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RESEARCH ARTICLE



Exploring bilingual and dual language teachers' perspectives on asset-based professional development in science and engineering

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ABSTRACT

In this article, we report on a mixed method study conducted through a previously validated bilingual instrument. The purpose was to understand elementary bilingual and dual language (BDL) teachers' perspectives of science and engineering (S&E) teaching in Massachusetts and Puerto Rico with the goal of developing situated professional development in science and engineering (S&E). Our findings suggest that an asset-based, and content-language integrated approach is needed to develop BDL professional development models attuned to specific locations, program models, and grade levels. Implications for our findings transferred to academic practices for BDL teachers are included.

Motivation

Providing ongoing, high-quality professional development for bilingual and dual language (BDL) in-service teachers in highly specialized preparation areas is considered an essential factor for program implementation and excellence (Guerrero & Lachance, 2018; Howard et al., 2018; U.S. Department of

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Idalis Villanueva Alarcón, Ph.D., is an Associate Professor of Engineering Education at the University of Florida in their Engineering Education Department. She previously was an Assistant Professor of Engineering Education at Utah State University. Her research areas are primarily in science and engineering education around topics of hidden curriculum, mentoring, motivation, learning spaces and environments, and bilingual/dual language instruction. In 2019, she received the Presidential Early Career Award for Scientists and Engineers (PECASE) award for her National Science Foundation CAREER award on developing advocacy mentoring models around hidden curriculum in engineering.

Elizabeth McEneaney, Ph.D., is an Associate Professor in the Department of Teacher Education and Curriculum Studies at UMass-Amherst. A former math and science teacher, she utilizes mixed methods approaches to investigate equity and access in STEM fields in K-16, as well as processes of curricular stability and change from a comparative and international perspective. With Martina Nieswandt, she has been researching small group dynamics in high school science with support from the National Science Foundation.

Edwin Marte Zorrilla, is a Ph.D. student in Engineering Education at the University of Florida. He received a bachelor's degree in Electronics Engineering from the Pontificia Universidad Católica Madre y Maestra, in 1998, and a master's degree in Educational Technology from The Universidad Tecnológica de Santiago, in 2018, both in the Dominican Republic. His research interests include the exploration of motivation and learning pathways in science and engineering education.

Alberto Esquinca, Ph.D., is an Associate Professor in the Department of Dual Language and English Learner Education at San Diego State University (SDSU). He was selected as SDSU's Inaugural LGBTQIA+ Pride Faculty Scholar. He researches emergent bilinguals' (trans)languaging in academic contexts, especially in science and engineering. He is particularly interested in issues of identity construction and languaging among transnational/ *transfronterizx* children and youth. At SDSU he collaborates with Mexican teacher preparation programs as part of binational and transnational teacher preparation initiatives.

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Education, 2015). Positioning BDL teachers for success and preparing them to serve their students in content specialization (e.g., science and engineering) should include the three pillars of Dual Language education: (a) biliteracy and bilingualism (students can excel in reading, writing, speaking, listening, and develop metalinguistic awareness in the two languages of instruction); (b) grade-level academic achievement (students can achieve academic goals established according to their grade level in both program languages); (c) cross-cultural competence and critical consciousness (students develop socio-cultural competence skills and assume active advocacy roles in their communities) (Howard et al., 2018; Taju Educational Solutions, 2020).

Our study is grounded in the three pillars and focuses on the perspectives of BDL in-service teachers prior to the development of any TPD intervention or program. This latter premise is important because we position BDL teachers as professionals who bring cultural and linguistic assets that are often not structurally supported despite their realities of cultural pluralism (a condition in which minoritized groups fully participate in the dominant society, yet maintains their cultural differences) (Guerrero & Lachance, 2018).

For the first pillar, professional development of BDL teachers primarily focuses on teaching and promoting biliteracy development of their students both in English and the partner language, which, for the purpose of this study, is Spanish (Aguirre-Muñoz & Pando, 2021). These teacher professional development (TPD) programs are delivered to the teachers in English, for a number of reasons, including a lack of multilingual and multicultural experts to train teachers in a partner language (Guerrero & Guerrero, 2017) or the need to simultaneously juggle training for educators who work in multiple and different partner languages. While English may be perceived as a unifying language within these TPD programs, its dominance also limits how these teachers can cover disciplinary subjects in linguistically sustaining ways for their students (Guerrero & Guerrero, 2017).

For the second pillar, many TPD programs have limited to no linguistic- and grade-level appropriate disciplinary content (Alfaro & Hernández, 2016); these programs depend on teachers to translate and create content, abide to state and national standards, and respond to administrative/political influences on how to provide “proper” education and ensure grade-level achievement for English language learners (ELLs) (Dorner & Cervantes-Soon, 2020; Guerrero & Guerrero, 2017). Since language and disciplinary instruction are separate endeavors (e.g., NASEM, 2018) that rarely are integrated (Aquino-Sterling, 2016), teachers and students are not given the space to understand how their home cultures and contexts are represented in what they teach and learn; this tendency is more predominant in science and engineering (S&E) fields where making cultural and linguistic connections becomes difficult (Flores & Claeys, 2019).

For the third pillar, TPD of BDL teachers seldom demonstrates cross-cultural competence and critical consciousness in responding to local teachers’ needs, perspectives, and motivations. Multilingual and multicultural educators may often choose to become BDL teachers or transition to BDL education because they come from communities of color where bilingualism and biliteracy are seen as points of pride and empowerment (Bristol & Martin-Fernandez, 2019). Indeed, some of the most successful BDL professionalization efforts draw on the cultural and linguistic assets of local communities (Flores & Claeys, 2019). From a culturally sustaining pedagogies framework (Paris & Alim, 2017), in recognizing and valuing the cultural and linguistic assets of communities of color, teachers need to be included as well.

With this work, we respond to the call to incorporate an equity approach, rejecting linguistically marginalizing pedagogies and embracing a culturally and linguistically sustaining pedagogies approach (Lee, 2021) for S&E TPD in BDL settings. We conceptualize teaching and learning S&E in BDL contexts as an integrated language and content multimodal approach, where all students and teachers’ linguistic repertoires and funds of knowledge are considered from an asset-based perspective (Lee, 2021). Our approach to TPD assumes that the rigor of S&E teaching is elevated through the development of the whole students’ and teachers’ linguistic repertoires (Lee, Llosa, Grapin, Haas, & Goggins, 2019). We situate that in the process of disciplinary biliteracy development, multimodal construction of languages (e.g., different registers, interactions, etc.) and situated knowledge and

disciplinary practices (e.g., selection of local phenomena and experiences situated in the students and teachers' communities) can elevate the assets and funds of knowledge that both teachers and students bring to the classroom (Haas et al., 2021; Pierson & Grapin, 2021). Thus, the challenges of attending to these three critical areas for the professional development of BDL teachers, are compounded by the general challenges of ensuring that elementary educators are prepared to teach S&E in a culturally sustaining manner. To design appropriate and effective TPD, this study focuses on understanding BDL teachers' perspectives on professional development and about what constitutes an effective, asset-based approach.

Literature review: The state of TPD programs for BDL teachers

Multilingual learners are often referred, at the federal level, with the term of English Learners (ELs), who correspond to 10% of the total U.S. K-12 student population (U.S. Department of Education, 2022). In this work, we will use the term multilingual learners to denote a more asset-based terminology for a comprehensive consideration of learners' biliteracy development.

The quality and extent of TPD and their capability to address the needs of multilingual learners varies considerably from state to state (Ferraro, Valdiviezo, McEneaney, & Hoang, 2019). Only 38% of preservice teachers have taken courses on teaching multilingual students (Taie & Goldring, 2017) and only 28 states require professional development in this area (Rafa, Erwin, Brixey, McCann, & Perez, 2020). Similarly, in-service BDL teachers seldom receive adequate and ongoing opportunities for professional development in their language of instruction.

There is limited research on how teachers of multilingual learners can be prepared to implement effective strategies for their BDL students (Buysse, Castro, & Peisner-Feinberg, 2010). Furthermore, existing TPD for teachers of multilingual students is understudied, particularly around the context of disciplinary subjects such as S&E. In the scope of BDL teacher professional development programs, many controversies exist, such as: (a) the need to challenge pervasive deficit and racist ideologies; (b) the lack of preparation of BDL teachers to cultivate students' identities and funds of knowledge; (c) the need to engage in counter-hegemonic discourses and undo institutionalized, monoglossic policies and practices that work to marginalize multilingual students' identities and their culturally specific ways of knowing and doing (Alfaro, 2018; Darder, 2015; Fránquiz, Salazar, & DeNicolo, 2011; Stacy, Fernández, & McGovern, 2020; Téllez & Varghese, 2013). Existing TPD programs for BDL teachers simply do not prepare its teachers to be critical, dialogical, and challenge these difficult terrains (Alfaro, 2018; Kohli, Picower, Martinez, & Ortiz, 2015; Stacy et al., 2020; Taie & Goldring, 2017), especially when considering content-based instruction (DeMonte, 2013; DiCerbo, Anstrom, Baker, & Rivera, 2014).

