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Preservice secondary science and mathematics teachers' readiness to teach multilingual learners: An investigation across four teacher education programs

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Abstract

In this mixed methods study, we analyzed survey and interview data from 100 preservice secondary science and mathematics teachers enrolled in four teacher education programs (TEPs) to investigate their readiness to teach multilingual learners. We defined readiness as preservice teachers' sense of preparedness to teach multilingual learners and their understanding of effective multilingual learner instruction. We examined participants' self-reported levels of preparedness, their understanding of effective multilingual learner instruction, and sources contributing to and/or limiting their readiness. We found that participants' readiness to teach multilingual learners significantly increased between the beginning and end of their TEPs. We also found that participants' understanding of effective multilingual learner instruction was significantly associated with a higher sense of preparedness. Furthermore, we found that participants enrolled in graduate TEPs reported higher levels of preparedness than participants enrolled in an undergraduate TEP. Likewise, participants whose first language was other than or in addition to English reported higher levels of preparedness. Finally, participants identified field placement experiences, personal and professional background, and coursework as factors contributing to their readiness to teach multilingual learners. We close with recommendations for teacher educators intent on helping preservice teachers better understand and implement effective instruction for multilingual learners.

KEYWORDS
math/math education, science/science education, teacher education, teacher knowledge, teachers and teaching

Multilingual learners[1] are a large and growing population of K–12 students in the United States: They account for approximately 10% of all students across the country and approximately 19% of students in California, the context of this study (National Center for Education Statistics, 2021). Multilingual learners include students who recently immigrated to the United States, students born in the United States who speak a home language other than or in addition to English, and students who are transnational (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). They are recognized as diverse in their language and literacy background, including home language(s) and number of and proficiency in languages spoken; country of origin, ethnicity, and culture; and socioeconomic status. Indeed, "such diversity is at once a strength of the [M]L population and a complication to finding simple solutions to improving science, technology, engineering, and mathematics (STEM) outcomes for the group writ large" (NASEM, 2018, p. ix). In response to calls to better celebrate and challenge multilingual learners in science and mathematics classrooms (e.g., de Araujo et al., 2016; Lee et al., 2019), teacher education programs (TEPs) have begun to focus more intently on developing well-prepared beginning teachers (Association of Mathematics Teacher Educators [AMTE], 2017) to effectively teach these disciplines to multilingual learner students.

There is limited research, however, on how prepared preservice secondary science and mathematics teachers are to understand and implement effective multilingual learner practices at the close of their TEPs (de Araujo et al., 2018; Rutt et al., 2020). Those studies that do exist show preservice teachers continue to have room for growth at the end of their training—that they are not as ready to implement culturally and linguistically relevant instruction as TEPs would expect (e.g., Fernandes, 2012; Lyon et al., 2018; Tolbert et al., 2019). As such, the purpose of this convergent mixed methods study (Creswell & Plano Clark, 2018) was to investigate preservice secondary science and mathematics teachers' readiness to effectively teach multilingual learners. We use the term teacher readiness to capture preservice teachers' sense of preparedness to teach linguistically diverse students in their science or mathematics classrooms and their understanding of how to do so.

This study was part of a larger research project investigating preservice secondary science and mathematics teacher preparation. Over multiple years, a large team collected various data from preservice science and

mathematics teachers across six TEPs in California. We, the authors, were researchers involved with the conceptualization, data collection, and data analysis for this larger project. For the study presented here, we analyzed survey and interview data from 100 preservice science and mathematics teachers from four of the project's TEPs to better understand both their readiness to teach multilingual learners and how TEPs shaped their readiness. We posed three research questions: One, how ready did preservice science and mathematics teachers report they were to teach multilingual learners, and did their (a) reported sense of preparedness and (b) understanding of effective language, literacy, and multilingual learner (LLM) instruction change over time? Two, how did their understanding of effective LLM instruction align with their reported sense of preparedness? Three, what sources did they identify as contributing to and/or limiting their readiness to teach multilingual learners?

1 | CONCEPTUAL FRAMEWORK

We used the construct of teacher readiness to frame our study. Teacher readiness has been operationalized by researchers in different ways to align with their research purposes (e.g., Bischoff et al., 1999; Bismack et al., 2022; Moon et al., 2021). For example, in an early study, Bischoff et al. (1999) defined teacher readiness as the ability to plan, implement, and reflect on lessons appropriate for the stated objectives and aligned with current standards. In a more recent study, Bismack et al. (2022) built on the ideas of reading readiness and pedagogical content knowledge readiness to propose the construct of science practice-readiness, defined as initial understandings of science practices and how to teach them. Researchers emphasized that readiness can be understood as a collection of ideas held by preservice teachers that become more connected over time as they gain experience in teaching.

For our study, we focused on teacher readiness to teach multilingual learner students. We defined teacher readiness as consisting of two components: (a) preservice teachers' sense of preparedness to teach multilingual learners; and (b) their understanding of effective LLM instruction. Our first component, sense of preparedness, focuses on preservice teachers' beliefs about themselves—beliefs that they are competent to teach multilingual learners and that they can positively affect multilingual learners' learning outcomes (Flores et al., 2015). This sense of preparedness has been tied to the construct of self-efficacy (Bandura, 1977), the belief in one's capacity to complete a task or to achieve a goal (Coady et al., 2011; Flores et al., 2015).

