Abstract

Research in science education with multilingual learners (MLs) has expanded rapidly. This rapid expansion can be situated within a larger dialogue about what it means to provide minoritized students with an equitable education. Whereas some conceptions of equity focus on ensuring all students have access to the knowledge, practices, and language normatively valued in K-12 schools (*equity as access*), increasingly prominent conceptions focus on transforming those knowledge, practices, and language in ways that center minoritized students and their communities (*equity as transformation*). In this article, we argue that conceptions of equity provide a useful lens for understanding emerging research in science education with MLs and for charting a research agenda. We begin by tracing how conceptions of equity have evolved in parallel across STEM and multilingual education. Then, we provide an overview of recent developments from demographic, theoretical, and policy perspectives. In the context of these developments, we provide a conceptual synthesis of emerging research by our team of early-career scholars in three areas: (a) learning, (b) assessment, and (c) teacher education. Within each area, we unpack the research efforts in terms of how they attend to equity as access while pushing toward equity as transformation. Finally, we propose a research agenda for science education with MLs that builds on and extends these efforts. We close by offering recommendations for making this research agenda coherent and impactful: (a) being explicit about our conceptions of equity, (b) paying attention to the interplay of structure and agency, and (c) promoting interdisciplinary collaboration.

Keywords: equity, multilingual learners, learning, assessment, teacher education

Science Education With Multilingual Learners:

Equity as Access and Equity as Transformation

Over the past decade, research in science education with multilingual learners (MLs) has expanded rapidly. This rapid expansion can be attributed to three intersecting developments. First, K-12 science classrooms have become increasingly linguistically diverse. In the U.S. context, approximately one in five students reports speaking a language other than English at home, and among this heterogeneous population of MLs is a fast-growing subset of students bureaucratically classified by their schools as English learners (National Center for Education Statistics [NCES], 2022). Second, these demographic shifts have coincided with the proliferation of theories that move beyond narrowly conceived definitions of science and language learning to embrace more expansive conceptualizations (e.g., National Academies of Sciences, Engineering, and Medicine [NASEM], 2018; National Research Council [NRC], 2012). Third, these expansive conceptualizations have laid the groundwork for U.S. K-12 policy initiatives across STEM education (e.g., Next Generation Science Standards [NGSS] Lead States, 2013b) and multilingual education (e.g., WIDA Consortium, 2020) that, collectively, influence the teaching, learning, and assessment that occurs in linguistically diverse science classrooms across the nation. These developments at the intersection of shifting demographics, theories, and policies across STEM and multilingual education make the present moment ripe for reflecting on the contemporary landscape of science education with MLs and envisioning where this rapidly expanding research area might be headed next.

The ongoing developments in science education with MLs can be located within a larger dialogue about what it means to provide an equitable education to minoritized students (NASEM, 2022), including Black, Latinx, and Indigenous students, who are subject to persistent marginalization in U.S. schools at the intersection of multiple identity markers (e.g., language, race, gender; Takeuchi et al., 2022). At the heart of this dialogue have been conceptions of equity itself (e.g., Calabrese Barton & Tan, 2020; Gutiérrez, 2009; Jensen & Thompson, 2020; Morales-Doyle et al., 2021; Morita-Mullaney et al., 2020; NASEM, 2022; Philip & Azevedo, 2017; Santo et al., 2019; Secada, 2008; Warren et al., 2020). Some conceptions of equity focus on ensuring all students have access to the knowledge, practices, and language normatively valued in schools (i.e., equity as access). However, these conceptions have been criticized for perpetuating an inequitable status quo and leaving intact an education system responsible for marginalizing minoritized students in the first place (Bang & Vossoughi, 2016). Thus, increasingly prominent conceptions of equity focus on transforming the knowledge, practices, and language valued in schools in ways that center minoritized students and their communities (i.e., equity as transformation). The increasing prominence of equity as transformation has been bolstered by increasing awareness in the broader society of systemic inequities facing racially and linguistically minoritized individuals and communities (NASEM, 2021, 2022). In this article, we argue that conceptions of equity provide a useful lens for understanding emerging research in science education with MLs and for charting a path toward a coherent and impactful research agenda.

The purpose of this article is twofold: to (a) highlight multiple conceptions of equity that underpin emerging research in science education with MLs and (b) propose a research agenda that can move this research area forward. To achieve these interrelated goals, we first review evolving conceptions of equity across STEM and multilingual education. Second, we provide an overview of recent developments in science education with MLs from demographic, theoretical, and policy perspectives. Third, we synthesize emerging research by our team of early-career scholars in three areas that are central to MLs' science education experiences: (a) learning, (b) assessment, and (c) teacher education. Within each area, we unpack how the research efforts attend to equity as access while pushing toward equity as transformation. Finally, we propose a research agenda for science education with MLs that builds on and extends these research efforts. By synthesizing where we are and charting where we can go, we aim to advance the knowledge base on how to provide MLs with the transformative science education experiences they need and deserve.

Importantly, we do not aim to provide a comprehensive or systematic review of the literature. Instead, we provide a conceptual synthesis of our collective research efforts toward the goal of making explicit conceptions of equity that have often remained tacit in individual studies (including our own previous studies). Such a conceptual synthesis is warranted from both theoretical and empirical perspectives. Theoretically, a conceptual synthesis offers a unique opportunity for reflection, a central practice of equity-centered work (see Settlage & Williams, 2022, for a set of reflective essays on equity-centered science education). For example, in a retrospective critique of their own research efforts, Basile and Azevedo (2022) underscored the importance of reflection for fostering "continued ideological growth and development to more authentically step forward in our STEM education equity and social justice work" (p. 1084).

Empirically, a conceptual synthesis is timely given the rapid expansion of research in science education with MLs. As with any fast-growing research area, the accumulation of studies risks producing incoherence unless it is accompanied by efforts to "zoom out" and take stock, at a higher level of abstraction (Bass, 2017), of how diverse research efforts may be manifestations of shared goals and overarching constructs (e.g., conceptions of equity). To borrow Lubienski and Gutiérrez's (2008) metaphor of educational equity as a puzzle, we may be gathering many pieces of the "equity for MLs in science education" puzzle but fail to see the full picture that the pieces make up. This, in turn, compromises the potential impact of the knowledge produced. As will be emphasized throughout the article, the risk of incoherence (and the attendant consequence of attenuated impact) is even greater in an interdisciplinary research area, such as science education with MLs, that involves integrating perspectives from multiple fields in a principled manner (e.g., science education and multilingual education). Thus, a conceptual synthesis at this crucial juncture offers the potential to envision how the research community as a whole might continue building knowledge in this area in coherent and impactful ways.

At the outset, we clarify four points about our approach. First, we adopt the term "multilingual learners," or MLs, to refer to students who use a named language other than English in school, home, and/or community contexts (In a later section, we elaborate on the complicated and contentious landscape for describing this student population.). Second, while our primary focus is MLs in science education, we address the intersection of science with other STEM subjects, such as computer science and engineering. This reflects a broader trend toward convergence of multiple STEM disciplines (e.g., National Science Foundation [NSF], 2020) and subjects (e.g., NRC, 2012), which we argue is particularly important with MLs, who too often experience fragmented and decontextualized educational programs (e.g., pull-out programs aimed at remediating their perceived deficits) that exclude them from rigorous and meaningful STEM learning (NASEM, 2018). Third, although we situate our argument in the context of U.S. K-12 education, the conceptions of equity we discuss transcend national boundaries and will likely resonate in education contexts across the globe where students are learning STEM in and through an additional language. Fourth, we use examples from our own work as early-career scholars with diverse disciplinary, linguistic, racial, and ethnic positionalities. At the same time, we contextualize this work broadly within multiple fields that have contributed to knowledge in science education with MLs. In particular, we recognize the contributions of senior scholars who pioneered and established the foundation for this expanding research area and have mentored and advised us over the years in various capacities. The influence of these scholars across multiple fields as well as on our scholarship specifically will be evident throughout the article, particularly in the following sections that address conceptions of equity as well as demographic, theoretical, and policy perspectives on science education with MLs.

Conceptions of Equity: From Access Toward Transformation

While the centrality of equity in education is broadly recognized (e.g., Hess & Noguera, 2021), the meaning of this concept is often tacitly assumed rather than explicitly defined. Over the past several decades, scholars across STEM and multilingual education have proposed various conceptions of equity and the implications of different conceptions for minoritized students, including MLs. This dialogue about equity has been multi-voiced (Bakhtin, 1981; Valdés, 2004), with scholars proposing distinct, yet overlapping, conceptions that have not always been "heard by scholars who are members of other closely related professions" (Valdés, 2004, p. 103). We trace the evolution of this dialogue across multiple fields, including science and engineering, mathematics, computer science, and multilingual education. We conceptualize "multilingual education" broadly to encompass multiple disciplines (e.g., sociolinguistics, anthropology) that have been brought to bear on issues related to the education of MLs.

In science education, early writings by Secada (2008) surfaced multiple conceptions of equity that had been circulating in the field. These conceptions included, on the one hand, equity as achievement and representation of historically underrepresented groups in the STEM workforce and, on the other hand, equity as an expression of social justice. Secada's multiple conceptions of equity were subsequently featured in *A Framework for K-12 Science Education* (NRC, 2012, p. 278; see Box 11-1 titled "What is Equity?") and the NGSS, which highlighted its equity focus with the slogan "all standards, all students" (NGSS Lead States, 2013a). Though Secada did not recommend any particular conception of equity, he underscored the importance of making conceptions explicit, since "different understandings of equity itself affect the quality and form of science instruction available" to students learning English (p. 167).

In mathematics education, Gutiérrez (2009) criticized prevailing conceptions of equity that focused narrowly on closing achievement gaps, which reflected the accountability focus of U.S. K-12 education at the turn of the century (see Lubienski & Gutiérrez, 2008, for a debate over "gap gazing"). In response to this narrow focus, Gutiérrez argued that "equity must be framed with both dominant and critical definitions" (p. 5). Thus, she conceptualized equity along two axes: dominant and critical. Whereas the dominant axis consisted of access and achievement dimensions, the critical axis consisted of identity and power dimensions. Gutiérrez succinctly dubbed the dominant axis as "playing the game" (i.e., learning mathematics as it is currently constituted) and the critical axis as "changing the game" (i.e., rethinking what "counts" as mathematics). Overall, Gutiérrez characterized the pursuit of equity as a tension-filled enterprise that required seeking balance between dominant and critical axes.