Increasingly, scholars are calling for more critical and asset-based TPD approaches that empower and support BDL teachers to navigate difficult terrains and leverage and sustain their own linguistic and cultural capital as well as that of their students (e.g., Alfaro, 2018; Alfaro & Bartolomé, 2017; Darder, 2015; Fránquiz et al., 2011; Kohli et al., 2015; Stacy et al., 2020). Asset-based approaches in BDL education recognize that teachers and students enter classrooms with languages and funds of knowledge that are strengths in their learning and development. Informing this approach are fundamental conceptual understanding of funds of knowledge (Gonzalez & Moll, 1995), community cultural wealth (Yosso, 2005), culturally sustaining pedagogies (Paris & Alim, 2017), and translanguaging and heteroglossic ideologies (García & Wei, 2014). These scholars posit that communities' languages and cultures are assets for learning rather than deficits (Valencia, 2010) to overcome. After all, "supporting bilingual educators in their efforts to enact humanizing praxis that thwarts oppressive ideologies and instead centers students' community cultural wealth through critical and culturally sustaining pedagogies requires ideologically clarity in bilingual professional development" (Stacy et al., 2020, p. 132). It also benefits from centering BDL teachers' experiences and voices at the onset of TPD programs.

TPD Programs for BDL teachers need Asset-Based, Grade- and Subject Appropriateness (Howard et al., 2018). Existing TPD programs for BDL teachers are few and far between and severely understudied; this is especially true in the elementary grades (e.g., Esquinca, de la Piedra, & Herrera-Rocha, 2021). This is because asset-based professional development requires that teachers can: (a) sustainably leverage students' linguistic and cultural capital; (b) equip students with authentic and situated academic literacies needed to support their formation as bilingual, bicultural, and biliterate professionals in society; and (c) acknowledge the cultural and linguistic assets of communities of color including teachers. Instead, existing teaching materials are rich in White middle-class norms of knowledge and Western reasoning (Burke & Wallace, 2020) that dominate grade-level instruction and their accompanying assessments. As cautioned by Paris & Alim (2017), asset-oriented research and programmatic initiatives are not solely "abstract or fixed versions of the culturally situated practices of our communities" where there is an underlying assumption of "static relationships between race, ethnicity, languages, and cultural ways" (2017, p. 7). Rather, asset-based approaches, in interventions, such as TPD, must lie in "survival – a survival we want to sustain through education – and about changing the conditions under which *we live and work* by opening up new and revitalizing community rooted ways of thinking about education and beyond" (Paris & Alim, 2017, p. 13). We added emphasis on *live and work* in the prior quote to argue that most TPD programs make assumptions on behalf of the teachers but seldom consider teachers as critical agents, making choices, contributing perspectives about supporting the funds of knowledge of their students in different subject matters (Mejia & Wilson-Lopez, 2016). Inspired by the Paris & Alim's (2017) culturally sustaining pedagogies framework, we decided to first hear from the BDL teachers, their perspectives, experiences, and needs at the intersection of their culture and professional requirements. We posit that TPD spaces where teachers can authentically communicate their realities and the cultures that they *live and work* in can *agentically* change BDL education within their school contexts. Furthermore, in exploring potential intersections between cultural-, linguistic-, age-, and subject-appropriateness (particularly S&E), we can span a broader reach of considerations for future TPD programs for BDL teachers (Celedón-Pattichis et al., 2018; McLeman, Fernandes, & McNulty, 2012; Simic-Muller, Fernandes, & Felton-Koestler, 2015; Vogel, Hoadley, Ascenzi-Moreno, & Menken, 2019).

Rationale, design, and research questions

For this study, we used a sequential explanatory mixed-methods research design (Creswell & Plano-Clark, 2018) with a primary emphasis on the quantitative findings of the work (QUAN → qual). Exploration of BDL teacher perspectives, needs, and desires for TPD is understudied, especially for elementary grade levels (Esquinca et al., 2021), in subject matters like S&E (e.g., Johnson & Atwater, 2014), and across BDL program contexts (National Academies of Sciences Engineering and Medicine (NASEM), 2018), and so there was no appropriate instrument for exploring BDL teacher perspectives and contexts available in the research literature. We therefore developed a survey instrument for BDL educators that included open-ended items, which elevates the voices of teachers while increasing the strength of these voices in numbers (Creswell & Plano, 2018).

It is important to note that in order to situate elementary grade-level S&E practices within BDL instruction in our instrument, we derived from the Next Generation Science Standards (NGSS, 2021), specifically their grade-level S&E practices, their disciplinary core ideas, and crosscutting concepts. We also included considerations to culturally and linguistically sustaining pedagogy (Paris & Alim, 2017) and the three pillars of dual-language education (Howard et al., 2018; Taju Educational Solutions, 2020) in the survey. The survey is provided in the Appendix along with clarifying notes from the research team.

A key consideration in understanding BDL teacher perspectives is to consider different instructional contexts. To contextualize the need of teachers in specific programs, two differing BDL program

Table 1. BDL program models in Massachusetts and in Puerto Rico.

	Massachusetts (Dual Language model)	Puerto Rico (Bilingual Initiative)
Model Description and Context	School districts in Massachusetts have been implementing dual language models since the 1990s (Nieto, 2009). Currently, there are 80/20, 70/30, and 50/50 language allocation plans (the first number indicates instructional time spent in the partner language, the second number indicated time in English). Schools that follow the 80/20 or 70/30 plan in grades K2 transition to a 50/50 plan in grades 3–5.	The vast majority of students are Spanish native speakers whose content knowledge is taught and assessed in both Spanish and English. There are also about twenty 90/10 bilingual schools (90% English content instruction and 10% Spanish instruction, prevalently in private schools where Spanish dominant speaker students want to learn English) (PRDE, 2017).
Policies	Language Opportunity for Our Kids (LOOK) Act (H.3705/S.2070) 2017 to promote more flexibility in serving ELs.	Bilingual Initiative since 2012 (Puerto Rico Department of Education (PRDE), 2017), to promote the development of more BDL programs in public schools.
Teacher credentials	Grade teachers in dual language settings, teaching in partner languages (i.e., Spanish, need to have both a grade license and a Bilingual Endorsement.	Teachers can acquire a bilingual licensure, but it is not a requirement. University teacher preparation programs are largely monolingual in Spanish and focuses on teaching English as second language approaches.

models were compared (Table 1): a dual language program model in Massachusetts and a bilingual initiative model in Puerto Rico. These program contexts are described in Table 1.

Another key contextual factor to consider that might shape BDL teacher perspectives is the different challenges for teachers to develop understanding of the science and engineering curriculum across grade levels. Standards related to a particular topic, such as water, involve deepening understanding of the concepts and practices in the upper elementary grades compared to the lower grades (National Academies of Sciences, Engineering, and Medicine, 2022, pp. 79–83). Moreover, teachers in the upper primary grades face challenges due to the limited amount of school time typically allocated to science and engineering and the lack of classroom facilities and equipment to support more advanced inquiry and design activities (Varg, Näs, & Ottander, 2022).

With these considerations in mind, teacher perspectives within these two different program models and grade levels were explored. Our research questions were:

- (1) How do elementary BDL teachers perceive their educator qualities?
- (2) What S&E practices do elementary BDL teachers report they incorporate most in their classrooms?
- (3) How do elementary BDL teachers integrate BDL principles with S&E subject matter instruction, including culturally and linguistically sustaining practices?
- (4) What resources do BDL teachers identify as necessary to support their classroom practices in S&E?

Addressing these questions can inform the design of asset-based TPD for BDL teachers on culturally responsive S&E teaching.

Researchers' positionality

This is a cross-disciplinary, collaborative work. The researchers are all individuals who have different degrees of expertise in BDL education research and in science and engineering education research. Marialuisa is a multilingual and multicultural adult transnational teacher educator, who specializes in disciplinary biliteracy development in elementary BDL programs with a focus on integrated STEAM approaches (science, technology, engineering, art, and mathematics). Idalis is a Latina bilingual and bicultural educator who specializes in science and engineering education;

Idalis is also a trained scientist and engineer. Elizabeth is an expert in program evaluation and the use of data by school administrators and teachers, educational policy, statistics, and mixed methods research methods. Edwin is a Latino graduate student specializing in engineering education research and is fluent in Spanish and English; Edwin is also a trained engineer. Alberto is a queer transfronterizo, a Mexican immigrant, an applied sociolinguist, a former language teacher, and a bilingual teacher educator who specializes in S&E education. All authors subscribe to asset-based and culturally sustaining pedagogical principles and recognize the importance that both culture and language had in their professional formation as well as their professional preparation of BDL teachers. We conducted the broader study out of a concern that BDL teachers need professional development, materials, and resources to equitably serve multilingual learners.