Our second component of teacher readiness—effective LLM instruction—consists of four intersecting

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[1] We intentionally use the term multilingual learners as it is considered asset-based (González-Howard & Suárez, 2021). However, because data for this study were collected before this term was widely used, researchers and participants referred to multilingual learners as English learners, ELs, and/or culturally and linguistically diverse students.

principles (see also Moon et al., 2021; Roberts et al., 2017). One principle, building on students' funds of knowledge (Moll et al., 1992), emphasizes the importance of eliciting, celebrating, and using students' languages, everyday experiences, cultures, and home/community contexts to make science and mathematics more meaningful and to improve both participation and learning (Chval et al., 2021; Tolbert et al., 2019). A second principle, engaging all students in cognitively demanding work, requires teachers to implement instruction aligned with the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) or Common Core State Standards-Mathematics (CCSS-M; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) to engage students in science, engineering, and/or mathematics practices to promote high-level thinking, reasoning, and sensemaking. A third principle, supporting disciplinary language, includes the repertoire of all semiotic resources used to learn and display disciplinary knowledge and to engage in valued ways of thinking and communicating science and mathematics (Lee, 2021). Because the language and literacy demands specified in the NGSS and CCSS-M far exceed traditional instruction, teachers must attend to those aspects of language that might prove challenging for all students, including multilingual learners, and must provide adequate scaffolding for students to both interpret and produce language (Bunch, 2013; Chval et al., 2021). A fourth principle, providing opportunities for rich language production, asks teachers to engage their students in practicing the language of science and mathematics through speaking and writing (Lee, 2021; Moschkovich, 2007).

2 | LITERATURE REVIEW

Our study was informed by three bodies of prior research. One set of studies examined teachers' perceptions of their preparedness to teach multilingual learners and components contributing to their sense of preparedness (Coady et al., 2011; Flores et al., 2015; Kiramba et al., 2022; Turgut et al., 2016). Several examined general education or elementary teachers' reported levels and sources of preparedness to teach multilingual learners. These studies found that components contributing to a higher sense of preparedness included opportunities to work with multilingual learners during teacher education field experiences, specific coursework related to teaching multilingual learners, and teachers having proficiency in a language other than English (Coady et al., 2011; Kiramba et al., 2022; Turgut et al., 2016). A smaller number of studies specifically investigated science and/or mathematics teachers' sense preparedness to teach multilingual learners. Flores et al. (2015), for example, examined

science and mathematics teachers' efficacy beliefs and sources of efficacy related to teaching multilingual learners at the entry and exit of a TEP focused on developing culturally efficacious teachers. Flores et al. found that sources of efficacy included the peer support and sense of camaraderie afforded by the program's cohort model; synergistic relationships among teachers, mentors, and school leaders; and the feedback teachers received on their instructional practices.

A second set of studies examined preservice science or mathematics teachers' understanding of practices effective in teaching multilingual learners (Fernandes, 2012; Leckie & Wall, 2017; Lyon et al., 2018). As one example, Fernandes (2012) found that preservice middle school mathematics teachers adopted several best-practice strategies for teaching multilingual learners after they implemented task-based interviews to foster awareness of multilingual learners' challenges and resources; however, the task-based interviews reinforced some preservice teachers' deficit beliefs about multilingual learners and their beliefs about mathematics as a universal language. As a second example, Leckie and Wall (2017) investigated three preservice middle school science teachers' integration of disciplinary language into science units and found that preservice teachers were able to start with the core scientific concepts in the units and then determine relevant aspects of disciplinary language to support multilingual learners' access to and understanding of these concepts; however, their justifications for attention to language and how it relates to science illustrated the need to develop greater metalinguistic awareness. These studies make clear that the development of preservice teachers' understanding of practices effective in teaching multilingual learners is complex.

A third related set of studies identified components of TEPs that influence preservice science or mathematics teacher understanding of teaching multilingual learners (Heineke & Giatsou, 2020; Lavery et al., 2019; McLeman et al., 2012; Ollerhead, 2020). As one example, McLeman et al. (2012) analyzed survey data from over 200 preservice elementary and secondary teachers enrolled in urban universities to determine their conceptions of teaching mathematics to multilingual learners. They found that preservice teachers who had learned about issues related to multilingual learners through coursework and field experiences tended to have research-aligned, asset-based conceptions of teaching mathematics. As a second example, Heineke and Giatsou (2020) investigated how different components of one TEP supported preservice teachers across subject areas in learning to teach multilingual learners and found that preservice teachers' exposure to diverse multilingual learners in field placements connected to strategic coursework contributed to their learning. Taken together, then, studies of both preservice teacher preparedness and TEPs identify field placement experiences

and relevant teacher education coursework as important components in preparing teachers to teach multilingual learners.

Our study seeks to merge these three bodies of scholarship by investigating the relationship across preservice secondary science and mathematics teachers' sense of preparedness to teach multilingual learners, their understanding of effective multilingual learner practices, and components that contribute to and constrain their readiness. Our study responds to the call to go beyond case studies of individual teacher education courses (Sleeter, 2014) in that we examined a large number of participants from different TEPs to more clearly determine how preparation influences views and instructional practices (see also Lyon et al., 2018; McLeman et al., 2012). Our study also responds to the call to integrate qualitative and quantitative data to better understand similarities and differences across programs and preservice teachers' own background (McLeman et al., 2012). As such, our study is unique in its close examination of teacher readiness to teach multilingual learners across programs, STEM disciplines, and participant demographic characteristics using both quantitative and qualitative methods.