Returning to science education, Philip and Azevedo (2017) reinvigorated the dialogue around conceptions of equity, arguing that, despite prior attempts to define the concept, it was still "a moving target" (p. 526; see also a discussion of connections between equity and related constructs, such as "justice"). Criticizing the "dehistoricized and depoliticized meanings of equity" in the latest standards-based reform in science education and the "accompanying assumptions and goals of equity-oriented research and practice" (Philip & Azevedo, 2017, p.

526), Philip and Azevedo proposed four discourses of equity: (a) increasing students' achievement, access, and inclusion; (b) increasing students' interest in and identity with science; (c) broadening what "counts" as science; and (d) exploring the intersection of science with social movements. Applying Philip and Azevedo's four discourses to analyze a set of articles on NGSS-designed instructional materials (Campbell & Lee, 2021), Tzou et al. (2021) found that materials tended to reflect the first two discourses while falling short of reflecting the latter two.

In computer science education, a relative newcomer to K-12 STEM education, scholars have recently reviewed conceptions of equity circulating in the field (e.g., Madkins et al., 2020; Santo et al., 2019) and proposed critical justice-oriented approaches to computer science education (e.g., Vakil, 2018). Reviews by Santo et al. (2019) and Madkins et al. (2020) pointed to the prominence of conceptions that emphasize broadening participation in computer science for specific student groups (e.g., girls of color), captured by initiatives such as Computer Science For All (https://obamawhitehouse.archives.gov/blog/2016/01/30/computer-science-all). In contrast, emerging conceptions of equity seek to go beyond ensuring access to computer science as it is currently constituted to transforming what "counts" as participation in computing. These conceptions of equity emphasize empowering students to "grapple with varied forms of social inequality and ethics issues associated with computing technologies" (Santo et al., 2019, p. 2), "integrate their computer science knowledge with efforts to solve issues relevant to minoritized communities" (Madkins et al., 2020, p. 6), and consider the ethical and political implications of computer science work (Vakil, 2018). Santo et al. (2019) concluded that there is "no single, agreed upon understanding of equitable computer science education," which has significant implications "when the rubber hits the road of educational practice" (p. 1).

In multilingual education, the dialogue about equity has been equally vibrant, although this dialogue has often occurred separately from the dialogue in STEM education. Most recently, conceptions of equity have surfaced in a contentious debate over the merits of teaching the variably defined construct of “academic language” to minoritized students, especially MLs (see special issues by Jensen & Thompson, 2020, and Thompson, 2021). Jensen and Thompson (2020) describe how, for some scholars, “equity means teaching [academic language] to minoritized students” (p. 2), since this equips them with dominant ways of using language in academic contexts (e.g., Schleppegrell, 2004). In contrast, scholars working from critical perspectives argue that “equity may be undermined by teaching [academic language] to these students” (Jensen & Thompson, 2020, p. 2), since this privileges white, upper-middle-class ways of using language while casting minoritized students’ (trans)languaging practices as inherently nonacademic (e.g., Flores & Rosa, 2015; see the next section for further discussion of translanguaging theory). Likewise, both dominant and critical conceptions of equity have surfaced in a related debate over the merits of dual language programs, an increasingly prevalent instructional arrangement for teaching non-English-dominant MLs alongside their English-dominant peers (Cervantes-Soon et al., 2017; Morita-Mullaney et al., 2020). For example, Bernstein et al. (2020) identified dueling discourses about the merits of such programs, with one discourse fueled by instrumental and neoliberal conceptions of equity (i.e., equity is achieved when all students have access to the economic benefits of multilingualism) and another discourse fueled by social justice conceptions of equity (i.e., equity is achieved when all students develop critical awareness of how language intersects with history, context, and power).

The most recent development in conceptions of equity came with the publication of a consensus report published by the NASEM (2022) entitled *Science and Engineering in*

Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators. This report built on the discourses of equity proposed by Philip and Azevedo (2017) by articulating four approaches that represent a spectrum of conceptions: (a) increasing opportunity and access to high-quality science and engineering learning and instruction; (b) emphasizing increased achievement, representation, and identification with science and engineering; (c) expanding what constitutes science and engineering; and (d) seeing science and engineering as part of justice movements. The report used these four approaches to organize its review of the literature across multiple fields, including engineering education (e.g., Cunningham, 2017), computer science education (e.g., Dickes et al., 2016), and multilingual education (e.g., García & Kleifgen, 2020). Consistent with Gutiérrez's (2009) earlier assertion that educators must pursue balance among different conceptions, the report argued that "to genuinely and fully work toward disrupting systemic oppression, all four approaches are necessary" and must "work synergistically" (NASEM, 2022, p. 27). However, in agreement with Tzou et al.'s (2021) analysis of NGSS-designed instructional materials, the report found that "overall, there has been substantial effort made in the first two approaches, some significant pockets of progress in the third, and relatively little with regard to the fourth" (NASEM, 2022, p. 29).

While each conception of equity reflects its particular moment in time and the commitments of different scholars and fields, we propose that the conceptions can be organized into two broad sets: One set of conceptions emphasizes ensuring all students have access to the knowledge, practices, and language normatively valued in schools (e.g., dominant axis in Gutiérrez, 2009; Computer Science for All in Madkins et al., 2020, and Santo et al., 2019; dominant perspective on "academic language" in Jensen & Thompson, 2020; first and second equity approaches in NASEM, 2022). In this article, we refer to these conceptions broadly as *equity as access*. Another set of conceptions emphasizes transforming the knowledge, practices, and language valued in schools in ways that center minoritized students and their communities (e.g., critical axis in Gutiérrez, 2009; expanding what "counts" as participation in computing in Madkins et al., 2020, and Santo et al., 2019; critical perspective on "academic language" in Jensen & Thompson, 2020; third and fourth equity approaches in NASEM, 2022). We refer to these conceptions broadly as *equity as transformation*.

While these two broad sets of conceptions, like any representation of a complex phenomenon, foreground certain aspects (e.g., Lehrer & Schauble, 2015), the two sets of conceptions can help establish a mutual understanding and common vocabulary across fields that have, at times, worked on the "equity puzzle" separately and in parallel (Lubienski & Gutiérrez, 2008, p. 366). This need for a mutual understanding and common vocabulary is particularly urgent across STEM education and multilingual education, which, until recently, have not consistently engaged in meaningful dialogue (Lee, 2019). A lack of dialogue across these fields is problematic for MLs, who do not experience schooling in ways that adhere to the boundaries of fields. For example, MLs are learning STEM subjects at the same time as they are learning language to participate in those subjects. Thus, working toward equity for MLs requires consideration of what we mean by equity in STEM, what we mean by equity in language, and how the conceptions of equity can be integrated within and across fields. By making explicit the two broad sets of conceptions that cut across fields, we aim to sharpen our collective efforts at pursuing an equitable education for MLs.

In this article, we illustrate how research in science education with MLs is one of the "significant pockets of progress" (NASEM, 2022, p. 29) in addressing multiple conceptions of equity by leveraging synergy across STEM and multilingual education. Specifically, we highlight examples from our own research efforts that attend to equity as access while pushing toward equity as transformation. By synthesizing these efforts and unpacking them in relation to the different conceptions of equity, we aim to chart a research agenda for science education with MLs while also elevating the dialogue about how science education broadly can grapple with multiple conceptions of equity and their implications for minoritized students.

We intentionally characterize our research efforts as *attending to equity as access while pushing toward equity as transformation*. This characterization makes explicit that we do not advocate abandoning a focus on access in favor of transformation nor unproductively "pitting [the conceptions] against each other" (Gutiérrez, 2002, p. 148). As emphasized in the NASEM (2022) consensus report, different conceptions of equity have different possibilities and pitfalls (see table on pp. 24-25 of the report). For example, a focus on access can facilitate attainment of currently valued science and engineering learning goals, even as it leaves privileged forms of science and engineering untouched (NASEM, 2022, p. 24). At the same time, given the outsized influence of equity as access on research with minoritized students broadly (e.g., Gutiérrez, 2002) as well as the limitations of a focus on access for racialized MLs in the U.S. context specifically (as elaborated in the next section), we advocate a push toward transformation that can help rebalance our collective efforts in this research area. Moreover, we intentionally characterize our research efforts as pushing toward transformation (rather than, for example, "achieving" transformation) to acknowledge the ongoing struggle and unfinished work of pursuing equity in oppressive systems (Basile & Azevedo, 2022) as well as the promise of opening up possibilities, even if small ones at first, for teachers and students to enact agency

(Varelas et al., 2015) in thinking, doing, and communicating STEM more expansively and in ways that center what MLs bring and care about (García et al., 2021).

Recent Developments in Science Education With MLs

In this section, we provide an overview of recent developments that have set the stage for research in science education with MLs that synergizes perspectives across STEM education and multilingual education. Specifically, we highlight developments from demographic, theoretical, and policy perspectives.

Demographic Perspectives

Intensified patterns of migration and globalization have resulted in a growing number of students across the globe who are learning content (e.g., science, math) while developing proficiency in a second or additional language (Cenoz & Gorter, 2022; Kibler et al., 2014). In the U.S. K-12 context specifically, over 20% of students report speaking a language other than English at home (NCES, 2022). As a subset of this broader ML population, students bureaucratically classified by their schools as English learners (Kibler & Valdés, 2016), or ELs, increased by 26% between 2000 and 2017 (i.e., the most recent longitudinal data available), including across 43 of the 50 U.S. states (U.S. Office of English Language Acquisition, 2020). Currently, more than 10% of students are classified as ELs (NCES, 2022), and in some states, this percentage is substantially higher (e.g., nearly 20% in California).

