Burant, T. J., Chubbuck, S. M., & Whipp, J. L. (2007). Reclaiming the moral in the dispositions debate. *Journal of Teacher Education, 58*(5), 397-411. doi:10.1177/0022487107307949
Buxton, C. A. (2005). Creating a culture of academic success in an urban science and math magnet high school. *Science Education, 89*(3), 392–417. doi:10.1002/sce.20057
Buxton, C. A., Carlone, H. B., & Carlone, D. (2005). Boundary spanners as bridges of student and school discourses in an urban science and mathematics high school. *School Science and Mathematics, 105*(6), 302–312. doi:10.1111/j.1949-8594.2005.tb18131.x

Cahnmann, M. S., & Remillard, J. T. (2002). What counts and how: Mathematics teaching in culturally, linguistically, and socioeconomically diverse urban settings. *The Urban Review, 34*(5), 179-204. doi:10.1023/A:1020619922685

Carlone, H. B., Haun-Frank, J., & Webb, A. (2011). Assessing equity beyond knowledge- and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *Journal of Research in Science Teaching, 48*(5), 459–485. doi:10.1002/tea.20413

Cho, S., & McDonnough, J. T. (2009). Meeting the needs of high school science teachers in English language learner instruction. *Journal of Science Teacher Education, 20*(4), 385-402. doi:10.1007/s10972-009-9136-9

Chval, K. B., & Chavez, O. (2010/2011). Designing math lessons for English language learners. *Mathematics Teaching in the Middle School, 17*(5), 261-265. http://www.jstor.org/stable/10.5951/mathteacmiddscho.17.5.0261

Chval, K. B., & Pinnow, R. J. (2010). Pre-service teachers' assumptions about Latino/a English language learners in mathematics. *Teaching for Excellence and Equity in Mathematics, 2*(1), 6-13.

Chval, K. B., Pinnow, R. J., & Thomas, A. (2015). Learning how to focus on language while teaching mathematics to English language learners: A case study of Courtney. *Mathematics Education Research Journal, 27*(1), 103-127. doi:10.1007/s13394-013-0101-8

Coady, M. R., Harper, C., & de Jong, E. J. (2016). Aiming for equity: Preparing mainstream teachers for inclusion or inclusive classrooms? *TESOL Quarterly, 50*(2), 340-356. doi:10.1002/tesq.223

de Araujo, Z. (2017). Connections between secondary mathematics teachers' beliefs and their selection of tasks for English language learners. *Curriculum Inquiry*. Advanced online publication. doi:10.1080/03626784.2017.1368351

de Araujo, Z., I, J. Y., Smith, E., & Sakow, M. (2015). Preservice teachers' strategies to support English learners. In T. G. Bartell, K. N. Bieda, R. T. Putnam, K. Bradfield, & H. Dominguez (Eds.), *Proceedings of the 37th annual meeting for the North American Chapter for the Psychology of Mathematics Education* (pp. 648–655). East Lansing, MI.

de Araujo, Z., Smith, E., & Sakow, M. (2016). Reflecting on the dialogue regarding the mathematics education of English learners. *Journal of Urban Mathematics Education, 9*(2), 33-48.

Deaton, C. C. M., Deaton, B., & Koballa, T. (2014). Teachers' awareness of their diverse classrooms: The nature of elementary teachers' reflections on their science teaching practice. *Action in Teacher Education, 36*(3), 211-233. doi:10.1080/01626620.2014.917363

Dong, Y. R. (2002). Integrating language and content: How three biology teachers work with non-English speaking students. *International Journal of Bilingual Education and Bilingualism, 5*(1), 40-57. doi:10.1080/13670050208667745

Durgunoğlu, A. Y., & Hughes, T. (2010). How prepared are the U. S. preservice teachers to teach English language learners? *International Journal of Teaching and Learning in Higher Education, 22*(1), 32-41.

Estapa, A., Pinnow, R. J., & Chval, K. B. (2016). Video as a professional development tool to support novice teachers as they learn to teach English language learners. *The New Educator, 12*(1), 85-104. doi:10.1080/1547688X.2015.1113350

Fernandes, A. (2012). Mathematics preservice teachers learning about English language learners through task-based interviews and noticing. *Mathematics Teacher Educator, 1*(1), 10-22. doi:10.5951/mathteaceduc.1.1.0010

Flores, B., Claeys, L., Gist, C., Clark, E., & Villarreal, A. (2015). Culturally efficacious mathematics and science teacher preparation for working with English learners. *Teacher Education Quarterly, 42*(4), 3-31. Retrieved from http://www.jstor.org/stable/teaceducquar.42.4.3

Flores, B. B., Hernández, A., García, C. T., & Claeys, L. (2011). Teacher academy induction learning community: Guiding teachers through their zone of proximal development. *Mentoring & Tutoring: Partnership in Learning, 19*(3), 365-389. doi:10.1080/13611267.2011.597124

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. doi:10.1007/s10972-011-9263-y

Gandarà, P., Maxwell-Jolly, J., Driscoll, A. (2005). *Listening to teachers of English language learners: A survey of California teachers' challenges, experiences, and professional development needs*. Berkeley, CA: Policy Analysis for California Education.