3 | METHOD

We conducted a convergent mixed methods study (Creswell & Plano Clark, 2018), administering quantitative surveys and conducting qualitative interviews both near the beginning and end of preservice participants' TEPs. Our purpose in doing so was to achieve complementarity (Johnson & Onwuegbuzie, 2004): We sought to clarify and elaborate on the results of our quantitative analysis (the survey findings) with the results of our qualitative analysis (the interview findings) to obtain a more complete understanding of preservice teachers' readiness to teach multilingual learners.

3.1 | Teacher education context

As noted, this study was part of a larger research project examining secondary science and mathematics teacher preparation at six TEPs. All six were small in size, part of the same university system, run by directors who met regularly, and connected to a system-wide STEM teacher recruitment program. Five were year-long graduate TEPs that offered a teaching credential and options for a master's degree. The sixth was an undergraduate TEP that offered only a teaching credential. For this study, the two TEPs that did not have complete datasets for at least 10 participants were excluded from analysis. Table 1 contains details about the length, degrees offered, coursework, and fieldwork for the four TEPs included in this study.

3.2 | Participants

In this study, we investigated two cohorts of participants enrolled at these four TEPs during the 2016–2017 (Year 1) and 2017–2018 (Year 2) academic years. Our 100 participants constituted 58% of all preservice secondary science and mathematics teachers enrolled in these four programs; the other 72 preservice teachers were invited to participate but declined for various reasons. Table 2 presents demographic information on participants across the four TEPs.

3.3 | Data

For this study, we examined two types of data: (a) participants' pre and post surveys; and (b) their final interviews conducted as they neared completion of their TEPs. For the three graduate TEPs, we collected data at the beginning and end of their year-long programs. For the undergraduate TEP, we collected data at the beginning and end of the last semester of their bachelor's degree when they completed their full takeover field placement.

Our survey was based on a previous instrument developed by the Effective Science Teaching for English Language Learners (ESTELL) and the related Secondary Science Teaching with English Language and Literacy Acquisition (SSTELLA) projects (Bravo et al., 2014; Tolbert et al., 2014). This instrument was shown to reliably measure constructs reflecting the principles of effective LLM instruction described in our conceptual framework (Bravo et al., 2014). Our survey included 47 items: We drew 38 Likert scale questions (using a 5-point scale) from the ESTELL/SSTELLA survey and added a nine open-ended questions adapted from the Flexible Application and Student-Centered Instruction survey (Talbot, 2017).

For this study, we focused our quantitative analysis on a subset of the Likert scale questions: one question that explicitly asked participants to rate their preparedness to teach multilingual learners; and six questions that explored participants' understanding of LLM instruction based on the principles described in Section 1(see Table 3 for the specific questions included in our analysis). As a data reduction strategy, we combined these latter six items into a factor labeled LLM instruction. The reliability of items was found to be good, calculated using a *Cronbach's alpha* (α) at 0.95. A one-factor analysis provided evidence of adequate fit of the LLM instruction items (chi-square $p = 0.08$, RMSEA = 0.05, CFI = 0.88, TLI = 0.86); this provided support that the LLM instruction items measured a single construct. The LLM items were then averaged and used in subsequent analysis. We add that this LLM instruction construct was used in a

TABLE 1 Overview of teacher education programs.

TEP	Type	Length	Credential and degrees	Coursework and Field placements	No. of multilingual learners in takeover classroom: Average (range)
1	Graduate credential program	13 months	Potential to earn MEd concurrently with credential	• University-based courses concurrent with field placements • Two multilingual learner courses and three language and literacy courses • Three consecutive field placements over the school year (two may be in the same classroom), including a literacy-focused classroom in each placement; full takeover responsibilities for one semester during the third field placement	2 (0–11)
2	Graduate credential program	11 months	Potential to earn MEd the year following the credential	• University-based courses concurrent with field placements • One language and literacy course • Two simultaneous field placements lasting the entire school year, one with full takeover responsibilities	3 (0–13)
3	Graduate credential program	12 months	Potential to earn MA concurrently with credential	• University-based courses concurrent with field placements • One multilingual learner course and one language and literacy course • Two consecutive field placements during the school year, the second one being longer and with full takeover responsibilities	3 (0–15)
4	Integrated undergraduate credential program	4 years	Earn bachelor's degree (in content area), minor in STEM education, and credential	• University-based courses • Information about multilingual learners and language and literacy integrated into other courses • Short-term field placements throughout the 4 years, plus one semester field placement with full takeover responsibilities and concurrent university seminar	6 (0–33)

Note: Full takeover responsibilities are when a preservice teacher takes over all classroom responsibilities from the mentor teacher for at least one class period.

related study—along with constructs capturing standards-based instruction and teacher self-efficacy—to explore Year 1 preservice teachers' readiness to teach science or mathematics more broadly (Moon et al., 2021).

Our second dataset was preservice teachers' final interviews, which were conducted using a semi-structured protocol (Brenner, 2006) based on our conceptual framework and that included a subset of questions about multilingual learners. All 100 participants were interviewed individually. All interviews were audio-recorded, and each lasted approximately one hour. For the purposes of this study, we examined preservice teachers' responses to the following question from the interview protocol: How prepared do you feel to teach in a culturally and linguistically diverse classroom? Interviewers asked follow-up questions to clarify or probe participant responses to this question. Examples of follow-up questions were: Where [which placement] was this? What about teaching specifically for English learners—how prepared do you feel for that? So, more individual focus and attention [are needed to support students]? Responses to these follow-up questions were also included in our analysis.