Despite the unifying label, students bureaucratically classified as ELs are perhaps best marked by their heterogeneity. ELs vary in terms of language background, English proficiency, literacy skills, socioeconomic status, disability status, and prior STEM learning experiences, among other salient characteristics (NASEM, 2017). One characteristic of this student population that comes as a surprise to many is that the majority of ELs in U.S. schools were born in the US

(NASEM, 2018). This reality runs contrary to the images often portrayed of these students as recently arrived immigrants struggling to acquire basic English proficiency and therefore struggling to comprehend and communicate in science classrooms. In contrast, many of these students are not only English *learners*, as their bureaucratic classification indicates (Kibler & Valdés, 2016); they are also English *users*, who use English to carry out a range of tasks in their daily lives and are fully capable of engaging in rigorous science learning alongside their non-EL peers. Moreover, ELs are learning science in contexts that vary widely in terms of their goals and characteristics, including English-dominant classrooms, dual language classrooms, and extracurricular programs (García, 2009; Morita-Mullaney et al., 2020; NASEM, 2018).

Over the last decade, the EL label has become the subject of substantial controversy (e.g., Kibler & Valdés, 2016), and this controversy can be understood in terms of conceptions of equity. On the one hand, the EL label designates students learning English as a protected class under federal law, thus safeguarding their *access* to content learning (see Linquanti et al., 2016 for a review of the legal and policy roots of the label). The EL label also provides a mechanism by which researchers and policymakers can monitor students' progress over time and uncover large-scale trends in achievement and opportunity to learn, including in STEM subjects (e.g., Callahan, 2018). On the other hand, the EL label has been criticized on multiple fronts, including its inconsistent definition across contexts, its monoglossic English orientation, and its stigmatizing consequences for students (see Umansky & Avelar, 2022, for a recent review). Thus, the EL label risks perpetuating the marginalization of students learning English if it is not accompanied by efforts to *transform* the system that manufactured the label in the first place.

In both schools and society, ELs (and MLs broadly) are marginalized as part of interlocking systems of oppression (e.g., Takeuchi et al., 2022). In the U.S. context specifically, multilingual Black, Latinx, and Indigenous learners (as well as ELs and MLs from other subjugated communities) are racialized, that is, “positioned as inferior in racial and linguistic terms . . . as a result of long processes of domination and colonization” (García et al., 2021, p. 203). Flores and Rosa (2015), in their work on raciolinguistic ideologies, have called attention to the ways that racialized learners’ linguistic practices are routinely framed as deficient, deviant, and in need of remediation based on how these practices are heard by the “white listening subject” (p. 152). Extending this work, Flores and Rosa (2022) recently drew on Wynter (2003) to offer a genealogical analysis of how the very notion of linguistic competence (i.e., what it means to a competent language user) is steeped in universalizing framings that position whiteness as normative. This work, which originated with scholars in multilingual education, reflects dominant ideologies in science education that frame science as white property (Mensah & Jackson, 2018), that is, as normatively “belonging” to white men by privileging white ways of knowing and doing while excluding racialized learners (see also Wilson-Lopez & Hasbún, 2023).

Increased attention to ELs specifically and MLs broadly in U.S. K-12 education has brought with it a proliferation of terminology. Federal legislation through the No Child Left Behind Act of 2001 first introduced the term “limited English proficient” to characterize students learning English. Nearly a decade and a half later, the Every Student Succeeds Act of 2015 departed from the clear deficit orientation of this term and instead adopted the term “English learner” that is now widely used in U.S. schools and districts (Thompson et al., 2022), particularly for accountability purposes (e.g., measuring science achievement and opportunity to learn of EL-classified students as compared to their non-EL peers). In parallel with these developments in policy, researchers have been developing new terms that reflect their theoretical commitments. For example, researchers in science education have proposed retiring terms such as EL and "English language learner" that focus narrowly on the English that students are perceived to lack (González-Howard & Suárez, 2021; see also #RetireELL on Twitter). These researchers instead favor terms that foreground the assets that students bring, such as ML and "emergent bilingual" (e.g., García & Li, 2014). However, a challenge with newer terms is that, while more asset oriented, they are less clearly defined (e.g., an ML may or may not be bureaucratically classified as an EL in school; Grapin, 2021). Still other researchers across STEM education (e.g., Takeuchi et al., 2022) and multilingual education (e.g., Flores et al., 2020) advocate interrogating the colonial logics and racializing processes that create such terms in the first place.

In this article, we use the term "multilingual learner" broadly to refer to students classified as ELs as well as any student who uses a named language other than English in school, home, and/or community contexts. We use EL when referring specifically to the subset of MLs who are bureaucratically classified with this label in schools (Kibler & Valdés, 2016). We employ these terms strategically with the goal of unifying diverse research efforts carried out in the context of an evolving policy and theoretical landscape (as described in the sections that follow). At the same time, we use these terms with an awareness that pushing toward equity as transformation for racialized MLs must go beyond adopting more asset-oriented terms to dismantling systems of oppression and raciolinguistic hierarchies that have created the conditions of marginalization in the first place (Takeuchi et al., 2022).

Theoretical Perspectives

Coinciding with demographic shifts in the student population, the fields of science education and multilingual education have undergone significant theoretical developments. The origins of these developments can be traced to *A Framework for K-12 Science Education* (NRC, 2012), which synthesized the latest theory and research on science and how children learn science, and the *English Learners in STEM Subjects* report (NASEM, 2018), which synthesized the latest theory and research on language and how MLs use language to learn STEM subjects.

In science education, traditional perspectives focused on learners' acquisition of discrete science facts, procedures, and terms (see Duschl, 2008, for a review and critique). Thus, the focus was *what science is* as a static body of knowledge but not how learners put that knowledge to use for a purpose. In contrast, contemporary perspectives view science "not just as a body of knowledge" but "also a set of practices used to establish, extend, and refine that knowledge" (NRC, 2012, p. 26). This practice turn (Ford & Forman, 2006) argues that, if learners are to be inducted into ways of knowing and doing in scientific communities, they must not only acquire science knowledge but also engage in the disciplinary practices used to generate that knowledge (Furtak & Penuel, 2019; Lehrer & Schauble, 2015). Thus, the focus of contemporary perspectives is *what science does* to explain phenomena and solve problems, consistent with how scientists and engineers go about their professional work.

In recent years, critical theories in science education have gained heightened prominence (Bang et al., 2017; Mensah & Jackson, 2018; Warren et al., 2020). These perspectives argue that working toward equity in science learning environments requires more than facilitating access to canonical disciplinary practices; it also involves reconceptualizing how science is done in light of learners' heterogeneous sense-making practices. Specifically, these perspectives empower learners to transform disciplinary practices for purposes that are meaningful to them and to their communities. The increasing prominence of critical perspectives represents an evolution from *what science does* to *what learners could do with science* if the education system were to cultivate their diverse sense-making resources.

In multilingual education (including related fields, such as second language acquisition), traditional perspectives focused on learners' acquisition of discrete elements of language (see Larsen-Freeman, 2007 for a review and critique). In other words, the focus was *what language is* as a static body of rules and structures, which de-emphasized the central role of meaning in language use (Grapin et al., 2019). In content classrooms, acquisition of these rules and structures (e.g., technical science terms) was considered a prerequisite to content learning, which led to school policies (e.g., pull-out-programs) and classroom practices (e.g., pre-teaching vocabulary) that ended up excluding MLs from the very learning goals that these policies and practices were meant to attain. In contrast, contemporary perspectives emphasize using language for purposeful communication (NASEM, 2018; Valdés et al., 2014). Thus, the focus is *what language does* to achieve communicative goals. From contemporary perspectives, language is not a prerequisite to learning content, but rather "a product of interaction and learning" (NASEM, 2018, p. 99) as MLs participate in their classroom communities.

In recent years, critical theories in multilingual education have gained heightened prominence (Flores & Rosa, 2015; García et al., 2021). These perspectives argue that working toward equity for MLs requires more than facilitating access to dominant ways of using language in school; it also involves questioning narrowly conceived definitions of communication that have privileged some ways of making meaning while marginalizing others. Specifically, these perspectives have sought to deconstruct restrictive boundaries between named languages ("English" and "Spanish"; e.g., Otheguy et al., 2015, 2019), between "academic language" and everyday languaging practices (e.g., Jensen & Thompson, 2020), and between language and other semiotic modalities and resources (e.g., visual modality, gesture; e.g., Canagarajah, 2018). One prominent theory, translanguaging (García et al., 2021), turns attention to what language users *do* (hence languag*ing* as a verb) to make meaning as they deploy resources fluidly and strategically in ways that transcend such restrictive boundaries (see Jakobsson et al., 2021, for a recent volume on translanguaging in science education). Beyond being a scaffold toward normative ways of using language in academic contexts (e.g., MLs use home language and visual aids until they transition to "academic English"), translanguaging emphasizes sustaining MLs' hybrid, agentive ways of making meaning and, ultimately, disrupting monoglossic ideologies and transgressing language policies that have contributed to the marginalization of multilingual people and communities (Poza, 2017). The increasing prominence of critical perspectives represents an evolution from *what language does* to *what learners could do with language* if the education system were to cultivate their diverse meaning-making resources.

Critical theories across science education and multilingual education throw into relief the limitations of equity as access for racialized MLs. Specifically, these theories converge in reframing the problem of inequity not in MLs' sense-making or meaning-making practices, but in how those practices are perceived within a system that is fundamentally inequitable and responsible for their marginalization in the first place. Thus, even when afforded access to practices that conform to those of dominant groups (e.g., white monolingual English speakers), MLs may continue to be viewed as deficient, not because of how they think or communicate in any empirical sense but because of *who they are* (i.e., racialized people). In light of this, Warren et al. (2020) argue for going beyond assimilating learners into settled disciplinary expectations to instead "positioning [them] as agentive thinkers, poised not only to participate in but to imagine, articulate, and reshape disciplinary activity" (p. 280). Likewise, Flores and Rosa (2015) argue that efforts to work toward equity “cannot be based solely on supporting language-minoritized students in engaging in the linguistic practices of the white speaking subject but must also work actively to dismantle the hierarchies that produce the white listening subject” (p. 167). Notably, neither Warren et al. (2020) nor Flores and Rosa (2015) fully dismiss some attention to access (“*not only* to participate in” and “cannot be based *solely* on”); however, they contend strongly that the systemic nature of inequities renders equity as access insufficient, as it focuses on modifying the practices of *individuals* rather than dismantling *systems* of oppression. Thus, a singular focus on equity as access is susceptible to reproducing the very inequities it aims to challenge (see also Janks, 2004, on the *access paradox*). Critical theories across science education and multilingual education have formed the foundation of recent calls (e.g., Kayumova & Dou, 2022) to go beyond equity as access and “transform dominant science spaces to be more diverse, ethical, and thriving for all” (p. 1113), including for racialized MLs (e.g., Harper & Kayumova, 2022).