Research methods

For the survey item development, the research team gained inspiration from Paris & Alim's (2017) culturally and linguistically sustaining pedagogies framework paired with the Next-Generation Science Standard for science and engineering (National Research Council [NRC], 2015) and informed by engineering professional identity research (e.g., Villanueva & Nadelson, 2017). The survey was originally created and simultaneously developed in English and Spanish (meaning that the Spanish version is not a translation of the English version but both were developed simultaneously to create equivalent but not separate instruments). This was achieved with the help of a cohort of multilingual in-service and pre-service BDL teachers. This multilingual survey development reflects the cultural and language fluidity and introduces a critical asset-based approach (García & Wei, 2014; Paris & Alim, 2017) to develop ecologically valid instruments situated around the multilingual realities of BDL teachers and their everyday practices (Cobb, McClain, deSilva Lamberg, & Dean, 2003; Musanti, Marshall, Ceballos, & Celedón-Pattichis, 2011).

The purpose of this manuscript is not the validation of an instrument but rather to present data collected using the instrument. We pilot tested this survey two times with a population similar to our intended study group before administering the final version (trial #1, $n = 22$; trial #2, $n = 42$). Through these trials, we intended to verify that teachers would interpret their practices in ways consistent with the NGSS framework used during the development of items. These survey trials and additional reviews by graduate students, who had experiences teaching at elementary level in multilingual and multicultural contexts in the U.S. and abroad, enabled us to check for clarity of language and meaning. No monetary incentives were offered to the participants at any time, although participants were offered the opportunity to sign up for the follow-up portion of the study that included customized, free TPD sessions.

Through this survey instrument, we collected data that was centered around three main factors: (a) BDL teachers' perspectives of their educator qualities (RQ1 and 1a; 11 quantitative items); (b) Reported Implementation of S&E Practices in Teaching (RQ2 and 2a; 10 quantitative items); (c) Existing BDL practices in the context of S&E and culturally and linguistically sustaining practice (RQ3, 3a, 3b; 7 quantitative items). Questions in each of these three main constructs were developed using a common 5-point Likert scale; based on frequency of exposure (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always). We also inquired about the resources BDL teachers identified as necessary to support their classroom practices in S&E (RQ4; open-ended qualitative question). Additionally, 12 demographic questions were included (see Table 2 for demographic breakdown of the participants).

From this point forward in the manuscript, we are referring to the instrument as the **Science and Engineering Teaching in Bilingual and Dual Language Scale (SET-BDL Scale)**. The SET-BDL scale was disseminated using the web-based survey tool Qualtrics (see Appendix for the written copy). All procedures were approved for human subject research with the Institutional Review Board offices at the home institution of the authors.

Table 2. Demographics of bilingual and dual-language teachers in the study (n = 105).

#	Category	Sub-categories	Percent (%)	Frequencies (N)
1	Survey language of choice	English	52.38%	55
		Spanish	47.62%	50
2	Grade level they teach (multiple choices allowed)	K-2 nd grade	29.36%	37
		3 rd to 5 th grade	42.85%	54
		ESL teacher	6.35%	8
		SPED teacher	15.08%	19
		Other: (literacy coach, teaching other grades in addition to K-5, PreK-12 specialist, co-teachers, district leader, paraprofessional, retired, STEM teacher)	6.35%	8
3	Language used for S&E teaching (multiple choices allowed)	Spanish	47.62%	50
		English	22.86%	24
		Portuguese	0.95%	1
		English and Spanish	20.95%	22
		English + others (Portuguese, Spanish, French, Haitian Creole)	2.86%	3
4	U.S. State or Territory	Massachusetts	49.52%	52
		Puerto Rico	50.47%	53
5	Years of experience in BDL teaching	0-3	73.96%	71
		4-5	20.83%	20
		6+	5.21%	5
6	Total years of teaching	0-3	86.66%	91
		4-5	9.53%	10
		6+	3.81%	4
7	Teaching license/certification (open question)	Early childhood	14.29%	15
		Elementary	61.90%	65
		ESL + Elementary/ECE	9.52%	10
		SPED + Elementary/ECE	6.67%	7
		STEM + other	2.86%	3
		Elementary/ECE/Secondary	4.76%	5
8	Language(s) in which you teach (multiple choices allowed)	French	1.34%	2
		Haitian Creole	1.34%	2
		Portuguese	4.03%	6
		Spanish	57.05%	85
		English	36.24%	54
9	Age	18-29 years of age	16.19%	17
		30-59 years of age	80.95%	85
		60 years of age	2.86%	3
10	Self-identified gender	Female	79.81%	83
		Male	11.54%	12
		Non-binary/third gender	0	0
		Prefer to self-describe	2.88%	3
		Prefer not to say	5.77%	6
11	Country(ies) of cultural self-identification (open question)	USA	18.10%	19
		Puerto Rico	38.10%	40
		USA + Puerto Rico	6.67%	7
		USA + Latin American countries	2.86%	3
		Other (multiple combinations including USA and PR)	15.24%	16
12	Race/ethnicity of self-identification (multiple choices allowed)	No answer	14.29%	15
		American Indian or Alaska Native	1.82%	2
		Asian	0	0
		Black or African American	0.91%	1
		Hispanic, Latina/o, Chicana/o	56.36%	62
		Native Hawaiian or Pacific Islander	0.91%	1
		White	37.27%	41
		Other	2.73%	3

Participant recruitment and demographics

We used a purposeful and maximal variation sampling strategy (Creswell, 2014) as well as snowball sampling (Glesne, 2011) for participant recruitment. We focused on two differing program models,

located in the state of Massachusetts (dual-language programs; Howard et al., 2018) and the U.S. territory of Puerto Rico (the Bilingual Initiative model; Puerto Rico Department of Education (PRDE), 2017). We selected these sites due to: (a) the researchers' familiarity with the languages and cultures of the teachers in these regions; (b) the implementation of new BDL policy in Massachusetts (Look Act, 2017) and in Puerto Rico (Bilingual Initiative; PRDE, 2017); and (c) the lack of studies in BDL education that includes a significant cohort of teachers from Puerto Rico, whose cultural and contextual hybridity highlight the complexity of BDL program models and approaches compared to traditional US-based BDL program models.

To increase participant recruitment and response rates, we partnered with two organizations, the Multistate Association for Bilingual Education – Northeast (MABE-NE) and the Puerto Rican Center for Research on Bilingualism and Learning (CeIBA for its acronym in Spanish). MABE and CeIBA are currently two of the biggest proponents of asset-based, additive bilingual education models in Massachusetts and Puerto Rico, respectively. Both MABE and CeIBA provide support to their affiliated teachers with professional development sessions and conferences, knowledge-sharing, community-building, and networking events. Participants were introduced to the study scope, a letter of consent, and were given the option to complete the survey in their language of choice (i.e., English or Spanish). A cohort of 105 teachers participated in the survey (52 or the 49.5% from Massachusetts and 53 or the 50.5% from Puerto Rico). BDL teachers working in Massachusetts tended to respond to the survey in English, while teachers working in Puerto Rico tended to respond in Spanish. Out of 55 responses in English, only three were from teachers working in Puerto Rico. Out of the 50 responses in Spanish, only nine were from Massachusetts BDL teachers (see Table 2).

Validity and reliability of the SET-BDL scale

Scale validation procedures of the SET-BDL Scale support the conclusion that the items in the survey – the first instrument validated before the implementation in this study – are valid and reliable measures of three underlying constructs: (a) BDL Teacher Perspectives of their Educator Qualities; (b) Reported Implementation of S&E Practices in Teaching; and (c) Existing BDL practices in the context of S&E and culturally and linguistically sustaining practice (Di Stefano et al., *Forthcoming*; Di Stefano & Villanueva- Alarcón, 2021). All three factors (i.e. constructs under which participants encountered survey items) were identified with eigenvalues over 1.0. As a check on internal consistency, Cronbach's alphas were calculated on items loading on each factor, and all alphas were over .80, easily surpassing the suggested threshold for scale reliability of .70 (Cronbach, 1951; DeVellis, 2016). Taken together, these results suggest factor scores to be valid and reliable measures of these three constructs.

Validity of the SET-BDL scale is based on the following criteria: (a) the multilingual process by which items were developed in Spanish and English simultaneously; (b) the alignment of test content with Culturally Sustaining Pedagogies (CSP) principles (Paris & Alim, 2017) (i.e., one of the questions ask teachers to think how often they intentionally incorporated contextual views of S&E in the partner language countries); (c) evidence of the response processes; (d) the internal structure of the measures (AERA, 2014, p. 14) and (e) recognition for the fluidity in culture and communities that these teachers live and work in (i.e., demographic question #11 inquiry about which country/countries the participant identifies culturally, avoiding a one-to-one correlation among participants' race, ethnicity, language, and state/territory in which they teach).