3.4 | Data analysis

To answer our first research question on preservice teachers' reported level of readiness to teach multilingual

TABLE 2 Preservice teacher participants' demographic information.

	n	TEP 1	TEP 2	TEP 3	TEP 4
Discipline					
Science	60	18	13	17	12
Mathematics	40	12	7	8	13
Gender					
Female	65	18	15	12	20
Male	35	12	5	13	5
Race/ethnicity					
White/European American	55	19	15	18	3
Asian/Asian American	17	4	3	2	8
Multiracial/ multiethnic	13	2	2	4	5
Latinx	9	4	0	1	4
Other	5	1	0	0	4
Pacific Islander	1	0	0	0	1
First language[a]					
English	78	22	20	22	14
Language(s) other than or in addition to English	22	8	0	3	11
Totals	100	30	20	25	25

Note: All demographic data were self-reported.

[a]First language(s) refers to the language(s) preservice teachers learned as children. In their interviews, some participants who reported English as their first language reported proficiency in one or more other languages as well.

learners, we examined their pre and post survey responses to determine if there was a significant change in (a) their sense of preparedness; and (b) their understanding of effective LLM instruction. More specifically, we used a repeated measures within-between-subjects analysis involving multiple dependent variables, a repeated measures MANOVA (Abu-Bader, 2010), to examine the changes in preservice teachers' sense of preparedness and their understanding of effective LLM instruction and to examine whether the change in their sense of preparedness and their understanding of effective LLM instruction over time differed by (a) TEP type (i.e., undergraduate vs. graduate), (b) discipline (i.e., mathematics vs. science), or (c) first language (i.e., a language other than or in addition to English vs. English). These three groups are our between-subjects factors. We conducted these analyses in SPSS (Version 25.0) all at once instead of conducting these separately so as not to inflate type I error (Field, 2013).

TABLE 3 Survey questions included in analysis.

Question	5-point Likert scale
• I feel well prepared to science/ mathematics to English language learners.	*Strongly Agree* to *Strongly Disagree*
• Students master and retain science/mathematics concepts most effectively when reading, writing, and talking are used in support of science/ mathematics learning.	*Strongly Agree* to *Strongly Disagree*
• English language learners need to be able to read and write proficiently in English before being taught science/ mathematics.	*Strongly Agree* to *Strongly Disagree* (reverse coded)
• Connecting science/ mathematics instruction to students' culture and communities will distract them from actually learning science/ mathematics content.	*Strongly Agree* to *Strongly Disagree* (reverse coded)
• Science/mathematics teachers are to address students' language development as well as their content understanding in science/math lessons.	*Strongly Agree* to *Strongly Disagree*
• Science/mathematics teachers are responsible for teaching students both how to read and produce science/mathematics texts.	*Strongly Agree* to *Strongly Disagree*
• How important is it for secondary science/ mathematics teachers to provide students with language supports (e.g., graphic organizers, sentence frames).	*Very Important* to *Very Not Important*

To answer our second research question, we used structural equation modeling (SEM) path analysis in Mplus 8.7 (Muthen & Muthen, 2021) to investigate if preservice teachers' understanding of effective LLM instruction correlates with their sense of preparedness. Path analysis is an approach to modeling explanatory relationships between observed variables. Within the path analysis framework, independent variables are assumed to have no measurement error, whereas dependent variables may contain residual terms. Residual terms are the parts left unexplained by the independent variables. For example, other constructs we have not measured and/or that are outside of our variables of interest can impact preservice teachers' sense of preparedness (e.g., subject matter preparation, amount of previous teaching

experience). Preservice teachers' sense of preparedness, the dependent variable, was predicted by their understanding of effective LLM instruction, the independent variable. We also included TEP type, discipline, and first language as covariates in the model.

To answer our third research question on sources of readiness to teach multilingual learners, we qualitatively analyzed transcript data from the final interviews. We began by identifying responses to the relevant interview question: How prepared do you feel to teach in a culturally and linguistically diverse classroom? We then identified preservice teachers' descriptions of their sources of readiness and inductively coded these descriptions using emergent codes that became relevant during analysis (Saldaña, 2016). See Table 4 for the codes and their descriptions used in this analysis. We established intercoder reliability in a stepwise fashion: We initially coded the same responses individually, calculated the kappa coefficient, and then met to discuss disagreements until

consensus was reached. This process continued until we had coded one-third of the responses and had consistently reached a kappa coefficient greater than 0.80, which indicates a high level of agreement (MacPhail et al., 2016). We then coded the remaining two-thirds of the responses independently. After coding was completed, we identified patterns in codes across the entire sample, by TEP type, and by first language.

4 | FINDINGS

4.1 | Changes in preservice teachers' sense of preparedness and their understanding

In answer to our first research question, the results of the tests of within-subject effects showed a significant change in participants' sense of preparedness ($F_{(1,87)} = 63.35$,

TABLE 4 Codes and subcodes used for analysis of sources of readiness.