In sum, theoretical developments in science education and multilingual education have been mutually supportive, with both fields shifting from more structure-oriented (*what science is*; *what language is*) to more practice-oriented (*what science does*; *what language does*) views of learning. Moreover, critical perspectives in both fields have made progress in expanding what “counts” as participation in science and language learning by cultivating learners’ heterogeneous sense-making and meaning-making resources (*what learners could do with science*; *what learners could do with language*). These mutually supportive theoretical developments have played a key role in shaping policy initiatives across science education and multilingual education, as described next.

Policy Perspectives

Building on the theoretical and empirical foundation established by *A Framework for K-12 Science Education* (NRC, 2012), the NGSS promote an ambitious vision of science teaching, learning, and assessment. Adopted by 20 states and the District of Columbia as well as adapted by 28 states across the US (https://ngss.nsta.org/About.aspx), the NGSS aim to engage learners in three-dimensional learning that blends science and engineering practices, disciplinary core ideas, and crosscutting concepts (NGSS Lead States, 2013b), all for the purpose of explaining phenomena and designing solutions to problems. While this ambitious vision can present challenges for MLs, particularly given the language-intensive nature of science and engineering practices (Hakuta et al., 2013), science classrooms that embrace this vision can also be ideal contexts for language learning, as they reflect contemporary theoretical perspectives that emphasize purposeful communication in classroom communities using language and other semiotic modalities (see previous section). In the decade since the release of the *Framework* and the NGSS, implementation efforts have been underway, with key priorities being curriculum design and professional learning (Campbell & Lee, 2021; Reiser et al., 2021; Short & Hirsh, 2020). Some of these efforts have focused specifically on curriculum design and professional learning that leverage the strengths and meet the needs of MLs in linguistically diverse science classrooms (e.g., Haas et al., 2021; Lee et al., 2019; Miller et al., 2021; Pierson & Grapin, 2021).

In addition to content standards (e.g., NGSS), the education of MLs in U.S. schools is informed by English language proficiency standards, which articulate what MLs can do with English across domains (i.e., listening, reading, speaking, writing), proficiency levels (e.g., Levels 1-6), and content areas (e.g., science, math). These standards are intended to inform teachers' planning and instruction with MLs in content areas, such as science, while also forming the basis of English language proficiency assessments in both large-scale and classroom contexts

(Bailey & Carroll, 2015), which carry significant consequences for EL-classified students (Shohamy, 2007; Wolf, 2022). According to the Every Student Succeeds Act (U.S. Department of Education, 2015), each state must adopt English language proficiency standards that *align* with its content standards, in other words, that reflect the ways language might be used to engage in content area work. In the context of science specifically, federal legislation for alignment means that English language proficiency standards should reflect the language to engage in NGSS three-dimensional learning, with a particular emphasis on MLs' engagement in science and engineering practices (Council of Chief State School Officers, 2012). This federal legislation for alignment at the policy level reflects contemporary conceptualizations at the theoretical level that view the goals of content learning and language learning not as separate but as intimately intertwined (Lee, 2018, 2019; NASEM, 2018).

The most widely adopted English language proficiency standards in the US are those developed by the WIDA Consortium, which encompasses 36 states, the District of Columbia, and four territories and agencies (https://wida.wisc.edu/memberships/consortium). Recently, the Consortium undertook a multiyear effort of revising its standards (WIDA Consortium, 2020) to promote greater alignment with content standards (Grapin & Lee, 2022), including the NGSS, and to reflect the latest theoretical perspectives on content and language learning (see also Boals, 2022, on WIDA's conceptualization of equity). For example, whereas previous editions of the WIDA standards fell short of holding the same high expectations for content learning across English proficiency levels (see Lee, 2018, 2019, for critiques), the revised standards expect *all* students, regardless of English proficiency level, to engage in disciplinary practices of content standards (e.g., argue, explain). Also, whereas previous editions of WIDA privileged meaning-making through language generally and "academic language" specifically (see Grapin, 2019, and

Grapin et al., 2019, for critiques), the revised standards reflect contemporary theoretical perspectives in multilingual education that recognize the wide-ranging resources that students deploy to make meaning of content, including everyday languaging practices and multiple semiotic modalities beyond language. Moreover, the standards' commitment to an asset-based view of MLs is evident in the decision to adopt the term ML, consistent with recent theoretical developments, despite the fact that federal legislation still uses the term EL (U.S. Department of Education, 2015). Instructional frameworks based on the revised standards are currently being developed and disseminated (e.g., Molle & Wilfrid, 2021), including a framework that specifically addresses MLs in science classrooms (MacDonald et al., 2020). It remains to be seen how the theoretical perspectives that informed the revision of the standards will be operationalized in standards-based English language proficiency assessments in large-scale and classroom contexts (Grapin, 2022b).

Summary of Demographic, Theoretical, and Policy Perspectives

In the context of demographic shifts that are reshaping the linguistic make-up of the U.S. student population, theory and policy in science education and multilingual education have undergone significant developments. These developments have been synergistic, with theory and policy pushing each other to advance and science education and multilingual education pushing each other to reflect the latest theories and policies in their respective fields. As a result of this synergy, theories and policies across science education (NRC, 2012; NGSS Lead States, 2013b) and multilingual education (NASEM, 2018; WIDA Consortium, 2020) have coalesced around taking an asset-based view of MLs and promoting MLs' engagement in science and engineering practices using multiple and varied meaning-making resources. Collectively, these developments provide the crucial foundation for emerging research in science education with MLs.

At the same time, when it comes to translating theory and policy into research and practice, the devil is very much in the details. As Miller et al. (2018) point out, the NGSS and the theoretical perspectives that undergird the standards, while offering great promise, “are not a silver bullet for transforming science classrooms” for minoritized students (p. 1053). The challenge of creating transformative science education experiences is amplified in science education with MLs specifically, as it involves integrating perspectives from multiple fields in a principled manner. For example, if research conceives of equity as *transformation* from a language perspective (e.g., viewing translanguaging as a transgressive act) but equity only as *access* from a science perspective (e.g., valuing translanguaging in the service of narrowly defined disciplinary ends), it may fall short of realizing either conception of equity (Pierson & Grapin, 2021). Thus, depending on how research is conceptualized and carried out, it could provide MLs with access to science and language as these are currently constituted (i.e., equity as access) and/or transform what “counts” as science and language in ways that center MLs and their communities (i.e., equity as transformation). In the next section, we describe emerging research that pursues multiple conceptions of equity simultaneously.

Emerging Research in Science Education With MLs

We describe emerging research in science education with MLs in three overarching areas: (a) learning, (b) assessment, and (c) teacher education. Several research efforts intersect multiple areas. For example, research efforts that focus on co-designing learning environments and assessment tasks with teachers sit at the intersection of learning, assessment, and teacher education. Below, we present each research effort within one of the three overarching areas to foreground its primary emphasis and contribution. For each area, we begin with a brief overview of current research trends contextualized within the developments described above. Then, we highlight emerging research efforts by our team of early-career scholars, which span multiple grade levels (i.e., elementary, middle, and high school) and STEM subjects (i.e., science, engineering, and computer science). Finally, we unpack how the research efforts within each area attend to equity as access while pushing toward equity as transformation.

Learning

With the K-12 student population becoming more linguistically diverse, research on MLs' science learning has received increased attention (see Buxton & Lee, 2023, for a recent review). Major research programs led by Brown (e.g., Brown, 2021; Brown et al., 2019; Lemmi et al., 2021) and Lee (e.g., Lee, 2018, 2019; Lee & Stephens, 2020; Lee et al., 2013) have elevated the status of everyday languaging practices and multimodality in science learning, particularly in classrooms designed for the vision of the NGSS. Moreover, research rooted in translanguaging theory has invited students to deploy their full linguistic and semiotic repertoire in the service of science learning (e.g., Infante & Licona, 2018; Karlsson et al., 2019; Oliveira et al., 2019; Poza, 2018; Probyn, 2015). Still other research programs have focused on uncovering and amplifying students' heterogeneous sense-making practices (e.g., Bang et al., 2018; Hudicourt-Barnes, 2003; Warren et al., 2020), especially in informal science learning settings that are not bound by restrictive curriculum and assessment mandates associated with formal schooling (e.g., Ash, 2004; Calabrese Barton et al., 2021; Harper, 2017; Kayumova & Tippins, 2021; Suárez, 2020; Tan & Faircloth, 2016). In this section, we highlight our emerging research on science learning with MLs in two different learning contexts: (a) formal learning settings and (b) informal learning settings.

Formal Learning Settings

Pierson and colleagues (Pierson, in press; Pierson & Brady, 2020; Pierson & Grapin, 2021; Pierson et al., 2020, 2021, 2022), with support from the National Academy of Education, Spencer Foundation, and NSF, engaged in a 3-year design study (Cobb et al., 2003) in sixth-grade STEM classrooms that brought together disciplinary modeling practices and students' multimodal translanguaging practices (see Gutiérrez & Jurow, 2016, on *syncretic* designs that reorganize disciplinary and everyday practices in the service of equitable learning). Whereas research with MLs often takes place in bilingual classrooms in which many students speak a common named language (e.g., García, 2009), this research was unique in that it took place in English-dominant classrooms (where multiple named languages have not traditionally been valued) and foregrounded "the role of meaning-making resources [that have] long been considered outside of language" (García et al., 2021, p. 208; see also Kusters et al., 2017, on the relationship between multimodality and translanguaging theory). In collaboration with the classroom teacher, Ms. S, Pierson and colleagues designed a 9-week biology and ecology unit in which students developed multiple types of models (diagrammatic, physical, computational, embodied) of guppies' ecosystems. Each model (e.g., computational) and semiotic modality used within the model (e.g., computer code) was framed as a "language" that students, both MLs and their monolingual peers, could draw on flexibly for different purposes of reasoning and expression. The unit was explicitly designed to be heterogeneity-seeking (Pierson et al., 2022), meaning that, rather than emphasizing convergence with *disciplinary* expectations, the unit centered *students'* heterogeneous meaning-making and sense-making resources that did not always conform to these expectations (Sengupta et al., 2021).