To analyze the data of this study, we conducted exploratory factor analysis (EFA). Factor loadings lower than an absolute value of .40 alerted us that an item in the instrument needed to be discarded or revised (Warner, 2008, p. 809). We also checked for cross-loading of items in different factors, noting cross-loadings of values higher than the absolute value of .30 (Fischer & Karl, 2019). Reliability of the instrument was analyzed through Cronbach alpha coefficients of the quantitative items in the three constructs of the survey. Reliability analysis was conducted to measure internal consistency of the scale as a whole and on its items, considering the 105 responses. Cronbach alpha coefficient values of .70 or above are considered adequately reliable (Cronbach, 1951). After factors

were identified and then scores were computed, two-way ANOVA tests were used for statistical comparisons. Principal axis factoring and promax rotation for EFA was conducted on completed survey responses. The promax rotation allowed factor solutions that are correlated rather than constraining factors to be uncorrelated (orthogonal) (Carpenter, 2018). All three quantitative factors (i.e. constructs under which participants encountered survey items) were identified with eigenvalues over 1.0 as shown in Table 3. Mostly, items loaded on the three factors as expected. Although a formal test of factor structure invariance between the two location subgroups was not possible due to limited sample size, we ran the factor analysis separately on the Massachusetts (n = 52) subsample and the Puerto Rico subsample (n = 53).

All items loaded similarly across both groups except for “to what degree do you see yourself as a questioner” and likewise “a resilient person,” which loaded strongly on the BDL Teacher Qualities factor for the Puerto Rico teachers but not for Massachusetts. These two items were removed for the final factor analysis. The factor that loaded the strongest was Factor 3 (Existing BDL practices). For this factor, all expected items loaded positively and strongly (loading over |0.40|), which had an eigenvalue of 8.67, explaining 34.7% of total variance. The item on “planning and carrying out investigations” in S&E teaching loaded substantially on this first factor, perhaps due to respondents’ attaching of various meanings to “investigations,” but the loading was short of the |0.40| level to be included in the factor. Among the other two identified factors, BDL Teacher Perspectives of their Educator Qualities (Factor 1) had an eigenvalue of 1.99, explaining 8.0% of total variance across all items. Here, too, the factor loadings mirrored our expectations, with loadings over |0.40| except for the item, “See self as attentive person,” which did not load on any of the retained factors. The last factor corresponded to items assessing Factor 2 (Reported Implementation of S&E Practices in Teaching). Items pertaining to *Implementing S&E Practices in Teaching* loaded positively and strongly with an eigenvalue of 2.98, explaining 11.5% of total variance; with the exception of the item about applying math concepts, which fell short of the |0.40| loading level. S&E teaching-related items on frequency of asking students to “communicate findings” and “define problems” also loaded on the BDL Teacher Perspectives of their Educator Qualities (Factor 1), but with loadings less than |0.40|. Hence, they were included only in the Implementing S&E practices in teaching (Factor 2).

As a check on internal reliability, Cronbach’s alphas (α) were calculated for the set of items retained under each factor that have factor loadings over |0.4|. For factor 1, labeled *BDL teacher perspectives of their educator qualities*, α was .82 for the 8 retained items. For factor 2, reported *implementation of S&E teaching practices*, the nine retained items had $\alpha = .83$, while the seven-item third factor in Table 3, which addressed *BDL practices*, had $\alpha = .85$. All three factors easily surpassed the suggested threshold for scale reliability of 0.70 (Cronbach, 1951; DeVellis, 2016). Taken together, these results suggest factor scores to be valid and reliable measures of these three constructs.

Qualitative analysis of open-ended question

The research team analyzed the frequency of the Likert-scale choice selected by the participants to the survey questions, the options selected in the demographic questions (i.e., those that involved a multiple selection such as languages of instruction, etc.), and the words used in the participants’ written responses to the open-ended question. Because the research team is multilingual and multicultural, the data was not translated but rather was analyzed simultaneously in English and Spanish. Multilingual translation issues in qualitative studies research showed the critical role of construct development in multiple languages when research team members work with data collected in cultures and languages different from their own (Oxley, Günhan, Kaniamattam, & Damico, 2017). In the case of this study, the team members’ knowledge of the language and the culture of the participants informed and supported the instrument development and validation, and the qualitative data analysis process happened simultaneously in English and Spanish. Coding cycles entailed the following:

Table 3. Factor loadings for exploratory factor analysis (principal axis factoring, promax rotation).

	FACTOR 1 BDL Teacher Perspectives of their Educator Qualities Eigenvalue = 1.99% Variance Explained = 8.0%	FACTOR 2 Reported Implementation of S&E Practices in Teaching Eigenvalue = 2.98% Variance Explained = 11.5%	FACTOR 3 Existing BDL practices in the context of S&E and culturally and linguistically sustaining practice Eigenvalue = 8.67% Variance Explained = 34.7%	Commonality h^2
<i>To which degree do you see yourself as:</i>				
1. Collaborator	.731			.488
2. Reflective person	.610			.450
3. Hands-on teacher	.676			.472
4. Problem solver	.657			.387
5. Creator	.630			.365
6. Questioner*				
7. Resilient person*				
8. Tinkerer	.439			.306
8. Communicator	.485			.353
9. Innovator	.532			.395
10. Attentive Person				
<i>How often do you incorporate S&E teaching?</i>				
11. Design solutions		.818		.688
12. Develop & use models		.804		.539
13. Construct explanations		.738		.573
14. Analyze & interpret data		.613		.444
15. Ask questions		.577		.315
16. Plan & carry out investigations		.549	.363	.448
17. Formulate argument from evidence		.505		.350
18. Communicate explanations	.385	.492		.506
19. Define problems	.376	.452		.506
20. Apply math concepts, computation				
<i>How often do you incorporate BDL teaching?</i>				
21. Partner Language Culture			.897	.820
22. Connect English & Partner Language			.875	.704
23. Bilingual, biliteracy strategies to develop both languages simultaneously			.850	.627
24. Content assessment in Partner Language			.668	.607
25. Specific Academic Vocabulary in Partner Language			.678	.653
26. Context of S&E in Partner Language Countries			.570	.448
27. Differentiate by language proficiency			.533	.380

Pattern Matrix Loadings over .30 shown, items loading over .4 are bolded and included in factor score.

* Item dropped from analysis due to substantially different loading across locations

- (1) Pre-analysis phase: The research team took their analytic memos (DeLyser, 2008) with English and Spanish comments and reflections on each *a priori* code (i.e., cultural self-identification, etc.) established through the culturally and linguistically sustaining pedagogies framework (Paris & Alim, 2017), NGSS (NGSS, 2021), the three pillars of BDL education (e.g., Howard et al., 2018), and the research on engineering professional identity (Villanueva & Nadelson, 2017). These memos described the meaning of each code, reflected upon and acknowledged the

- positionality of each researcher in relation to the data, and to organize the data for two cycles of coding (Saldaña, 2016);
- (2) First cycle of coding: This coding cycle was conducted through exploratory methods, including both holistic coding (where researchers applied a single code to a chunk of text to obtain the overall message) and provisional coding (where researchers used a set of pre-generated codes based on the research questions and literature review; i.e., needs of hands-on materials, etc.) (Saldaña, 2016);
 - (3) Second cycle of coding: This cycle of coding included pattern coding where segments from the first cycle of coding were summarized, and organized in patterns of categories, themes, or concepts (Saldaña, 2016). Purposeful dual and simultaneous coding in English and Spanish was done to reflect the multilingual identity of the authors and coders of this paper. In this way, we acknowledge that “being bilingual includes not only the use of two languages, but, in most cases, also management of two cultures” (Bakić & Škifić, 2016, p. 36). Triangulation and validation of the coding schema and its output were provided by jointly comparing the quantitative and qualitative data by a co-occurrence model that tied participants’ demographic characteristics and responses to the survey items.

Results

Quantitative results

To answer RQ1 and its sub-question, regarding teacher perspectives of their educator qualities, we found that teachers across locations (indicative of program model type) overwhelmingly perceived themselves as problem-solvers (55% responded always and 44% often) and collaborators (64% responded always and 36% often). The boxplot in Figure 1 compares no standardized scores on Factor 1 (BDL Teacher Perspectives of their Educator Qualities) across grade level taught as well as location. We compared responses from teachers in the lower (grades K-2) and the upper (grades 3-5) elementary level. In general, there are no significant differences across program models (PRmean = -.11 vs. MAmean = .06) and grade level taught (K-2 mean = .17 vs. Gr3-5 mean = -.18). A two-way

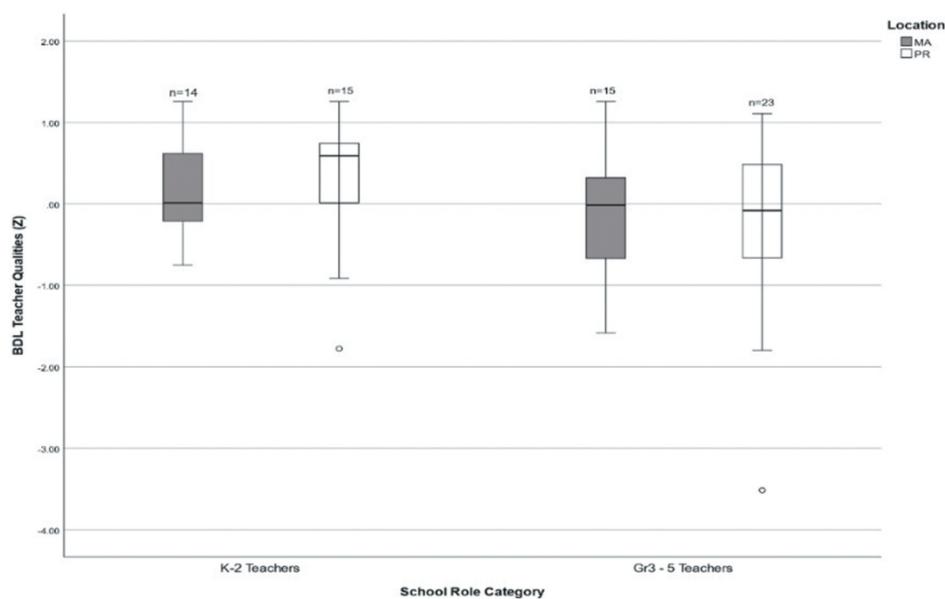


Figure 1. Grade-Level and location effects on factor 1 (BDL teacher perspectives of their educator qualities).