Code	Subcode	Description
Field experiences		Preservice teacher described the ways their teaching placements prepared or failed to prepare them to work effectively with multilingual learners.
	Multilingual learners in placement	Discussed teaching multilingual learners in their placement.
	Few multilingual learners in placement	Discussed the presence of few to no multilingual learners in their placement.
	Range and type of linguistic diversity	Discussed the number and proficiency levels of language spoken by their students.
	Critique of placement	Identified limitations of their placement.
Personal and professional background		Preservice teacher described the ways their own background prepared or failed to prepare them to work effectively with multilingual learners.
	Childhood experiences	Discussed growing up in a community or having attended K–12 schools that were culturally and linguistically diverse.
	Disposition	Expressed a desire to work with culturally and linguistically diverse students.
	Multilingual	Grew up multilingual.
	Learned an additional language	Studied a language other than English but did not grow up multilingual.
	Worked with diverse communities	Worked with culturally and linguistically diverse populations prior to starting their credential.
	Critique of own background	Identified limitations of their personal background (e.g., not being able to speak their students' home languages).
Teacher education coursework		Preservice teacher described the ways their teacher education coursework prepared or failed to prepare them to work effectively with multilingual learners.
	TEP coursework	Discussed teacher education coursework in general or discussed specific courses.
	Critique of coursework	Identified limitations in coursework either in general terms or with respect to a particular course.
Other		Preservice teacher described another source of readiness to teach multilingual learners.

$p < 0.001$) and their understanding of effective LLM instruction ($F_{(1,87)} = 20.73$, $p < 0.001$) between the beginning and end of their TEP. Mean scores for preservice teachers' sense of preparedness were significantly greater at the end of their TEP ($M = 4.34$, $SE = 0.06$) than at the beginning ($M = 3.38$, $SE = 0.12$), $p < 0.001$. Likewise, mean scores for their understanding of effective LLM instruction were significantly greater at the end of their TEP ($M = 4.08$, $SE = 0.09$) than at the beginning ($M = 3.64$, $SE = 0.09$), $p < 0.001$. The results of the tests of between-subject effects showed no significantly different changes in sense of preparedness and understanding of effective LLM instruction over time by TEP type, discipline, or first language.

4.2 | Relationship between preservice teachers' understanding and sense of preparedness

To answer our second research question on the possible relationship between preservice teachers' understanding of effective LLM instruction and their sense of preparedness, we conducted an SEM path analysis. The results of this path analysis showed that preservice teachers' understanding of effective LLM instruction was significantly associated with a higher sense of preparedness ($\beta = 0.276$, $p < 0.01$) when controlling for the effects of their TEP type, discipline, and first language (see Figure 1). If all other conditions were the same, preservice teachers enrolled in graduate TEPs thought that they were better prepared to teach science or mathematics to multilingual learners than those enrolled in the undergraduate TEP ($\beta = 0.242$, $p < 0.05$). Preservice teachers whose first language was English thought that they were less prepared to teach science or mathematics to

multilingual learners than those whose spoke a first language other than or in addition to English ($\beta = -0.194$, $p < 0.05$). Furthermore, preservice teachers' discipline (mathematics or science) was not significantly associated with their sense of preparedness ($\beta = 0.065$, $p = 0.497$); as such, we did not include preservice teachers' discipline in Figure 1.

4.3 | Sources of readiness

To answer our third question on sources that contributed to or limited preservice teachers' readiness, we turned to their qualitative responses from interviews. We identified three sources that preservice teachers commonly reported as shaping their readiness to teach multilingual learners. From most to least common, these three sources were field placement experiences, personal and professional background, and teacher education coursework. The order of how often these three sources were discussed was the same across universities except for TEP 2, whose participants discussed coursework more often than background. We clarify that some preservice teachers identified a number of these sources in their responses; some, only one; and a few, none. We used pseudonyms for participant names in the examples that follow.

4.3.1 | Field placement experiences

We found that 68 participants discussed their field placement experiences when referring to their readiness to teach multilingual learners; of these, 52 preservice teachers reported that having first-hand experiences working with culturally and linguistically diverse learners in their field placements informed their sense of
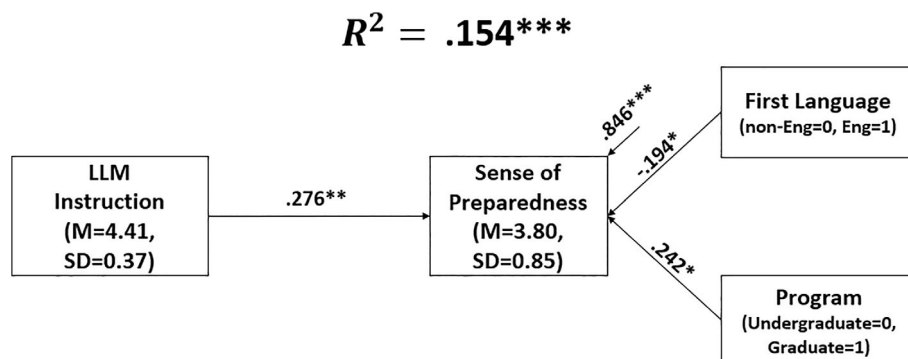