As an illustration of the potential of heterogeneity-seeking learning designs, Pierson et al. (2021) documented how MLs and their peers drew flexibly and creatively on their translanguaging practices to describe phenomena that emerged as important in their classroom community. For example, when Ms. S noticed that many students were using a wave-shaped gesture to describe a pattern in the graph produced by their computational model when their computational ecosystem was stable, she prompted students to nominate English, Spanish, and invented terms that captured what was, for them, salient about the pattern. One student, Eli, shared an invented term: "Flectorate. It sounds like fluctuate, and it means the rates are changing" (Pierson et al., 2021, p. 806). Another student, Luis, combined English, Spanish, and invented terms: "We did fluctuate, balanciado, and we also made up a word. It's from balanced and graph. It's a balagraph" (Pierson et al., 2021, p. 806). Moving fluidly across "languages" (broadly defined) also invited students to consider phenomena from new perspectives. For example, as Nora and Carlos moved from a written representation of the guppies' ecosystem to a diagrammatic visual model, this brought into relief aspects of the ecosystem that they had not previously considered, such as the guppies' social behavior, the adequacy of their living space, and the importance of both factors for the health of the ecosystem as a whole (Pierson et al., 2021). In this way, multimodal translanguaging helped surface values, such as care and empathy, that became part of the class's collective ethical commitment (Pierson et al., 2022) despite falling outside of what has been normatively privileged in science (see Tzou et al., 2021 on the Learning in Places project). Together, these examples give a sense of the wealth of meaning-making and sense-making resources that students brought to their science learning and the potential of heterogeneity-seeking learning designs (Pierson et al., 2022) for legitimizing these resources, especially in English-dominant classrooms that have normatively privileged a much narrower set of resources (e.g., "academic English," linguistic modality).

Informal Learning Settings

Ryu and colleagues (Daniel et al., 2021; Ryu & Daniel, 2020; Ryu & Tuvilla, 2018; Ryu et al., 2019, 2020) designed and studied a community-based afterschool STEM program that invited resettled Chin refugee high school students to learn about climate change. Chin people are ethnic minorities in Myanmar that comprise more than 30 different groups, each with unique cultural practices and named languages. Chin youth participants in the afterschool program were ethnically and linguistically diverse and spoke multiple named languages, including Chin languages (e.g., Hakha, Falam), Burmese (the official language of Myanmar), and English. At the outset of their NSF-funded project, the researchers conducted interviews with the youth to uncover their multilingual repertoires and funds of knowledge (González et al., 2005), thus countering disempowering narratives of refugees as "victims who need extra help" (Ryu & Tuvilla, 2018, p. 541). The researchers then drew on findings from the interviews, in particular youth participants' orientation toward social justice and their interest in redressing inequities faced by historically marginalized people, to engage them in authoring multimodal texts (e.g., videos) about climate change for various audiences. A key tension identified by the researchers in their learning design was how to identify and meet refugee youth's unique needs while simultaneously positioning them as change agents and raising "fundamental questions" about whose knowledge and language "count" (Ryu & Daniel, 2020, p. 324).

Analysis of ethnographic data (e.g., recordings of program sessions, youth-created texts) revealed several ways in which Chin youth participated in the afterschool program. First, youth strategically blended humor and STEM discourse, thus crafting a space for themselves and their peers in which diverse identities (e.g., a funny person, a person who cares about others) could contribute meaningfully to collaborative justice-oriented work. Second, youth drew flexibly and strategically from their wide range of linguistic and semiotic resources to engage in scientific sense-making and provide caring social support for others (Daniel et al., 2021). For example, in situations in which learners had different levels of proficiency in different named languages, they communicated by speaking in one named language while listening in another (e.g., A spoke to B in Hakha, and B responded to A in Falam) while also leveraging other semiotic resources, such as gaze and body language. Finally, rooted in their deep knowledge of developing parts of the world, the youth raised critical questions regarding the impacts of climate change, including who is severely impacted, who is responsible, and who needs to take actions (Ryu et al., 2020). The youth also proposed solutions to mitigate the impacts of climate change for local and global communities. For example, some youth pointed out that many Chin people do not have access to weather forecasts and therefore could not be warned about severe weather events in advance. Thus, they proposed an early alert system to prepare Chin people for upcoming severe weather. Other youth grappled with the dilemma between protecting forests from deforestation and the Chin people's need for fuel and heat in the absence of societal electric infrastructure—a dilemma that they recognized would impact historically marginalized people across the globe.

Unpacking Research on Learning in Terms of Equity as Access and Equity as Transformation

These emerging research efforts attend to equity as access while pushing toward equity as transformation. Specifically, these efforts attend to **equity as access** by engaging learners with the knowledge, practices, and language expected by the latest science education reform. For example, Pierson and colleagues' learning design in STEM classrooms engaged students in core science ideas (e.g., interdependent relationships in ecosystems) and practices (e.g., modeling) emphasized in the state science standards—a key priority expressed by their teacher collaborator (Pierson, in press)—as well as the language to engage with those knowledge and practices (e.g., "population levels"). Likewise, Ryu and colleagues' afterschool program helped build learners' knowledge, practices, and language related to weather and climate phenomena (e.g., temperature, air pressure, humidity), thus providing supplementary STEM learning experiences for refugee youth who often had interrupted schooling and emerging English proficiency.

At the same time, these research efforts push toward **equity as transformation** by expanding what “counts” as science and language learning and interrogating the roles of science and engineering in disrupting (or, alternatively, exacerbating) inequities faced by historically marginalized communities. For example, Pierson and colleagues positioned students’ “silly” contributions (e.g., “flectorate,” “balagraph”) and ethical commitments (e.g., care, empathy) as generative resources, thus (re)framing science as a creative meaning-making and sense-making process rather than a rigidly prescribed set of procedures accomplished primarily (or exclusively) through English or “academic English.” Likewise, Ryu and colleagues’ afterschool program invited youth to draw strategically from their full linguistic and semiotic repertoire as they posed ethical questions about a societally pressing challenge (i.e., climate change) and leveraged their knowledge and experiences related to this challenge to design justice-oriented solutions that centered the interests and needs of historically marginalized people they cared deeply about. Together, these research efforts illustrate how leveraging synergy across STEM education (e.g., cultivating heterogeneous STEM practices, or *what learners could do with science*) and multilingual education (e.g., cultivating heterogeneous languaging practices, or *what learners could do with language*) can work toward transforming science learning environments for MLs.

Assessment

Much research on science assessment with MLs has focused on accommodating MLs’ access to tasks, for example, by simplifying complex language (e.g., Noble et al., 2020; Rivera & Stansfield, 2004), providing multimodal response options (e.g., Kopriva & Wright, 2017;

Thurlow & Kopriva, 2015), and embedding scaffolds (e.g., Lyon, 2013; Siegel, 2007). While accommodations have made important contributions to improving the validity of science assessments for MLs, particularly on large-scale tests (e.g., Abedi et al., 2004), accommodations seek to compensate for what MLs "lack" in terms of English proficiency and, in doing so, risk devaluing the rich repertoire of meaning-making resources these students bring to science classrooms. With the implementation of the NGSS in schools across the US, researchers have turned attention to classroom-based assessment as a key lever for promoting the standards' ambitious vision of science teaching and learning (Harris et al., 2019; NRC, 2014). In particular, classroom-based assessment holds promise for providing real-time information about MLs' science learning and their multiple ways of expressing that learning (Heritage et al., 2015; NASEM, 2018). Based on a recent synthesis of the literature on science assessment with MLs, Lyon (2023) called for classroom-based formative assessments that move beyond "a restricted view where science teachers just make accommodations to support emergent bilinguals' 'English' language development" (p. 7) toward assessments that "open up opportunities for emergent bilinguals to show what they know and do through an expanded communicative repertoire" (p. 19).

Consistent with this call, research has begun to document the affordances of science assessment for cultivating MLs' rich meaning-making potential. Specifically, studies have examined the potential of co-designing assessment tasks with teachers (e.g., Buxton et al., 2019), conducting multilayered analyses of MLs' responses to those tasks (e.g., Cardozo-Gaibisso et al., 2020), and interrogating the language ideologies underlying teachers' formative assessment practices in science classrooms (e.g., Lemmi et al., 2019). In this section, we highlight our emerging research on science assessment with MLs that examines innovative approaches to classroom-based assessment: (a) multimodal, dynamic assessment and (b) translanguaging assessment co-design.

Multimodal, Dynamic Assessment

Grapin and colleagues (Grapin, 2022a, 2022b; Grapin & Llosa, 2022a, 2022b; Grapin et al., 2022), with support from Educational Testing Service and NSF, explored innovative approaches to science assessment in the context of a yearlong NGSS-designed curriculum for fifth-grade MLs and their peers. Specifically, this research addressed a persistent problem that the assessment of MLs' content learning has narrowly privileged learning expressed through linguistic modalities (e.g., written language modality) and independent performance (i.e., what students can do on their own). Thus, one set of studies (Grapin, 2022a; Grapin & Llosa, 2022b) investigated the potential of *multimodal assessment*, or assessment that elicits responses to science modeling tasks in multiple modalities (i.e., visual, written, oral). Another set of studies (Grapin & Llosa, 2022a; Grapin et al., 2022) investigated the potential of *dynamic assessment*, or assessment that embeds dynamic interaction in the form of contingent questions and probes. A unique feature of this research was that it examined student performance on the assessments using both quantitative and qualitative methods, including comparisons across bureaucratic EL classifications (e.g., ELs compared to non-ELs).