Gann, L., Bonner, E. P., & Moseley, C. (2016). Development and validation of the mathematics teachers' beliefs about English language learners survey (MTBELL). *School Science and Mathematics, 116*(2), 83–94. doi:10.1111/ssm.12157

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice, 15*(2), 273-289. doi:10.1080/13540600902875340

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. doi:10.1002/tea.1043

Hansen-Thomas, H., & Cavagnetto, A. (2010). What do mainstream middle school teachers think about their English language learners? A tri-state case study. *Bilingual Research Journal, 33*(2), 249-266. doi:10.1080/15235882.2010.502803

Harklau, L. (2000). From the "Good kids" to the "worst": representations of English language learners across educational settings. *TESOL Quarterly, 34*(1), 35–67. doi:10.2307/3588096

Harper, C. A., & de Jong, E. J. (2009). English language teacher expertise: The elephant in the room. *Language and Education, 23*(2), 137-151. doi:10.1080/09500780802152788

Harré, R., & van Langenhove, L. (Eds.). (1999). *Positioning theory: Moral contexts of intentional action*. Oxford, UK: Blackwell Publishers.

Jackson, C., & Roberts, S. A. (2017). Dimensions of equity within preservice teachers' responses to equity quotations. *Teaching for Excellence and Equity in Mathematics, 8*(1), 6-14.

Johnson, C. C., & Bolshakova, V. L. J. (2015). Moving beyond "those kids": Addressing teacher beliefs regarding the role of culture within effective science pedagogy for diverse learners. *School Science and Mathematics, 115*(4), 179-185. doi:10.1111/ssm.12120

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Johnson, C. C., Bolshakova, V. L. J., & Waldron, T. (2016). When good intentions and reality meet: Large-scale reform of science teaching in urban schools with predominantly Latino ELL students. *Urban Education, 51*(5), 476-513. doi:10.1177/0042085914543114

Kang, H., & Zinger, D. (2017, April). *Promoting rigorous and responsive science teaching with well-prepared beginners.* Paper presented at the meeting of the American Educational Research Association, San Antonio, TX.

Karabenick, S. A., & Noda, P. A. C. (2004). Professional development implications of teachers' beliefs and attitudes toward English language learners. *Bilingual Research Journal, 28*(1), 55-75. doi:10.1080/15235882.2004.10162612

Karathanos, K. A. (2010). Teaching English language learner students in US mainstream schools: Intersections of language, pedagogy, and power. *International Journal of Inclusive Education, 14*(1), 49-65. doi:10.1080/13603110802504127

Lee, O. (2004). Teacher change in beliefs and practices in science and literacy instruction with English language learners. *Journal of Research in Science Teaching, 41*(1), 65-93. doi:10.1002/tea.10125

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. doi:10.1002/tea.20198

Lee, O., Maerten-Rivera, J., Buxton, C., Penfield, R., & Secada, W. G. (2009). Urban elementary teachers' perspectives on teaching science to English language learners. *Journal of Science Teacher Education, 20*(3), 263-286. doi:10.1007/s10972-009-9133-z

Lee, O., Llosa, L., Jiang, F., Haas, A., O'Connor, C., & Van Booven, C. D. (2016). Elementary teachers' science knowledge and instructional practices: Impact of an intervention focused on English language learners. *Journal of Research in Science Teaching, 53*(4), 579–597. doi:10.1002/tea.21314

Lee, J. S., & Oxelson, E. (2006). "It's not my job": K–12 teacher attitudes toward students' heritage language maintenance. *Bilingual Research Journal, 30*(2), 453-477. doi:10.1080/15235882.2006.10162885

Lewis, J. L., Ream, R. K., Bocian, K. M., Cardullo, R. A., Hammond, K. A., & Fast, L. A. (2012). Con carino: Teacher caring, math self-efficacy, and math achievement among Hispanic English learners. *Teachers College Record, 114*(7), 1-42.