FIGURE 1 Structural equation model path diagram of LLM instruction and sense of preparedness. Path coefficients are all standardized. The effects of two covariates are on the right side of the diagram. R^2 represents the variance in preservice teachers' sense of preparedness explained by this model and residual variance not explained by this model is on the right corner of the "Sense of Preparedness" variable box. Significant relationships are marked with * in this diagram. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

readiness. For example, Daisy, a preservice science teacher from TEP 4, described how she had a "false sense of security" at the beginning because she believed a handful of routine strategies would be sufficient to support her multilingual learners. She described her field experiences as a "reality check," observing that "it wasn't until the middle of my credentialing placement that I realized how wrong I was. They needed a lot more. There was a lot more scaffolding that needed to happen." Daisy gave several examples of how she subsequently modified her teaching practice, describing how she began to integrate drawing, kinesthetics, and think-pair-shares in different ways to give multilingual learners multiple opportunities to communicate their scientific understandings. She concluded that in the end "because of my credentialing placement, and also because of the theories and practices that we learned about in our credentialing program as well, I feel a lot more prepared." Here, Daisy emphasized the importance of using appropriate scaffolds to support her multilingual learners.

At the same time, a limited number of preservice teachers who had multilingual learners in their field placements reported that they were not necessarily ready to teach multilingual learners in particular contexts. Specifically, they expressed reservations about their readiness to teach newcomer students, to teach classes comprised of large numbers of multilingual learners, or to teach multilingual learners who spoke a wide variety of home languages. For example, Timmy, a preservice mathematics teacher from TEP 1, described the limited range of linguistic diversity in his field placement classrooms:

> There really isn't that much diversity, and linguistic diversity, overwhelmingly English and Spanish, [in my placements]. I have two Tagalog-speaking students, which is unheard of in [city].... And if I were to go somewhere like San Francisco, where you might see six or seven different languages in a class, I don't know how prepared I would be.

Timmy indicated that he was not sure how prepared he would be "addressing multiple languages in a really diverse, truly culturally diverse class" because he had not had the opportunity to experience this kind of diversity in his field placement.

Sixteen preservice teachers remarked that they had few to no multilingual learners in their field placements and reported that this constrained their sense of readiness. In particular, they indicated that they did not have opportunities to apply the strategies they had learned in their coursework or to develop practical, rather than theoretical, knowledge of how to teach multilingual learners. Janelle, a preservice mathematics teacher from TEP 2, explained:

> I've learned a lot of tools and strategies to help specifically students who are English language learners in class.... I haven't had a chance to practice them as much because I don't have any English language learners in either of my student teaching placements. I think that that's one area for me that I'm concerned about because I haven't had the practice. I do think that I have the knowledge and the tools, and I know things that I can do to help those students be successful in math, but I also haven't gotten to practice them with the help of a mentor teacher and I haven't had that chance to try things out yet.

We return to the presence or absence of opportunities to practice teaching multilingual learners in field placements in our description of teacher education coursework.

Furthermore, we compared how preservice teachers discussed field placement experiences as a source of readiness across TEP types (i.e., undergraduate vs. graduate) and preservice teachers' first language backgrounds (i.e., first language instead of or in addition to English vs. English as first language). We found that preservice teachers discussed field placement experiences similarly across program types and first languages.

4.3.2 | Preservice teachers' own personal and professional background

We found 53 participants referred to their personal and professional background in discussing their readiness to teach multilingual learner students. Personal and professional background included participants' dispositions toward working with diverse students, their own home and community experiences, and their own languages spoken. Thirty of these 53 preservice teachers noted their positive disposition toward teaching multilingual learner students as contributing to their sense of readiness. These preservice teachers described having respectful, sensitive, or caring attitudes toward diverse students; a desire to work with diverse populations; and/or a willingness to know students, support students, and use students' ideas and experiences to inform their teaching. For example, Claire, from TEP 1, stated:

> I feel prepared [as a beginning science teacher] because I feel like the first thing that a teacher needs is to be sensitive of [culturally and linguistically diverse] students' needs and to be aware, and I feel sensitive and aware. There's always room for improvement, of course. There's always more to learn about how to better facilitate for those students, and I think I'm not immune to that, but I think that the first step is I need to be aware. I need to know what I can do, and I need to know what these students need.

Fourteen of the 53 preservice teachers described their own experiences living or working in diverse contexts as contributing to their sense of readiness. For example, Kevin, a preservice mathematics teacher from TEP 4, said:

> I grew up in a diverse neighborhood and went to a diverse middle school and high school where over 70% of the students are students of color. I feel that, from personal experience, I had the luxury to be in an environment full of students of different ethnicities and cultural backgrounds and also various students with different levels of English competency. So, I feel that I'm able to connect with students in that manner; to be able to recognize some of the difficulties that students have and be able to accommodate for those needs through my course learnings at [program name].

Kevin explained how his own school and community experiences—in interaction with coursework—helped him effectively meet the needs of his multilingual learner students.

In addition, 17 of the 53 preservice teachers described their own language backgrounds as contributing to their readiness, including their own experiences as multilingual learners or their proficiency in languages other than English. As one example, Wei, a preservice science teacher from TEP 4, noted: "English is my second language. And so, I feel having the personal experience with having to learn material in a new language gives me a different viewpoint and...a fair amount of confidence in modifying curriculum." As a second example, Sienna, a preservice science teacher from TEP 2, shared that she had "to learn French really fast" when she went to school in Paris. "So, I've been in the situation of an English language learner, someone coming from somewhere else that does not fit in." She added that "learning other languages and learning other cultures" as she "lived around the world" helped her teach multilingual learners.