In both sets of studies, the innovative approaches revealed aspects of students' science learning that would have otherwise remained hidden using more traditional approaches. In the first set of studies on multimodal assessment, non-ELs tended to outperform their EL-classified peers when responding to the science tasks in the written modality (i.e., using written language). However, ELs performed on par with, and sometimes better than, their non-EL peers when responding to the same tasks in the visual modality (i.e., using drawings and symbols), thus closing what appeared to be a gap in science understanding between the two groups. In the second set of studies on dynamic assessment, dynamic interaction with the researcher in the oral modality supported all students, but especially ELs, to demonstrate science understanding that would not have been apparent from their independent visual or written responses alone. For example, when asked to explain their visual responses, ELs described creative (and unanticipated) ways in which they had imbued their own interests and intentions into their multimodal models. One student, Javier, demonstrated a sophisticated understanding of interdependence in ecosystems by representing alternative paths of energy transfer than were normatively expected by the task (and thus were initially deemed incorrect). ELs also conveyed sophisticated science ideas using language traditionally considered everyday or nonscientific. For example, in response to persistent probing from the researcher (e.g., asking, “What do you mean?” and “Say it again”), it became evident that Juan was using an everyday expression, “the sun for them,” to identify each organism’s energy source (e.g., “the salamander is the sun for the snake” meant the salamander was an energy source for the snake). In contrast, non-ELs more frequently used canonical representations (e.g., arrows to represent energy transfer) and language (e.g., “energy source”) but fell short of demonstrating understanding of the underlying science ideas. By underscoring the limitations of science assessments that restrict their focus to written language and independent performance alone, these studies underscore the need for “more *expansive ways of assessing learning* that capture ELs’ *expansive ways of making meaning*” (Grapin, 2022b, p. 3).

Translanguaging Assessment Task Co-Design

Whereas Grapin and colleagues’ research sought to expand assessment beyond a narrow focus on written language and independent performance, research by Fine and colleagues (Fine, 2022; Fine & Furtak, 2020a, 2020b; Fine et al., 2023, in press) turned attention to the traditional monolingual (i.e., English only) orientation of science assessment. This research took a two-pronged approach of (a) developing a framework for science classroom assessment task design and (b) co-designing science tasks with teachers. Within the first prong, Fine and Furtak (2020a) reviewed the literature on the assessment of MLs across STEM and multilingual education to develop a framework for NGSS task design. The framework was explicitly motivated by the need to "move beyond adapting existing assessments prepared with European-American middle-class English speakers in mind" and "instead . . . to design assessment tasks that validate and sustain [MLs'] multiple linguistic and cultural ways of knowing" (Fine & Furtak, 2020a, p. 394). Ultimately, the framework addressed a range of design features, such as embedding scaffolds (e.g., sentence starters, graphic organizers) to accommodate MLs' access to three-dimensional science tasks and providing opportunities for students to translanguage (i.e., use all of their linguistic and semiotic resources) in the context of place-based phenomena in local communities (Fine & Furtak, 2020a). This framework subsequently informed a practitioner tool, the Science Assessment for Emergent Bilingual Learners (SAEBL) checklist, to support teachers as they create and adapt their own science assessment tasks (Fine & Furtak, 2020b).

The second prong of Fine and colleagues' research focused on examining how middle school science teachers co-designed assessment tasks, informed by the SAEBL checklist, to welcome translanguaging—what they called *(trans)formative assessments* (Fine, 2022, p. 196). Similar to Pierson's research (described as part of "Learning" above), this research took a participatory design approach and was carried out in an English-dominant schooling context in which multilingualism had not always been valued. Findings from this research indicated that, while teachers felt pressure to prepare students for English-medium district science assessments, they came to understand this tension as a productive site of dissonance that underscored the imperative of embracing (trans)formative assessment in their classrooms (Fine et al., 2023, in press). For example, through participation in a teacher-researcher collaborative (Fine, 2022), Emily, a monolingual English-speaking teacher, learned to pause to consider MLs' ideas, lean into her own knowledge about languaging in science, use Internet-based translation tools, and consider multimodal aspects of MLs' responses. By deepening her *translanguaging interpretive power* (Fine, 2022), Emily moved from ideological stances to agentive actions that came to permeate her general pedagogical practices with MLs.

Unpacking Research on Assessment in Terms of Equity as Access and Equity as Transformation

These emerging research efforts attend to equity as access while pushing toward equity as transformation. Specifically, these efforts attend to **equity as access** by ensuring that English proficiency does not present a barrier to MLs demonstrating what they know and can do on classroom-based assessments. For example, Grapin and colleagues found that providing opportunities for students to respond to science tasks in the visual modality helped close the perceived gap in science understanding between ELs and their non-EL peers, thus supporting a key goal of equity as access that "strives for comparable levels of attainment" across student groups (NASEM, 2022, p. 23). Likewise, Fine and colleagues' framework for classroom task design recommends the use of scaffolds (e.g., sentence frames, graphic organizers) to accommodate MLs' access to cognitively demanding grade-level science assessments.

At the same time, these research efforts push toward **equity as transformation** by expanding what "counts" as evidence of science learning beyond what has normatively been privileged. For example, by expanding beyond written language and independent performance, Grapin and colleagues uncovered ELs' sophisticated science ideas expressed in ways that diverged from what was normatively expected (e.g., creative visual representations, everyday languaging practices), whereas their non-EL peers tended to use canonical representations and "academic language" that turned out to be devoid of science understanding. Likewise, by expanding beyond assessment in English, Fine's research shows how teachers can be empowered to interrogate their taken-for-granted ways of interpreting MLs' work and critically examine how their assessment practices "welcome or limit students' linguistically heterogeneous contributions" (Fine, 2022, p. 194). Together, these research efforts leverage synergy across STEM education (e.g., expanding notions of "correctness" in the assessment of science models) and multilingual education (e.g., expanding ways of demonstrating science learning through multimodality and translanguaging) to raise fundamental questions about what meaning-making resources get valued in science assessment and who this privileges. By relocating the "problem" of assessing MLs not in how these students express their science learning, but in how we, as researchers and teachers, recognize—or fail to recognize—that learning, these research efforts work toward transforming science assessment for MLs.

Teacher Education

The changes in learning and assessment heralded by the latest science education reform call for teachers who are "fluent in the pedagogy of effective science instruction, including how to promote the success of culturally and linguistically diverse students." (NASEM, 2021, p. 23). Rutt et al. (2021) provided a state-of-the-art review of the literature on pre-service teacher preparation for teaching science to MLs and found that studies varied widely in their goals and emphases, with some studies focused on enhancing teachers' awareness of and instructional planning for "academic language demands" (e.g., Jung & Brown, 2016, p. 847) and others focused on supporting teachers to contextualize science learning in MLs' local communities (e.g., Tolbert et al., 2019). Notably, Rutt et al. (2021) found that, with this literature "just emerging" (p. 626), a key element missing from most studies was opportunities for teachers to critically examine their beliefs about science, language, and the integration of the two in linguistically diverse science classrooms (see Settlage et al., 2014 for an exception). In comparison with this literature on pre-service teacher preparation, even less literature exists on in-service teacher learning for teaching science to MLs (see Lucas et al., 2018, for a review that addresses content areas broadly). This research will likely pick up steam with the increasing availability of NGSS-designed educative curriculum materials and accompanying professional development (Campbell & Lee, 2021; see also Thompson et al., 2019, and Kang & Nation, 2022, for examples of professional learning centered on equity for minoritized students broadly). In this section, we highlight our emerging research on learning to teach science to MLs with two teacher populations: (a) pre-service teacher education and (b) in-service teacher education.

Pre-Service Teacher Education

Building on their earlier research focused on teacher learning to facilitate scientific argumentation with MLs (González-Howard & McNeill, 2016; González-Howard et al., 2015, 2017), González-Howard and colleagues are currently carrying out a 5-year project supported by an NSF CAREER grant to explore how pre-service teachers learn to support MLs' scientific sense-making and engagement in science practices through a translanguaging lens (Andersen et al., 2022; González-Howard et al., 2022; González-Howard & Suárez, 2021; Kang & González-Howard, 2022). In parallel with Ryu's approach of interviewing youth to inform the design of her afterschool program (described as part of "Learning" above), González-Howard and colleagues began their project by exploring pre-service teachers' current understandings of language, science, and their integration. This research was carried out within a 14-week science methods course for pre-service teachers seeking elementary bilingual certification in Texas, which serves 20% of the nation's emergent bilingual students (In September 2021, the Texas Education Agency passed legislation replacing the EL terminology with the more asset-oriented term "emergent bilingual.").

Findings from an analysis of course artifacts and interviews indicated that pre-service teachers expressed relatively narrow understandings of language, science, and their integration (González-Howard et al., 2022). For example, they conceived of language in terms of named languages with rigidly constructed boundaries (e.g., "Spanish" vs. "English"), in contrast with the fluid conceptualization of translanguaging (García & Li, 2014). They also conceived of science primarily in terms of decontextualized hands-on activities and investigations, in contrast with the sense-making and practice-oriented focus of the latest science education reform (NRC, 2012). Finally, the pre-service teachers saw a role for language in certain science practices (e.g., argue, explain) but less so in others, and they mainly emphasized the contributions of *linguistic* modalities (listening, reading, speaking, writing) to scientific sense-making, with less attention to other semiotic resources (e.g., gesture, drawing). One bright spot was that pre-service teachers, many of whom were multilingual themselves, reflected on how their own science learning experiences could have been more linguistically sustaining, for example, by expanding beyond, in one teacher's words, science "always [done] through the standard English academic language" (González-Howard et al., 2022). The researchers concluded that, without opportunities to critically reflect on their understandings of language, science, and the integration of the two, pre-service teachers would likely engage MLs in science in limited and limiting ways (González-Howard et al., 2022). In the next phase of their research, based on the understandings that pre-service teachers expressed in the initial phase, González-Howard and colleagues are revising various aspects of the science methods course to promote pre-service teachers' more expansive understandings and associated pedagogies. For example, in the most recent iteration of the course, pre-service teachers redesign science lessons using a researcher-developed translanguaging framework (Andersen et al., 2022). The larger project also involves partnering with a local school district to provide pre-service teachers with opportunities to work with teachers and students in bilingual elementary classrooms and observe firsthand how MLs deploy their wide-ranging meaning-making resources as they engage in science practices (Kang & González-Howard, 2022).