Llosa, L., Lee, O., Jiang, F., Haas, A., O'Connor, C., Van Booven, C. D., & Kieffer, M. J. (2016). Impact of a large-scale science intervention focused on English language learners. *American Educational Research Journal, 53*(2), 395-424. doi:10.3102/0002831216637348

McLeman, L., & Fernandes, A. (2012). Unpacking preservice teachers' beliefs: A look at language and culture in the context of the mathematics education of English learners. *Journal of Mathematics Education, 5*(1), 121–135.

Moore, F. M. (2008). The role of the elementary science teacher and linguistic diversity. *Journal of Elementary Science Education, 20*(3), 49-61.

Mosqueda, E., & Téllez, K. (2008). Teachers' attributions of language proficiency, mathematics achievement, and school context measures: An exploratory study. In O. Figueras, J. L.

Cortina, S. Alatorre, T. Rojano, & A. Sepúlveda (Eds.), *Proceedings of the Joint Meeting of PME 32 and PME-NA XXX* (Vol. 3, pp. 415-421). México: Cinvestav-UMSNH.

Nasir, A., & Heineke, A. J. (2014). Teacher candidates and Latina/o English learners at Fenton elementary school: The role of early clinical experiences in urban teacher education. *Journal of the Association of Mexican American Educators, 8*, 60–71.

National Academies of Sciences, Engineering, and Medicine. (2017). *Promoting the educational success of children and youth learning English: Promising futures*. Washington, DC: The National Academies Press.

National Center for Education Statistics. (2016). *English language learners in public schools*. Retrieved from https://nces.ed.gov/programs/coe/indicator_cgf.asp

National Governors Association Center for Best Practices, & Council of Chief State School Officers. (2010). *Common core state standards for mathematics*. Retrieved from http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Retrieved from http://www.nextgenscience.org/next-generation-science-standards

Ortega, I., Luft, J. A., & Wong, S. S. (2013). Learning to teach inquiry: A beginning science teacher of English language learners. *School Science and Mathematics, 113*(1), 29-40. doi:10.1111/j.1949-8594.2013.00174.x

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332. doi:10.3102/00346543062003307

Patchen, T., & Cox-Petersen, A. (2008). Constructing cultural relevance in science: A case study of two elementary teachers. *Science Education, 92*(6), 994-1014. doi:10.1002/sce.20282

Pettit, S. K. (2013). Teachers' and students' beliefs about ELLs in mainstream mathematics classrooms. *Journal of Contemporary Research in Education, 1*(3), 130-143.

Polat, N., & Mahalingappa, L. (2013). Pre- and in-service teachers' beliefs about ELLs in content area classes: A case for inclusion, responsibility, and instructional support. *Teaching Education, 24*(1), 58-83. doi:10.1080/10476210.2012.713930

Rader-Brown, L. L., & Howley, A. (2014). Predictors of the instructional strategies that elementary school teachers use with English language learners. *Teachers College Record, 116*(5), 1-34.

Reeves, J. (2006). Secondary teacher attitudes toward including English-language learners in mainstream classrooms. *The Journal of Educational Research, 99*(3), 131-142. http://www.jstor.org/stable/27548123

Richardson Bruna, K., Vann, R., & Escudero, M. P. (2007). What's language got to do with it?: A case study of academic language instruction in a high school "English learner science" class. *Journal of English for Academic Purposes, 6*(1), 36-54. doi:10.1016/j.jeap.2006.11.006

Rillero, P., Koerner, M., Jimenez-Silva, M., Merritt, J., & Farr, W. J. (2017). Developing teacher competencies for problem-based learning pedagogy and for supporting learning in language-minority students. *Interdisciplinary Journal of Problem-Based Learning, 11*(2). https://doi.org/10.7771/1541-5015.1675

Rios-Aguilar, C., Gonzalez Canche, M. S., & Moll, L. C. (2012). A study of Arizona's teachers of English language learners. *Teachers College Record, 114*(9), 1-33.

Rivera Malucci, M. S. (2009). Language experience narratives and the role of autobiographical reasoning in becoming an urban science teacher. *Cultural Studies of Science Education, 6*(2) 413-434. doi:10.1007/s11422-011-9323-9

Roberts, S., Bianchini, J. A., Lee, J. S., Hough, S., & Carpenter, S. (2017). Developing an adaptive disposition for supporting English language learners in science: A capstone science methods course. In A. W. Oliveira & M. H. Weinburgh (Eds.), *Science teacher preparation in content-based second language acquisition* (pp. 79-96). Dordrecht, the Netherlands: Springer.

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. doi:10.3102/000283120390041017

Rosebery, A. S., & Warren, B. (Eds.). (2008). *Teaching science to English language learners: Building on students' strengths.* Arlington, VA: NSTA Press.