Although we found that many preservice teachers described their personal and professional backgrounds as contributing positively to their sense of readiness to teach multilingual learners, a limited number of participants did discuss aspects of their personal and professional backgrounds as constraining their sense of readiness. These preservice teachers tended to note limitations in their own knowledge of their students' home languages, and/or concerns about connecting with students because of differences between their own and their students' backgrounds. The former point was illustrated by Mia, a preservice science teacher from TEP 1, who said, "I think what would help me feel more prepared would be learning Spanish in this case or learning the language that my students are coming in knowing."

Furthermore, we compared how preservice teachers discussed personal and professional background as a source of readiness across TEP types and first language. Largely, preservice teachers discussed personal and professional background similarly by TEP type and language background. However, there was one notable difference found at their intersection: 73% (8/11) of preservice teachers who spoke a first language in addition to or instead of English from the graduate programs talked about the importance of speaking multiple languages, specifically being a multilingual learner themselves; in contrast, only 9% (1/11) from the undergraduate program did so. This difference was particularly striking given that 44% (11/25) of all preservice teachers from the undergraduate program spoke a first language in addition to or instead of English in comparison to 15% (11/75) from the graduate programs.

4.3.3 | Teacher education coursework

We found that 36 participants identified teacher education coursework as a source of readiness to teach multilingual learner students. The majority of these preservice teachers viewed their coursework as helpful in learning resources and strategies needed to successfully teach diverse students. Matthus, a preservice science teacher from TEP 1, explained that he had learned how to both challenge and support multilingual learner students in his coursework:

> With the classes that we've had, I think that a huge focus has been on every level, how can we support these students and how can we make sure that not only are we

supporting them, but we're still challenging them a lot of the way, right? ... The focus hasn't just been like, "Okay, well, let's give everyone sentence starters," and then were good. It's been like, "How can you push them while making sure that they're not frustrated?"

Similarly, Lacey, a preservice mathematics teacher from TEP 3, emphasized that she had learned the importance of providing her multilingual learner students with cognitively demanding work:

> From everything I've read, the most important part is being able to scaffold the instructions so that even if, say, they're not completely fluent in English, they can still obtain the different concepts and ideas despite the language. They don't need to have, I guess, dumbed down curriculum. They can achieve at the same level as everyone else.

If both supported and challenged, Lacey explained, multilingual learners could excel in learning.

While most preservice teachers indicated that their programs provided coursework to help them understand how to support multilingual learner students, a limited number of participants stated that they wished their courses had been of higher quality or had spent more time on strategies and resources they could use to teach multilingual learners. Brandon, a preservice mathematics teacher from TEP 2, emphasized this latter point:

> I wish we had spent more time on those topics. There was one week in the methods class that was spent on ELs, students with diverse language backgrounds, and then there was another week spent on just differentiated instruction in general. I think both of those could have easily been expanded to two weeks, three weeks if time had allowed for it.

As described in our findings on field placement experiences, some preservice teachers expressed concerns about coursework tied to their placements: They could not practice what they learned in their courses because they had no multilingual learners in their placements. As Kayleigh, a preservice science teacher from TEP 2, explained, "Yeah, I've had a class on it, but I haven't been able to put anything into practice yet. I have no English learners in my placements." This

directly ties to our finding reported under field placement experiences.

As with the other reported sources of readiness, we compared preservice teachers' discussions of coursework by TEP type and first language. We found no substantive differences.

5 | DISCUSSION AND IMPLICATIONS: STRENGTHENING READINESS TO TEACH MULTILINGUAL LEARNERS

Our findings make clear that preservice teacher participants reported a higher level of readiness to teach multilingual learners at the close of their TEP than near the beginning. In answer to our first research question, we found that both preservice teachers' sense of preparedness and their understanding of LLM instruction significantly improved from the beginning to the end of their program. This held regardless of their TEP type, discipline, or first language. These changes were expected: Other studies have also found preservice secondary science and mathematics teachers' sense of preparedness (Flores et al., 2015) and understanding of multilingual learner instruction (Fernandes, 2012; Leckie & Wall, 2017; Lyon et al., 2018; Moon et al., 2021) improved after completing their TEP. Importantly, findings from our qualitative analysis resonate with these changes as preservice teachers discussed field experiences and coursework as sources of their readiness.

In answer to our second research question, we narrowed our focus to the survey data collected near the end of preservice teachers' TEPs and examined the relationship between their understanding of LLM instruction and their sense of preparedness. From this analysis, we found that those enrolled in a graduate TEP had a higher sense of preparedness than those enrolled in an undergraduate TEP, which is similar to findings from a related study (Moon et al., 2021). This difference between graduate and undergraduate preservice teachers might be explained, in part, because the graduate TEPs required completion of at least one course that specifically addressed LLM instruction, while the undergraduate TEP did not. Both Turgut et al. (2016) and Kiramba et al. (2022) found preservice teachers with specific coursework on how to teach multilingual students reported higher levels of preparedness to teach these students. Additional structural differences between the graduate and undergraduate TEPs might have contributed to this finding as well. As examples, the preservice teachers in the graduate programs completed courses carefully integrated with each other and with field placements in an intense year

of work, while preservice teachers in the undergraduate program completed education courses and field placements spread out over 4 years. The preservice teachers in the undergraduate TEP also undertook their takeover placement after completing their coursework, rather than concurrently as in the graduate TEPs (see again Table 1 for information about each program). Further investigation is needed to determine if and how these differences in program structure contribute to differences in readiness to teach multilingual learners.