In-Service Teacher Education

Vogel and colleagues (Radke et al., 2022; Vacca et al., in press; Vogel, 2021, 2022; Vogel et al., 2020; Vogelstein et al., 2022), with support from NSF, have been investigating how in-service teachers (including, but not limited to, science teachers) co-design computing-integrated learning experiences in bilingual middle school classrooms. This research-practice partnership was launched in response to a Computer Science for All Initiative in a large urban school district where over 40% of students speak a named language other than English at home. Similar to Pierson's research (described as part of "Learning" above), this research aimed to syncretize (Gutiérrez & Jurow, 2016) disciplinary practices with MLs' translanguaging practices and computational literacies (Vogel et al., 2020). An early finding from the project was the tensions that can arise in syncretic designs as teachers navigate between lesson goals and students' emergent sense-making goals. For example, Radke et al. (2022) offered a microethnographic account of one lesson in a bilingual seventh-grade science classroom in which students developed physical and computational models to explain the social impacts of

Hurricane María, which had recently devastated Puerto Rico in ways personally meaningful to many of the MLs and their families. As MLs drew agentively from a wide array of meaning-making resources (e.g., mathematical notation, procedural algorithms, material artifacts) to explain post-hurricane migration patterns, the researchers observed what they called a "push and pull between accepted mathematical, computational, or scientific arguments [on the one hand] and social, often personally rooted arguments for migration [on the other hand]" (Radke et al., 2022, pp. 219-220). While this "push and pull" served to challenge the normative privileging of STEM ways of knowing and doing over local knowledge and practice (Radke et al., 2022, p. 219), it also led to vulnerability for teachers as they renegotiated their teacher-as-expert roles. Thus, promoting *student* agency in the classroom needed to begin with promoting *teacher* agency.

Eschewing transmission-based models of in-service teacher learning that position teachers as "mere implementers of [canned] curriculum rather than agents who craft . . . student learning" (Vacca et al., in press, p. 4), Vogel and colleagues organized professional learning communities that engaged researchers and middle school teachers in co-designing computing-integrated content area lessons guided by translanguaging theory (Vacca et al., in press; Vogel, 2022; Vogelstein et al., 2022). A key construct informing the co-design process was *acompañamiento*, or acknowledging and addressing the vulnerability that teachers experience as agency is renegotiated in the classroom (Vacca et al., in press). A range of strategies supported this acompañamiento, including context-dependent goal setting with teachers (such that collaboration centered on the goals of MLs and their communities) and intensive in-classroom support (such that the vulnerability of trying something new and making room for student agency was shared between researchers and teachers). Through this co-design process, teachers made shifts toward seeing themselves as co-learners alongside their students (García & Li, 2014) and embracing MLs' creative and critical translanguaging practices as well as their computational literacies across communities of practice. Vogelstein et al. (2022), for example, shared how one teacher, who had initially interpreted her MLs talking about hacking as disruptive, moved these conversations from the margins to the center of her classroom by co-designing lessons that recruited students' multilingual, embodied, and computational expressive resources to develop a collective definition of hacking and a class "hacker's code of ethics."

Unpacking Research on Teacher Education in Terms of Equity as Access and Equity as Transformation

These emerging research efforts attend to equity as access while pushing toward equity as transformation. Specifically, these efforts attend to **equity as access** by equipping teachers with the pedagogies they need to ensure MLs' access to high-quality science and STEM learning. For example, in González-Howard and colleagues' research, pre-service teachers had opportunities to engage in science practices called for by the latest science education reform, identify challenges that MLs might face in participating in those practices (e.g., writing scientific explanations that include technical science terms and specialized discourse structures), and then plan and implement lessons that ensured MLs' meaningful participation (e.g., by embedding scaffolds). Likewise, Vogel and colleagues bolstered in-service teachers' pedagogies related to infusing computer science into standards-based science instruction with MLs, consistent with the aims of a city-wide initiative that was explicitly framed in terms of broadening participation of underrepresented groups in the technology workforce (Santo et al., 2019).

At the same time, these research efforts push toward **equity as transformation** by guiding teachers to interrogate their fundamental assumptions about teaching science to MLs and design learning experiences that transform whose knowledge, practices, and language “count” in science and STEM learning. For example, González-Howard and colleagues began their research by surfacing pre-service teachers’ narrowly conceived understandings of science and language, which we argue is a crucial first step toward confronting pervasive ideologies that have contributed to the marginalization of MLs in science classrooms (Indeed, when this step is skipped, teacher education may promote only surface-level shifts in teachers’ pedagogies that fall short of being transformative or, worse, that exacerbate existing inequities.). Likewise, Vogel and colleagues’ professional learning communities fostered in-service teacher’ agency for designing learning experiences that “took seriously [MLs’] ways of knowing, languaging, and doing STEM” (Radke et al., 2022, p. 207), which, in turn, afforded students the agency to deploy their translanguaging practices and local community knowledge in transgressive and liberatory ways. By leveraging synergy across STEM education (e.g., expanding teachers’ understandings of whose expertise “counts” in the classroom) and multilingual education (e.g., expanding teachers’ understandings of whose languaging practices “count”), these research efforts guide teachers at varying stages of the teacher learning continuum to take on roles fundamentally different than those they have traditionally assumed.

Research Agenda for Science Education With MLs

Building on and extending the emerging research efforts described above, we propose a research agenda for science education with MLs that continues the push toward equity as transformation. This research agenda articulates promising directions in the three overarching areas of learning, assessment, and teacher education. Given the systemic nature of inequities faced by MLs in science education (NASEM, 2018), these three areas and the promising directions within each area are not intended to be comprehensive, but rather to offer examples of what it might take to advance the knowledge base. To conclude, we offer recommendations that cut across the three areas toward ensuring that this research agenda is coherent and impactful.

Learning

One promising direction related to learning involves further investigating the role of context. As described earlier, MLs are a heterogeneous group subject to persistent marginalization at the intersection of multiple identity markers (e.g., language and race). MLs are also learning science in contexts that vary widely in terms of their goals and characteristics (e.g., English-dominant classrooms, dual language classrooms, extracurricular programs). Given this diversity, science learning environments need to be designed in ways that are responsive to the unique characteristics of each context. For example, in Pierson's research in English-dominant classrooms, legitimizing named languages other than English involved a strategic tactic of positioning translanguaging as something *all* students could do (both MLs and their monolingual peers), for example, by drawing on multiple semiotic modalities and inventing new terms. In Ryu's research with refugee youth in an afterschool program, a key tension involved leveraging affordances of informal science learning for expanding what "counts" as science and language while, at the same time, attending to refugee youths' unique needs as they encountered cultural practices and school norms that were largely unfamiliar to them. Moreover, Pierson and Ryu (as well as Fine in an assessment context) uncovered both opportunities and challenges associated with promoting multilingualism in contexts in which teachers or facilitators did not share the named language(s) of their students, a common arrangement in U.S. K-12 schools where the majority of teachers identify as white and English-monolingual (NCES, 2022). The centrality of context is reinforced by Flores and Rosa (2022), who caution that, because "colonial logics play out differently in different contexts," research aimed at disrupting systems of oppression for racialized MLs must "account for the racialization processes at play in particular local contexts" (p. 8). Given the particulars of each context (and the design decisions that follow from these particulars), further research is needed to understand how learning designs can address different conceptions of equity in the multiple and varied contexts in which MLs' science learning takes places. It is likely that design-based research (Cobb et al., 2003), which was the most commonly employed methodological approach among the research efforts, will continue to figure prominently in future research, given the affordances of this methodology for attending to "local contextual particulars" (Barab, 2006, p. 155).

Another promising direction involves investigating learning over time. Because research by Pierson and Ryu focused on refining learning designs over multiple iterations, with different groups of students participating in each iteration, this research did not examine MLs' science learning over extended time periods beyond the focal unit or program. The issue of time is particularly salient when it comes to conceptions of equity, as different conceptions have different possibilities and pitfalls in the short versus long term (NASEM, 2022). For example, while a focus on transformation can, in the long term, offer possibilities for redefining what "counts" as science and language, in the short term, it may "eclipse . . . [the] more proximal learning goals" associated with equity as access (NASEM, 2022, p. 24), which often emerge as priorities in education systems due to accountability pressures. Moreover, different grade levels in K-12 education may offer different possibilities (e.g., flexibility of curriculum in the elementary grades, disciplinary specialization of teachers in the secondary grades) and pitfalls (e.g., lack of instructional time in the elementary grades, high-stakes nature of assessment in the secondary grades) for promoting different conceptions of equity. Thus, further research is needed to understand how science learning environments can address multiple conceptions of equity over time, including over a school year (e.g., through ethnographic studies of MLs' changing participation in science practices) and across K-12 grade levels (e.g., through longitudinal studies of MLs' STEM course-taking opportunities; Morita-Mullaney et al., 2020).

Assessment

One promising direction related to assessment involves the design of tasks. While research by Grapin and Fine illustrates the affordances of assessment tasks that expand opportunities for MLs to demonstrate what they know and can do, these tasks were still limited in several respects: First, they targeted a limited spectrum of science practices, with a particular emphasis on science modeling. Second, few tasks were explicitly grounded in local contexts. Third, many tasks were designed to be administered via paper and pencil. As future research seeks to address these limitations and develop a broader range of assessment tasks, new questions and tensions related to equity will inevitably emerge. For example, how do we develop tasks that expand opportunities for meaning-making in the context of science practices that have not traditionally been considered as semiotically rich as modeling? How do we develop tasks that are contextualized within local communities, thus leveraging MLs' rich funds of knowledge, while also being useful across multiple contexts, thus addressing the still limited availability of NGSS-designed assessments that disproportionately impacts underresourced schools and districts where MLs are concentrated? And how can technology play a role in science assessment with MLs while recognizing that technology has the potential to disrupt inequities but also exacerbate them? For example, technology-enhanced assessments can expand opportunities for meaning-making (e.g., Smith et al., 2021) while reproducing raciolinguistic ideologies that position the "culture, language, and representations of White people [as] the standard against which all answers ought to be seen, heard, and measured" (Cheuk, 2021, p. 826; see also Vogel, 2021).