Santau, A. O., Secada, W., Maerten-Rivera, J., Cone, N., & Lee, O. (2010). US urban elementary teachers' knowledge and practices in teaching science to English language learners: Results from the first year of a professional development intervention. *International Journal of Science Education, 32*(15), 2007-2032, doi:10.1080/09500690903280588

Sharkey, J., & Layzer, C. (2000). Whose definition of success? Identifying factors that affect English language learners' access to academic success and resources. *TESOL Quarterly, 34*(2), 352-368. doi:10.2307/3587961

Shaver, A., Cuevas, P., Lee, O., & Avalos, M. (2007). Teachers' perceptions of policy influences on science instruction with culturally and linguistically diverse elementary students. *Journal of Research in Science Teaching, 44*(5), 725–746. doi:10.1002/tea.20151

Sherin, M., Jacobs, V., & Philipp, R. (Eds.). (2011). *Mathematics teacher noticing: Seeing through teachers' eyes*. New York, NY: Routledge.

Smetana, L. K., & Heineke, A. J. (2017). Preparing science teachers for English learners: A targeted and integrated approach to pre-service teacher education. In A. W. Oliveira & M. H. Weinburgh (Eds.), *Science teacher preparation in content-based second language acquisition* (pp. 137-159). Dordrecht, the Netherlands: Springer.

Song, S. Y., & Samimy, K. (2015). The beliefs of secondary content teachers of English language learners regarding language learning and teaching. *International Journal of TESOL and Learning, 4*(1), 3-19.

Sowa, P. A. (2009). Understanding our learners and developing reflective practice: Conducting action research with English language learners. *Teaching and Teacher Education, 25*(8), 1026-1032. doi:10.1016/j.tate.2009.04.008

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. doi:10.1002/tea.10040

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. doi:10.1002/tea.21057

Swanson, L. H., Bianchini, J. A., & Lee, J. S. (2014). Engaging in argument and communicating information: A case study of English language learners and their science teacher in an urban high school. *Journal of Research in Science Teaching, 51*(1), 31-64. doi:10.1002/tea.21124

Swars, S. L., & Chestnutt, C. (2016). Transitioning to the Common Core State Standards for Mathematics: A mixed methods study of elementary teachers' experiences and perspectives. *School Science and Mathematics, 116*(4), 212-224. doi:10.1111/ssm.12171

Téllez, K., & Manthey, G. (2015). Teachers' perceptions of effective school-wide programs and strategies for English language learners. *Learning Environment Research, 18*(1), 111-127. doi:10.1007/s10984-015-9173-6

Tolbert, S., & Knox, C. (2016). "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. *International Journal of Science Education, 38*(7), 1133-1149. doi:10.1080/09500693.2016.1183266

Turkan, S. (2016). In-service teachers' reasoning about scenarios of teaching mathematics to English language learners. *The Mathematics Enthusiast, 13*(1), 130-148. https://scholarworks.umt.edu/tme/vol13/iss1/9

Turner, E. E., Drake, C., McDuffie, A. R., Aguirre, J., Bartell, T. G., & Foote, M. Q. (2012). Promoting equity in mathematics teacher preparation: A framework for advancing teacher learning of children's multiple mathematics knowledge bases. *Journal of Mathematics Teacher Education, 15*(1), 67–82. doi:10.1007/s10857-011-9196-6

Vomvoridi-Ivanović, E., & Razfar, A. (2013). In the shoes of English language learners: Using baseball to help pre-service teachers understand some complexities of language in mathematics instruction. *Teaching for Excellence and Equity in Mathematics, 5*(1), 7-15.

Von Esch, K. S., & Kavanagh, S. S. (2017). Preparing mainstream classroom teachers of English learner students: Grounding practice-based designs for teacher learning in theories of adaptive expertise development. *Journal of Teacher Education*. Advanced online publication. doi:10.1177/0022487117717467

Wilson, P. H., Sztajn, P., Edgington, C., Webb, J., & Myers, M. (2017). Changes in teachers' discourse about students in a professional development on learning trajectories. *American Educational Research Journal, 54*(3), 568-604. doi:10.3102/0002831217693801

Youngs, C. S., & Youngs, G. A. (2001). Predictors of mainstream teachers' attitudes toward ESL students. *TESOL Quarterly, 35*(1), 97-120. doi:10.2307/3587861

Zwiep, S. G., Straits, W. J., Stone, K. R., Beltran, D. D., & Furtado, L. (2011). The integration of English language development and science instruction in elementary classrooms. *Journal of Science Teacher Education, 22*(8), 769-785. doi:10.1007/s10972-011-9254-z