Also related to our second research question, we found that preservice teachers whose first language was not English had a higher sense of preparedness to teach multilingual learners than those whose first language was English. This is similar to what Coady et al. (2011) found in their study of preservice elementary teachers. This finding also connects to our analysis of interview responses for our third research question: We found that some preservice teachers noted that their own experiences as multilingual learners contributed to their sense readiness. They shared that they understood their multilingual learner students, at least to some extent, because they had been multilingual learner students themselves.

In answer to our third research question, we found that field placements, teacher education coursework, and personal and professional background were the three most commonly discussed sources of preservice teachers' sense of readiness. Regarding field placements, participants who had multilingual learners in their classrooms emphasized the importance of having opportunities to teach these students. However, some preservice teachers expressed concerns about the limited range of linguistic diversity present in their placements. Others who had few to no multilingual learners in their classrooms reported concerns about not having adequate opportunities to teach multilingual learners, and to practice what they had learned in their coursework. For preservice teachers in our study, then, field placements and coursework seemed to act in synergistic ways to contribute to their sense of readiness to teach multilingual learners. As such, we echo recommendations from previous studies that TEPs ensure that all preservice teachers have sustained opportunities to teach multilingual learners in their placements and that such opportunities are coordinated with their coursework (Heineke & Giatsou, 2020; Lavery et al., 2019). Both AMTE (2017) and the National Science Teachers Association (NSTA, 2017) also recommended TEPs ensure their research- and standards-based goals are integrated into higher education coursework and field placements in schools. We add that TEPs should specifically attend to the range of linguistic diversity present in their preservice teachers' field placements.

Further related to our third research question, we found that preservice teachers' personal and professional backgrounds contributed to their reported level of readiness to teach multilingual learners. More specifically, we found that many preservice teachers described dispositions that demonstrated their willingness to work hard to reach all students, regardless of challenges they might encounter. This resonates with calls from AMTE (2017) and NSTA (2017) for TEPs to foster dispositions for effective teaching, including a sense of responsibility to students and a dedication to continued professional growth, in their preservice teachers. While having dispositions do not necessarily guarantee that preservice teachers will be adequately prepared to teach multilingual learners, we recommend TEPs work to elicit their preservice teachers' personal and professional views and experiences and to provide them with the time and space needed to cultivate dispositions that will be generative rather than limiting (see also Ollerhead, 2020). In these ways, TEPs can support preservice teachers in developing the types of dispositions, including a positive stance toward linguistic diversity and an inclination to advocate for their multilingual learners that Lucas and Villegas (2013) argued are critical components of linguistically responsive teaching.

Finally, again connected to personal and professional backgrounds, we found that some preservice teachers tied their level of readiness to their (in)ability to speak multiple languages. For example, preservice teacher participants who had been multilingual learners themselves viewed their previous schooling experiences and their ability to speak multiple languages as an asset in teaching multilingual learners in their own classrooms. We also found in our path analysis, connected to our second research question, that preservice teachers who spoke a first language other than or in addition to English had a greater sense of preparedness to teach multilingual learners than their English only colleagues. Previous studies have determined that preservice and practicing teachers with a bilingual certification have more asset-oriented knowledge and beliefs about multilingual learners than their non-certified colleagues (Gandarà et al., 2005; Tolbert & Knox, 2016). As such, TEPs should recognize that preservice teachers' fluency in multiple languages can influence their sense of readiness to teach multilingual learners. While effective instruction for multilingual learners does not and should not rest on speaking the same language as one's students, all preservice teachers—not just those earning a bilingual certification—should have the opportunity to learn another language as part of their program. TEPs can also offer service-learning opportunities for preservice teachers to gain more experience with the languages and cultures of the local community (Cone, 2012; Wallace, 2013).

6 │ LIMITATIONS

We recognize that our study is not without its limitations. First, for our quantitative analysis, although our factor analysis of LLM instruction was found to have adequate fit, we did not create a new measure; additional data are needed to prove the reliability and validity of this factor as a measure. Second, for our qualitative analysis, we recognize that we analyzed a subset of questions from a larger interview that included other topics, thus leaving less time in the interviews to ask follow-up questions to further probe participants' responses and obtain richer data about their teaching of multilingual learners. Third, only one of the TEPs studied was an undergraduate program. As such, it is difficult to determine if differences identified between preservice teachers in this program and those in the three graduate programs would hold had more undergraduate programs been included. We note that TEPs in California are predominately graduate programs. This leads to a fourth limitation, namely that our study was situated in the context of California teacher education, which may limit the extent that our study can be replicated in or our findings be compared to other states or countries.

7 │ CONCLUSION

In closing, this study provides needed insight into preservice secondary science and mathematics teachers' readiness to teach multilingual learners. To better prepare preservice teachers, TEPs should more carefully orchestrate field placement opportunities with coursework so that all gain experience working with multilingual learners and so that limitations in the range of linguistic diversity present in placements can be explicitly discussed in coursework. TEPs should also encourage preservice teachers to use their own experiences learning and using multiple languages as an asset in their instruction—and to provide opportunities for those who do not speak multiple languages to learn to do so. In these ways, TEPs can better support their preservice teachers in providing all multilingual learner students with substantive opportunities to excel in reform-based science and mathematics (National Council of Teachers of Mathematics, 2018; Schwarz et al., 2017).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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