ANOVA of the effects of school role, that is, grade level taught, and location on teachers' perceived educator qualities was not statistically significant ($F(3,59) = .905$, $p = .44$). This indicates that BDL teachers in all subgroups share about the same perspectives of their educator qualities, regardless of program type and the grade level in which they work.

To answer RQ2, we considered the responses collected for Factor 2 (Reported Implementation of S&E Practices in Teaching). Answers to individual items suggest that nearly all teachers incorporate "asking questions" into their S&E teaching practice (98% "often" or "always") and "constructing explanations" and "communicating explanations" (with "often" or "always" at 72% and 77%, respectively). Less frequently used practices reported were "analyzing and interpreting data" (45% only "sometimes" or less often), and "planning and carrying out investigations" (42% only "sometimes" or less often). The boxplot in Figure 2 shows standardized scores on Factor 2, broken down by grade-level (K-2 vs. grades 3-5) and location (Massachusetts vs. Puerto Rico). Overall, teachers in Puerto Rico score somewhat higher than teachers in Massachusetts (PRmean = .11 vs. MAmean = -.14) on the reported implementation of S&E practices, with much of the difference driven by higher scores by K-2 teachers in Puerto Rico. There was little difference between grade levels taught (K-2 mean = -.03 vs. Gr3-5 mean = .03). However, these differences were not statistically significant based on the two-way ANOVA, $F(3,59) = .824$, $p = .49$. Stepping back from the finer-grained statistical test, it is worth highlighting that while Massachusetts BDL teachers followed the pattern we had tentatively expected (that upper-grade teachers would have a higher mean on this factor than lower grade teachers). The opposite was true for teachers in Puerto Rico.

To respond to RQ3 and subquestion about BDL practices in culturally, linguistically sustaining S&E instruction, we found that BDL teachers across locations overwhelmingly reported incorporating the following practices: (a) Differentiating instruction/adapting teaching methods according to different language proficiency level (40% responded "always" and 38% "often") and (b) including bilingual and biliteracy practices to develop literacies in both languages simultaneously (26% responded "always" and 35% "often"). Across locations, BDL teachers reported integrating contextual views of S&E in the partner language less frequently ("often" ~30% or "rarely" 22%). The boxplot in Figure 3 reveals wide

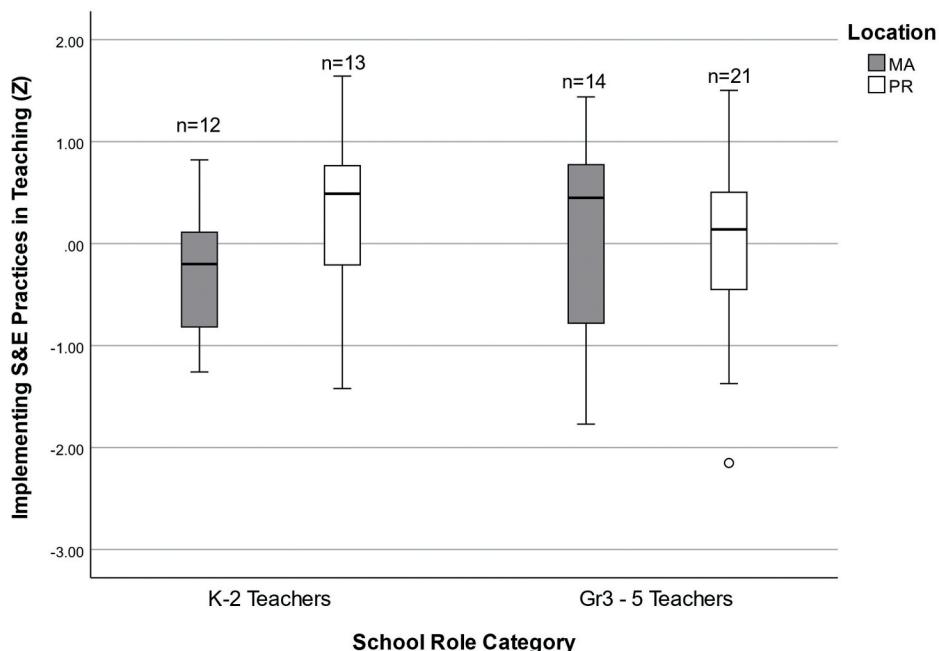


Figure 2. Grade-Level and location effects on factor 2 (reported implementation of S&E practices in teaching).

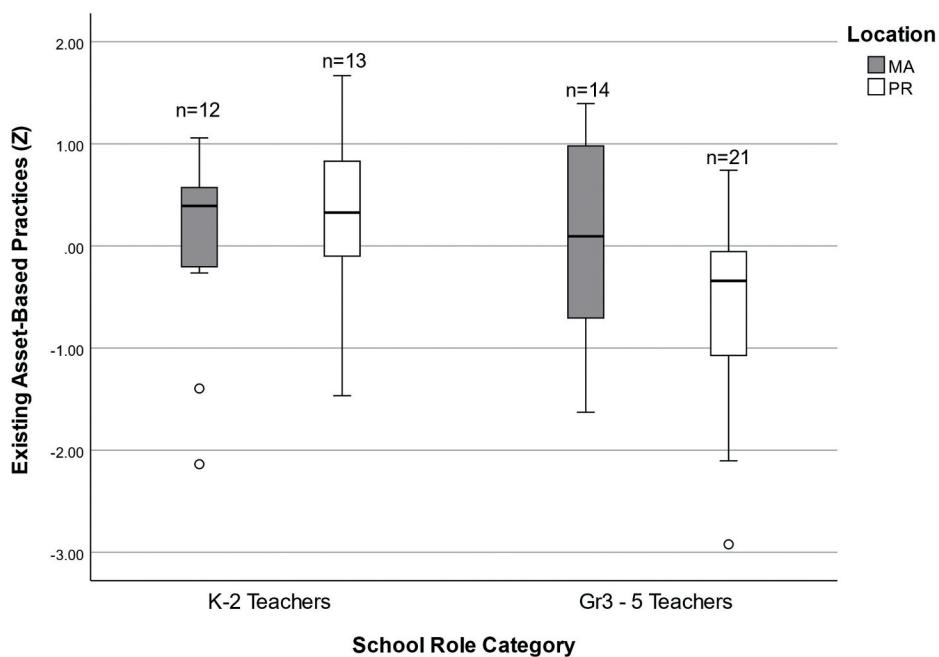


Figure 3. Grade-Level and location effects on factor 3 (existing BDL practices in the context of S&E and culturally and linguistically sustaining practice).

variation and several notable outlying cases within grade-level and location subgroups for Factor 3 (Existing BDL practices in the context of S&E and culturally and linguistically sustaining practice). Overall, teachers in Puerto Rico scored somewhat lower than teachers in Massachusetts (PRmean = $-.29$ vs. MAmean = $.04$), K-2 teachers scored somewhat higher than their counterparts at the upper grades (K-2 mean = $.18$ vs. Gr3-5 mean = $-.37$). However, we can see from the boxplot that while K-2 Massachusetts teachers scored only slightly higher on the BDL practices factor than Grade 3-5 teachers from that state, upper primary teachers tended to score substantially lower than K-2 teachers in Puerto Rico. A two-way ANOVA test was statistically significant $F(3,59) = 3.38$, $p = .024$, with the main effect of grade level and the interaction between grade level and location approaching significance at $p = .062$ and $p = .056$, respectively, providing modest evidence that the incorporation of BDL practices in this context drops off a bit for teachers at the upper grades, and more so in the Puerto Rican model than in Massachusetts.

We also compared grade-level and location on the number of key S&E concepts taught out of 10 concepts (5 science and 5 engineering, see questions #2 and #3 in the Appendix). Grade 3-5 teachers generally reported teaching slightly more S&E concepts (mean = 5.19 topics) than teachers at the K-2 level (mean = 4.62). Also, Massachusetts teachers addressed a mean of 5.56 topics compared to 4.48 topics among Puerto Rico teachers. The two-way ANOVA analysis approached statistical significance ($F(2,73) = 2.91$, $p = .061$) with the main effect of location significant at $p = .033$. There was no significant main effect of grade level on the number of concepts taught, nor a significant interaction between grade-level and location.