Another promising direction involves the enactment of assessment tasks in the classroom. While Grapin employed researcher-developed tasks and interpreted students' performances on those tasks from the researcher perspective, Fine took this a step further by co-designing assessment tasks *with* teachers and co-interpreting MLs' responses to those tasks. A logical next step would be to closely study how teachers enact assessment tasks in their classrooms and the consequences of this enactment for MLs' science learning. Studying classroom enactment and its consequences has the potential to uncover tensions between different conceptions of equity. For example, even when employing tasks that explicitly invite students to draw from their full repertoire of sense-making and meaning-making resources, do teachers adopt a convergent approach to assessment (Torrance & Pryor, 2001) in which they "correct" students or quickly transition them to more canonical science and language? Or, alternatively, do teachers take a divergent approach that deprioritizes the "agenda of the assessor" (Torrance & Pryor, 2001, p. 617) and sustains students' heterogeneous ways of making sense and making meaning (see also Kang, 2022)? Moreover, teachers' enactment is likely to be influenced by their own ideologies about science and language learning as well as the ideologies circulating in their local contexts (e.g., Lemmi et al., 2019). By opening up the black box (Black & Wiliam, 1998) of what happens in the classroom when teachers and students engage in assessment together, research can realize the promise of making assessment transformative for MLs in science classrooms.

Teacher Education

One promising direction related to teacher education involves supporting teachers to recognize, affirm, and sustain MLs' cultural knowledge and experiences. With the exception of Ryu and Vogel, who offered examples of science teaching anchored in issues directly relevant to MLs' lives (i.e., climate change in Myanmar, Hurricane María in Puerto Rico), most of the research efforts emphasized expanding the "how" of meaning-making (e.g., translanguaging, multimodality) more so than the "what" (i.e., what students were making meaning *about*). This is consistent with a finding of the NASEM (2022) report that their fourth approach to equity—"seeing science and engineering as part of justice movements" (p. 25)—was significantly underrepresented in the literature. Moreover, research on pre-service teacher preparation has pointed to the difficulty faced by teachers, many of whom do not share the cultural backgrounds of their students, in "identifying and integrating [MLs'] funds of knowledge into their instruction" (Rutt et al., 2021, p. 656), although this difficulty is not exclusive to English-monolingual teachers (e.g., González-Howard et al., 2022). Future research should leverage this unprecedented moment in which societal challenges loom large (e.g., COVID-19, climate change) to support teachers in eliciting and cultivating MLs' rich knowledge and experiences related to these challenges (Calabrese Barton et al., 2021; Lee & Campbell, 2020; Lee & Grapin, 2022). For example, Grapin et al. (in press) studied how pre-service teachers made sense of an instructional unit that engaged MLs in leveraging their transnational knowledge, along with the meaning-making affordances of computational models, to explain COVID-19's disproportionate impact on historically marginalized communities and propose personally meaningful solutions. Consistent with our emphasis on the intersection of science with other STEM subjects, this research could draw inspiration from emerging efforts in engineering education that document how teachers cultivate MLs' knowledge, practices, and language for solving pressing problems facing their local communities (e.g., Frausto Aceves & Morales-Doyle, 2022; Wilson-Lopez & Acosta-Feliz, 2022). In the pre-service teacher education context specifically, this research will require a systems approach that extends beyond coursework into linguistically diverse schools and communities (e.g., Chen & Mensah, 2018; Rutt & Mumba, 2022). Overall, examining how teachers harness synergy between the "how" and "what" of meaning-making will be essential to supporting the goals of equity as transformation.

Another promising direction involves the design of in-service teacher learning. An exciting trend across multiple research efforts was the use of participatory designs (Bang & Vossoughi, 2016; Kang & González-Howard, 2022; Kang & Nation, 2022) that positioned teachers not as passive recipients but as co-generators of knowledge who were engaged in collective sense-making with each other and with researchers. For example, in Fine's research on (trans)formative assessment, teachers developed their translanguaging interpretive power through "participation in collective conversations" (Fine, 2022, p. 191) in which "each collaborative member brought her own existing practices . . . to the interpretation [of MLs'] work" (Fine, 2022, pp. 207-208). Likewise, Vogel's research on professional learning communities was grounded in the premise that, just as "dismantling power hierarchies is in the DNA of translanguaging theory . . . researchers must consider power dynamics . . . in their research process and its products . . . to promote transformation in educational environments" (Vogel, 2022, p. 2). This emphasis on "forming more equitable relationships with participants" (Vogel, 2022, p. 2) is consistent with a broader shift in the literature on professional development for teaching MLs "away from the familiar approach of having an external expert lead an occasional workshop" (Lucas et al., 2018, p. 168). We see this shift in *teacher* learning as parallel to the push toward equity as transformation in *student* learning. Indeed, we would argue that only when teacher learning experiences recognize, affirm, and sustain what teachers bring and what they care about (in other words, when teacher learning experiences are themselves transformative) will we make strides toward equity as transformation with students (NASEM, 2022). Because participatory designs create symmetry (Mehta & Fine, 2019) between how students and teachers learn, these designs will continue to play a significant role in research aimed at "transformative science learning" for MLs (Kang & González-Howard, 2022, p. 1192).

Recommendations Toward a Coherent and Impactful Research Agenda

In this article, we have illustrated how science education with MLs represents a "significant pocket of progress" (NASEM, 2022, p. 29) in addressing multiple conceptions of equity. Yet, as the research agenda above makes evident, tensions persist, and there is still much work to be done. Across the areas of learning, assessment, and teacher education, the core question is how we ensure MLs' access to the knowledge, practices, and language normatively privileged in science and STEM (in other words, "play the game"; Gutiérrez, 2009) while simultaneously working to transform those knowledge, practices, and language in ways that center what MLs bring and what they care about (in other words, "change the game"; Gutiérrez, 2009). While such tensions will not be easily resolved, we offer three broad recommendations for making the research agenda outlined above coherent and impactful: (a) being explicit about our conceptions of equity, (b) paying attention to the interplay of structure and agency, and (c) promoting interdisciplinary collaboration.

The first recommendation involves more explicitly articulating the conception(s) of equity that undergird our work. Just as researchers regularly define and explicate the theories and constructs central in their studies, we propose that it should also be common practice for researchers to articulate the conceptions of equity they are working with and how those conceptions inform various aspects of their research. Reflecting on our own prior writings, we were struck by how often we had only tacitly referenced the conceptions of equity that informed our work, and we found that the exercise of retrospectively unpacking when and why we were invoking different conceptions helped bring clarity and focus to our own research efforts (past, present, and future). Making explicit our conceptions of equity—and being candid about the tensions we face in balancing them—is important not only for individual researchers and research teams to carry out their work in principled ways, but also for the research community as a whole to develop a coherent body of literature on science education with MLs. Without being explicit about our conceptions, we may have the illusion of consensus based on generic and seemingly axiomatic statements (e.g., "Equity means leveraging MLs' assets") while overlooking the divergent conceptions of equity that such statements can imply (e.g., what assets are considered and for what purpose are they leveraged?). At an institutional level, this will require expanding what "counts" as scholarship (Canagarajah, 2021) to include less conventional genres, such as critical self-reflections (e.g., see the reflective essays in a special issue of *Science Education* by Settlage & Williams, 2022). By making conceptions of equity explicit and engaging in sustained dialogue around them, we can establish a mutual understanding and common vocabulary that enables us, as a research community, to make progress on the complex puzzle that is the pursuit of equity for MLs in STEM (Lubienski & Gutiérrez, 2008).

A second recommendation involves paying attention to the interplay between structure and agency. Myriad structural barriers constrain progress toward transforming the education system, ranging from the ideological (e.g., raciolinguistic ideologies that overdetermine racialized MLs as linguistically deficient) to the institutional (e.g., assessments and curricula that narrow what "counts"). At the same time, theoretical and empirical work across science education (e.g., Varelas et al., 2015) and multilingual education (e.g., Canagarajah, 2021) indicates that individuals and collectives can assert agency in pushing back against oppressive structures. This interplay of structure and agency was an underlying theme in the emerging research efforts described earlier. For example, Ryu showed how, in the face of disempowering narratives about their refugee status, participants in the afterschool program crafted a space for themselves in which diverse identities could contribute meaningfully to justice-oriented work. Likewise, Fine and Vogel showed how, despite pressure from English-medium science assessments and curricular mandates, collectives of teachers were empowered to enact translanguaging pedagogical practices that, in turn, empowered their MLs. Given this interplay of structure and agency, an important task for researchers will be to closely document the structural barriers that constrain progress toward equity as transformation in their research contexts (as such barriers cannot be challenged unless they are named) while also documenting the ways in which teachers, students, and other actors within and beyond the education system agentively open up cracks (Weber, 1997) to challenge those structures and create possibilities for transformation. Paying attention to the interplay of structure and agency enables the research community to acknowledge the very real power that such structures wield in science education with MLs while also offering hope that such structures can be challenged toward growing "a world made by racialized bilinguals themselves as they engage with their own knowledge systems and cultural and linguistic practices" (García et al., 2021, p. 206).

A final recommendation involves conceptualizing the research community as an interdisciplinary one. Addressing multiple conceptions of equity is challenging enough when dealing with one field alone, but this complexity is compounded when multiple fields come together, as is the case in science education with MLs. Because the fields of science education and multilingual education have not always engaged in meaningful dialogue (Lee, 2019), researchers across these fields are liable to work at cross purposes. For example, research that conceives of equity as *transformation* from a science perspective (e.g., promoting an expansive view of science modeling) but equity as *access* from a language perspective (e.g., privileging the use of “academic language” in students’ models) may end up compromising the goals associated with *both* conceptions of equity. The urgent need to develop mutual understanding across fields was a major impetus for this article, which brought together authors with complementary areas of emphasis and expertise across STEM education, science disciplines, multilingual education, and applied linguistics. We argue that such interdisciplinary collaboration must extend beyond the research community to multiple levels of the education system, including policy (e.g., through ongoing efforts to align English language proficiency standards with science standards) and practice (e.g., through on-the-ground collaboration between science and language educators). Ultimately, we hope that science education with MLs can serve as a model for how other areas of science education can take an interdisciplinary approach to addressing multiple conceptions of equity and their implications for minoritized students who, for too long, have been denied the transformative science education experiences they need and deserve.

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