The quantitative results support that perceived teacher qualities (e.g., encourager, responsible, and creative) along with grade-level differences, differentiation of S&E practices, and location differences could be elements that could be included in existing professional models for these teachers. Additional consideration in these areas is warranted for interested scholars, practitioners, and educators.

Qualitative results

In the open-ended question to answer RQ4, teachers were asked to indicate what resources (e.g., materials, skills, knowledge, literature, etc.) they would like to have in order to teach S&E in their BDL class. Teachers indicated that they would like to receive professional development in Spanish, including texts that address both the development of biliteracy, bicultural, and academic knowledge in connection with their home cultures according to the different students' linguistic and developmental stage (i.e., different reading levels of texts on S&E topics, visuals to describe complex concepts and phenomena in Spanish). For example:

Spanish	English
"Me gustaría tomar adiestramientos para aplicar en mi salón de clase los temas sobre la ciencia y la ingeniería"	"More resources in Spanish- encyclopaedias, articles, videos, etc." "training in hands-on teaching for SLIFE"

SLIFE stands for Students with Limited or Interrupted Formal Education

The professional development sessions should include information about the elementary-grade level content knowledge in S&E and how to use them in specific sociocultural contexts considering the assets that teachers and students bring to their classrooms. The need for course materials was also highlighted by BDL teachers. Teachers in Puerto Rico frequently mentioned the need for laboratorio/laboratories and tecnología/technology (i.e., smart screens, computers, internet services), while BDL teachers in Massachusetts indicated the need for scientific investigation kits and tools (i.e., materials for experiments, measuring utensils and magnifying glasses, hands-on science kits, etc.). While we assert that all teachers bring assets for S&E teaching, it is evident that there are systemic and school barriers that prevent them from fully implementing their desired approaches in the classroom.

Integration of quantitative and qualitative results

When integrating the quantitative and the qualitative results using co-occurrence modeling with the demographic items in the instrument (Creswell & Plano, 2018), we found that the professional development needs should be contextualized based on teachers' cultural identification (see question #11 in Demographics **Table 2**). We must mention that for cultural self-identification, we restricted the definition solely to the country participants identified being connected to, although we understand that culture is much more complex and unfixed. In summary, from the co-occurrence model, we found that:

- (1) BDL teachers in Massachusetts, who also culturally identified as connected to the US, desired more strengthening of their innovator and hands-on assets compared to attentive traits that were often suggested by BDL teachers as not culturally identified with the US. (i.e., from Caribbean and Latin American countries).
- (2) BDL teachers in Puerto Rico, who do not culturally self-identify with the US, reported needing more strengthening of their use of models and in their formulation of an argument from evidence. However, Puerto Rican teachers who identified with the US desired more support to apply concepts of math and computation, analysis and interpretation of data, planning and carrying out investigations, and defining problems.
- (3) All teachers in both locations who identified as being culturally connected with the US along with other countries (multicultural) desired more strengthening in their professional development to incorporate contextual views of S&E, as well as accompanying assessments in Spanish. However, MA teachers who identified as being culturally connected to the US wanted more asset-based strategies to connect English and Spanish. PR teachers who identified as culturally connected to the US tended to desire more asset-based strategies to incorporate Spanish with cultural practices in their classes.

Limitations

There were several limitations to this study. The first is that the main source of data is teachers' reported perspectives, and not observations of teaching practices. It is not possible to report on culturally sustaining practices yet, because the data analysis of the observation phase is currently in progress. Our focus was to gather teachers' perspectives prior to any TPD or incorporation of an intervention in a classroom; therefore, the study at this stage is limited in its interpretation. Since this study using a previously validated survey instrument, the authors have developed TPD based on these perspectives and a subset of the teacher cohorts for both MA and PR have implemented culturally and linguistically sustaining S&E practices in the classroom. Analysis of these data (i.e., teachers' lesson plans, classroom materials, teachers' reflections, etc.) are underway.

Another limitation of the study is that place-based contexts may lead to different perspectives and needs. In comparing two differing program models, our goal was to showcase how context matters and this was found, particularly as it related to teachers' cultural self-identification. Additional work is needed to tease different school-based contexts as well and expand our qualitative exploration of cultural self-identification as we understand that culture is not fixed and is more complex than what we showed. Future work will focus on these considerations in more detail. One final limitation is the finite transferability of our findings, both in numbers but also in the time that this study took place. One hundred five BDL teachers split between two different program models may not be sufficient to fully understand and capture the nuances of TPD for these teachers and models nor can it be generalized across other BDL program models. Finally, during the time of the study, Puerto Rico had recently been impacted by Hurricane María and some of their responses may have been connected to that event (FEMA, 2021) and may no longer apply to some of the perspectives and needs for resources conveyed in their responses.

Discussion and conclusions

With this work, we call for a reconsideration of BDL teacher professional development to be more mindful of the multiple teachers' linguistic and cultural backgrounds. From a culturally sustaining pedagogies perspective, we need to include those that *live and work* in their communities, especially teachers (Paris & Alim, 2017). Equitable access to S&E content in the partner language, dual-language programs allows for asset-based approaches to be used for multilingual students and teachers (Alfaro & Bartolomé, 2017; Dorner & Cervantes-Soon, 2020). As our findings suggest, TPD must expand beyond traditional resources for English-dominant practices (e.g., content knowledge) to include an acknowledgment and reflection of teachers' and students' cultural assets. For this exploratory study, we chose to explore BDL teachers' perspectives about their teacher qualities, incorporation of S&E practices, and existing BDL practices in the context of S&E.

From the findings, we identified that BDL teachers' perspectives differed based upon their program model and location (dual language in the MA context vs bilingual initiative in the PR context), their grade level (K-2 vs grades 3-5), and cultural self-identification. This was confirmed by the use of teachers' different linguistic repertoires (i.e., Spanish, English and a blend of multiple *Englishes* and *Spanishes*). Together, these findings also support the fluidity of languages and cultures that may be presented in the BDL classroom – an important aspect of asset-based approaches – and call for additional considerations of translanguaging practices in the BDL classrooms (García & Wei, 2014). Furthermore, when BDL teachers were asked to culturally self-identify their home countries, only a fourth of the teachers stated being connected solely to the U.S. while the vast majority either cited a Latin American country or Puerto Rico. The latter (selection of Puerto Rico, even though they are a U.S. territory) highlights existing tensions around colonization, nationalism, and perpetual foreignness of this BDL teachers operating across physical and metaphorical borders. This finding points to the need to consider situated (Cobb et al., 2003; Musanti et al., 2011) and "placed-based sensibilities" (Davidson-Hunt & O'Flaherty, 2007) in the TPD that recognize complex and political realities of BDL teachers and students.

We found that all BDL teachers, regardless of program model, location, or grade level, considered themselves to have teaching qualities connected to problem-solving and collaboration. When we explored in more detail, BDL teachers' open-ended descriptors connected to this aspect, words were primarily focused on their patterns of behaviors in their learning environments. Primarily, we found BDL teachers to self-characterize as either encouragers/*motivador(a)* or advocate/*guerrero(a)*. For the encouragement/*motivador(a)* domain, BDL teachers identified themselves using words such as caring/*cariñoso(a)*, encourager of students and advocate for students/*motivador(a)/guerrero(a)*, empathetic/*empatico(a)*. While it was not explicitly stated, we suspect that these actions occur by the BDL teachers in response to either the challenges they experience when keeping their students motivated when learning or applying language or content-specific literacies or in response to their need to meet school/state standards of student performance. CSP posits the need to reduce measures against normative and dominant views of academic achievement (Paris & Alim, 2017). Also, BDL teachers stated words such as creative/*creative(a)* or responsible/*responsable* suggesting that BDL teachers have to be "quick to respond" to the contextual needs and challenges present in their classrooms (Howard et al., 2018) in a timely manner. For advocate/*guerrero(a)*, words, such as flexible/*tolerante a los cambios*, shy/*tímido(a)*, or unprepared/*no preparado(a)* surfaced, pointing to systemic barriers (personal and professional) that may disempower them to sustain their linguistic and cultural capital in the BDL classroom (Alfaro & Bartolomé, 2017).

In terms of S&E topics, all BDL teachers acknowledged understanding the principles of S&E practices across the different grade levels, yet acknowledged rarely having the opportunity to incorporate any cultural or linguistic content in these materials. Furthermore, this discrepancy appeared more pronounced by grade level and location. For example, in K-2, Massachusetts BDL teachers addressed more science and engineering topics compared to Puerto Rico BDL teachers. While certainly fewer topics addressed does not necessarily translate to fewer teaching and learning opportunities for the students, it implies a differential curricular emphasis or less alignment to standards, such as NGSS for the Puerto Rico cohort. It is worth reminding that Massachusetts curriculum framework for science, technology, and engineering are an adaptation of the NGSS, including text that is drawn upon the NGSS appendices (Massachusetts DESE, 2016). As such, teachers in Massachusetts may have had longer exposure to the NGSS standards integration process. It may be, however, that there are differences in materials and resources available for the two program models. This was evidenced in how the Puerto Rico BDL teachers continually referred to a need for more integration of culture with partner language instruction compared to Massachusetts BDL teachers who communicated a need for more Spanish-translated materials. Nonetheless, the differences between the two program model points to a need for more individualized and contextualized professional development for BDL teachers, situated in their program models, hybrid cultural realities, and professional contexts (Cobb et al., 2003; Musanti et al., 2011). CSP posits that the conditions of life and work need to be situated by opening new rooted ways of thinking about education and ways to foster and sustain both teachers and students in the process (Paris & Alim, 2017). These rooted ways of thinking cannot occur without understanding deeper the cultural and political realities that these professionals find themselves in.

Among existing BDL practices, BDL teachers stated that for their students, they differentiated instruction and adapted their teaching methods to the language proficiency levels of their students. They also acknowledged their inclusion of bilingual and biliterate practices in both English and Spanish simultaneously. These two findings parallel the first two pillars of bilingual education but not the third one (cross-cultural competence and critical consciousness) (Howard et al., 2018; Taju Educational Solutions, 2020). The latter points to a critical area for future TPD of BDL teachers in that these pillars cannot be taught without the space or time to create curricular content that reflect the multiple assets of teachers and students. For example, all BDL teachers acknowledged the lack of time to develop content to integrate contextual views of science and engineering in partner language countries. Also, upper-grade teachers reported teaching more science and engineering compared to

lower-level grades but not in ways that were connected to the cultural realities of their communities and students.

We recommend that future professional development programs for in service teachers focus more intentionally on this aspect of BDL education. Collectively, the findings from this exploratory study point to two important considerations. First, fostering and supporting TPD of BDL teachers must reconsider critically the creation of materials and practices that reintroduces dominant views of academic achievement (Paris & Alim, 2017) in S&E. This was evidenced by the expressed use of teachers' partner language or use of a blend of English and Spanish (RQ4) and in the use of problem-solving rather than cultural integration in their classrooms (RQ3). Second, we found that K-2 teachers communicated being equally attuned to S&E compared to higher grade teachers (RQ2) yet these same teachers reported less TPD for S&E topics at this level. Both grade-levels also confirmed a need to introduce culturally contextual materials into their S&E topics.

This finding reveals a need for additional TPD for elementary BDL teachers to foster and sustain S&E in these programs connected to their home languages and cultures. As Paris & Alim (2017) suggest, it is not enough to foster these asset-based practices but we also need to "sustain linguistic and cultural pluralism as part of schooling for positive social transformation" (p. 1). In sum, we call for more reflexivity in BDL professional development models where teachers are seen as professionals with assets rather than seeing them from a deficit perspective. It is clear from our findings that teachers are uniquely attuned to the needs and realities of their classroom and as such, we call for more professional development models and initiatives to consider creating such programs that leverage the voices and experiences of these BDL teachers.

Disclosure statement

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References

- Aguirre-Muñoz, Z., & Pando, M. (2021). Conceptualizing STEM teacher professional knowledge for teaching ELs: Initial impact of subject matter and disciplinary literacy PD on content knowledge and practice. *Bilingual Research Journal*. doi:10.1080/15235882.2021.1970654
- Alfaro, C. (2018). The sociopolitical struggle and promise of bilingual teacher education: Past, present, and future. *Bilingual Research Journal*, 41(4), 413–427. doi:10.1080/15235882.2018.1540367
- Alfaro, C., & Bartolomé, L. (2017). Preparing ideologically clear bilingual teachers: Honoring working-class non-standard language use in the bilingual education classroom. *Issues in Teacher Education*, 26(2), 11–34.
- Alfaro, C., & Hernández, A. (2016). Ideology, pedagogy, access, and equity (IPAЕ): A critical examination for dual language educators. *The Multilingual Educator*, 8–11. <http://www.gocabe.org/index.php/communications/multilingual-educator/>

- American Educational Research Association. (2014). *Standards for educational and psychological testing*. Washington, DC: Author. https://www.testingstandards.net/uploads/7/6/6/4/76643089/standards_2014edition.pdf
- Aquino-Sterling, C. R. (2016). Responding to the call: Developing and assessing pedagogical Spanish competencies in bilingual teacher education. *Bilingual Research Journal*, 39(1), 50–68. doi:10.1080/15235882.2016.1139519
- Bakić, A., & Škifić, S. (2016). The relationship between bilingualism and identity in expressing emotions and thoughts. *Íkala. Revista de Lenguaje y Cultura*, 22(1). doi:10.17533/udea.ikala.v22n01a03
- Bristol, T. J., & Martin-Fernandez, J. (2019). The added value of Latinx and Black teachers for Latinx and Black students: Implications for policy. *Policy Insights from the Behavioral and Brain Sciences*, 6(2), 147–153. doi:10.1177/2372732219862573
- Burke, L. E. C. A., & Wallace, J. (2020). Re-examining postcolonial science education within a power-knowledge framework: A Caribbean case study. *Science and Education*, 29(3), 571–588. doi:10.1007/s11191-020-00116-8
- Buyssse, V., Castro, D. C., & Peisner-Feinberg, E. (2010). Effects of a professional development program on classroom practices and outcomes for Latino dual language learners. *Early Childhood Research Quarterly*, 25(2), 194–206. doi:10.1016/j.ecresq.2009.10.001
- Carpenter, S. (2018). Ten steps in scale development and reporting: A guide for researchers. *Communication Methods and Measures*, 12(1), 25–44. doi:10.1080/19312458.2017.1396583
- Celedón-Pattichis, S., Lunney Borden, L., Pape, S. J., Clements, D., Peters, S. A., Males, J., . . . Leonard, J. (2018). Asset-based approaches to equitable mathematics education research and practice. *Journal for Research in Mathematics Education*, 49(4), 373–389. doi:10.5951/jresematheduc.49.4.0373
- Cobb, P., McClain, K., deSilva Lamberg, T., & Dean, C. (2003). Situating teachers' instructional practices in the institutional setting of the school and district. *Educational Researcher*, 32(6), 13–24. doi:10.3102/0013189X032006013
- Creswell, J. W. (2014). *Research design. Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications, Inc.
- Creswell, J. W., & Plano, C. V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). Thousand Oaks, CA: SAGE.
- Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297–334. doi:10.1007/BF02310555
- Darder, A. (2015). *Freire and education*. New York, NY: Routledge.
- Davidson-Hunt, I. J., & O'Flaherty, R. M. (2007). Researchers, Indigenous peoples, and place-based learning communities. *Society and Natural Resources*, 20(4), 291–305. doi:10.1080/08941920601161312
- DeLyser, D. (2008). Teaching qualitative research. *Journal of Geography in Higher Education*, 32(2), 233–244. doi:10.1080/03098260701514074
- DeMonte, J. (2013). High-quality professional development for teachers: Supporting teacher training to improve student learning. *Center for American Progress*. 1–24. <https://files.eric.ed.gov/fulltext/ED561095.pdf>
- DeVellis, R. F. (2016). *Scale development: Theory and applications* (Vol. 26). Thousand Oak, CA: Sage publications.
- DiCerbo, P. A., Anstrom, K. A., Baker, L. L., & Rivera, C. (2014). A review of the literature on teaching academic English to English language learners. *Review of Educational Research*, 84(3), 446–482. doi:10.3102/0034654314532695
- Di Stefano, M., Esquinca, A., & Villanueva-Alarcón, I. (Eds.). (2023, Forthcoming). *Integrando STEAM: A guide for elementary bilingual and dual language programs*. El Monte, CA: Velázquez Press, Academic Learning Company, LLC.
- Di Stefano, M., & Villanueva-Alarcón, I. (2021). *Equity perspectives on teaching science and engineering in bilingual and dual language K-5 programs in Massachusetts and Puerto Rico*. 2021 AERA Virtual Meeting, April 9-12, 2021 <https://www.aera.net/Events-Meetings/2021-Annual-Meeting>
- Dorner, L. M., & Cervantes-Soon, C. G. (2020). Equity for students learning English in dual language bilingual education: Persistent challenges and promising practices. *TESOL Quarterly*, 54(3), 535–547. doi:10.1002/tesq.599
- Esquinca, A., de la Piedra, M. T., & Herrera-Rocha, L. (2021). Engineering design in dual language: How teachers leveraged biliteracy practices to add engineering disciplinary literacy practices. *Bilingual Research Journal*, 44(3), 298–317. doi:10.1080/15235882.2021.1970655
- Federal Emergency Management Agency (FEMA). (2021). Puerto Rico Hurricane Maria. <https://www.fema.gov/disaster/4339>
- Ferraro, M., Valdiviezo, L., McEneaney, E., & Hoang, H. (2019). *Retrofitting educators through sheltered instruction training: A longitudinal case study examining the efficacy of a five-year district-wide intervention effort*. Amherst, Massachusetts: University of Massachusetts Libraries.
- Fischer, R., & Karl, J. A. (2019). A primer to (cross-cultural) multi-group invariance testing possibilities in R. *Frontiers in Psychology*, 10, 1507. doi:10.3389/fpsyg.2019.01507
- Flores, B. B., & Claeys, L. (2019). Bilingual teacher workforce starts with English learner students. *The Learning Professional*, 40(2), 12–15.
- Fránquiz, M. E., Salazar, M. C., & DeNicolo, C. P. (2011). Challenging majoritarian tales: Portraits of bilingual teachers deconstructing deficit views of bilingual learners. *Bilingual Research Journal*, 34(3), 279–300. doi:10.1080/15235882.2011.625884

- García, O., & Wei, L. (2014). *Translanguaging: Language, bilingualism and education*. Basingstoke, UK: Palgrave MacMillan. doi:10.1057/9781137385765
- Glesne, C. (2011). *Becoming qualitative researchers* (4th ed.). Upper Saddle River, NJ: Pearson Education.
- Gonzalez, N., & Moll, L. C. (1995). Funds of knowledge for teaching in Latino households. *Urban Education*, 29(4), 443. <https://doi.org/10.1177/0042085995029004005>
- Guerrero, M., & Guerrero, M. C. (2017). El español académico: El pilar olvidado de la educación bilingüe. In M. D. Guerrero, M. C. Guerrero, L. Soltero-González, & K. Escamilla (Eds.), *Abriendo brecha. Antología crítica sobre la educación bilingüe de doble inmersión* (pp. 217–238). Albuquerque, NM: Fuente Press.
- Guerrero, M., & Lachance, J. (2018). *The national dual language education teacher preparation standards*. Albuquerque, NM: Dual Language Education of New Mexico/ Fuente Press.
- Haas, A., Januszyk, R., Grapin, S. E., Goggins, M., Llosa, L., & Lee, O. (2021). Developing instructional materials aligned to the next generation science standards for all students, including English learners. *Journal of Science Teacher Education*, 32(7), 735–756. doi:10.1080/1046560X.2020.1827190
- Howard, E. R., Lindholm-Leary, K. J., Rogers, D., Olague, N., Medina, J., Kennedy, D., ... Christian, D. (2018). *Guiding principles for dual language education* (3rd ed.). Washington, DC: Center for Applied Linguistics.
- Johnson, N. H., & Atwater, M. M. (2014). The impact of beliefs and actions on the infusion of culturally relevant pedagogy in science teacher education. In M. M. Atwater, M. L. Russell, & M. L. Butler (Eds.), *Multicultural Science Education Preparing Teachers for Equity and Social Justice* (pp. 81–102). Dordrecht, Netherlands: Springer.
- Kohli, R., Picower, B., Martinez, A. N., & Ortiz, N. (2015). Critical professional development: Centering the social justice needs of teachers. *The International Journal of Critical Pedagogy*, 6(2), 7–24.
- Lee, O. (2021). Asset-oriented framing of science and language learning with multilingual learners. *Journal of Research in Science Teaching*, 58(7), 1073–1079. doi:10.1002/tea.21694
- Lee, O., Llosa, L., Grapin, S., Haas, A., & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education*, 103(2), 317–337. doi:10.1002/sce.21498
- LOOK Act (2017) An Act Relative to Language Opportunity for Our Kids, The 192nd General Court of the Commonwealth of Massachusetts, Chapter 138. Retrieved from <https://malegislature.gov/Laws/SessionLaws/Acts/2017/Chapter138>
- Massachusetts Department of Elementary and Secondary Education (DESE) (2016). Science and Technology/ Engineering. Grades Pre-Kindergarten to 12. Massachusetts Curriculum Framework. Retrieved from <https://www.doe.mass.edu/frameworks/scitech/2016-04.pdf>
- McLeman, L., Fernandes, A., & McNulty, M. (2012). Regarding the mathematics education of English learners: Clustering the conceptions of preservice teachers. *Journal of Urban Mathematics Education*, 5(2), 112–132.
- Mejia, A., & Wilson-Lopez, A. (2016). Sociocultural analysis of engineering design: Latino high school students' funds of knowledge and implications for culturally responsive engineering education. In S. Marx (Ed.), *Qualitative research in STEM: Studies of equity, access, and innovation* (pp. 60–82). New York, NY: Routledge.
- Musanti, S. I., Marshall, M., Ceballos, K., & Celedón-Pattichis, S. (2011). Situating mathematics professional development: A bilingual teacher and researchers' collaboration. In K. Téllez, J. Moschkovich, & M. Civil (Eds.), *Latinos and Mathematics: Research on Learning and Teaching in Classrooms and Communities* (pp. 215–232). Charlotte, NC: Information Age Publishing.
- National Academies of Sciences Engineering and Medicine (NASEM). (2018). *English learners in STEM subjects: Transforming classrooms, schools, and lives* (D. Francis & A. Stephens, Eds.). Washington, DC: National Academies Press. doi:10.17226/25182
- National Academies of Sciences, Engineering, and Medicine (NASEM). (2022). *Science and engineering in preschool through elementary grades: The brilliance of children and the strengths of educators*. Washington, DC: The National Academies Press. doi:10.17226/26215
- National Research Council (NRC). (2015). *Guide to implementing the next generation science standards*. Washington, DC: National Academies Press.
- NGSS. (2021). *Next generation science standards*. Achieve. Retrieved from <https://www.nextgenscience.org/>
- Nieto, D. (2009). A brief history of bilingual education in the United States. *Perspectives on Urban Education*, 6(1), 61–72. Retrieved from http://www.urbanedjournal.org/sites/default/files/pdf_archive/61-72-Nieto.pdf
- Oxley, J., Günhan, E., Kaniamattam, M., & Damico, J. (2017). Multilingual issues in qualitative research. *Clinical Linguistics & Phonetics*, 31(7–9), 612–630. doi:10.1080/02699206.2017.1302512
- Paris, D., & Alim, H. S. (2017). *Culturally sustaining pedagogies: Teaching and learning for justice in a changing world*. New York, NY: Teachers College Press.
- Pierson, A., E., & Grapin, S., E. (2021). A disciplinary perspective on translanguaging. *Bilingual Research Journal*, 44(3), 318–334. doi:10.1080/15235882.2021.1970657
- Puerto Rico Department of Education (PRDE). (2017). *Consolidated state plan. The elementary and secondary education act of 1965, as amended by the every student succeeds act*. Retrieved from <https://de.pr.gov/>
- Rafa, A., Erwin, B., Brixey, E., McCann, M., & Perez, Z., Jr. (2020). *50-State comparison: English learner policies*. Education Commission of the States. <https://www.ecs.org/50-state-comparison-english-learner-policies/>

- Saldaña, J. (2016). *The coding manual for qualitative researchers*. Thousand Oaks, CA: Sage.
- Simic-Muller, K., Fernandes, A., & Felton-Koestler, M. (2015). "I just wouldn't want to get as deep into it": Preservice teachers' beliefs about the role of controversial topics in mathematics education. *Journal of Urban Mathematics Education*, 8(2), 53–86.
- Stacy, J., Fernández, Y., & McGovern, E. R. (2020). El Instituto: Centering language, culture, and power in bilingual teacher professional development. *Journal of Culture and Values in Education*, 3(i2), 120–137. doi:10.46303/jcve.2020.16
- Taie, S., & Goldring, R. (2017). *Characteristics of public elementary and secondary school teachers in the United States: Results from the 2015–16 national teacher and principal survey first look* (NCES 2017-072). Washington, DC: National Center for Education Statistics. U.S. Department of Education. Retrieved from <https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2017072>.
- Taju Educational Solutions (2020). *The three goals of dual language education*. Retrieved from <https://tajulearning.com/2020/09/14/the-three-goals-of-dual-language-education-ensuring-an-equity-foundation-by-design/>
- Téllez, K., & Varghese, M. (2013). Teachers as intellectuals and advocates: Professional development for bilingual education teachers. *Theory Into Practice*, 52(2), 128–135. doi:10.1080/00405841.2013.770330
- U.S. Department of Education (2015). *Dual language education programs: Current state policies and practices*. Retrieved from https://ncela.ed.gov/files/rcd/TO20_DualLanguageRpt_508.pdf
- U.S. Department of Education (2022). *Our nation's English learners*. Retrieved from <https://www2.ed.gov/dastory/el-characteristics/index.html>
- Valencia, R. R. (2010). *Dismantling contemporary deficit thinking: Educational thought and practice*. New York, NY: Routledge.
- Varg, L., Näs, H., & Ottander, C. (2022). Science teaching in upper primary school through the eyes of the practitioners. *Nordic Studies in Science Education*, 18(1), 128–142. doi:10.5617/nordina.8320
- Villanueva, I., & Nadelson, L. (2017). Are we preparing our students to become engineers of the future or the past. *International Journal of Engineering Education*, 33(2), 639–652.
- Vogel, S., Hoadley, C., Ascenzi-Moreno, L., & Menken, K. (2019). *The role of translanguaging in computational literacies: Documenting middle school bilinguals' practices in computer science integrated units*. SIGCSE '19: Proceedings of the 50th ACM Technical Symposium on Computer Science Education, 1164–1170. 2) Minneapolis MN USA.
- Warner, R. (2008). *Applied statistics: From bivariate to multivariate techniques*. Thousand Oaks, CA: Sage.
- Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, 8(1), 69–91. doi:10.1080/1361332052000341006