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RESEARCH ARTICLE



A disciplinary perspective on translanguaging

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ABSTRACT

Building on recent practice-oriented and multimodal shifts in bilingual education and content area education, we propose a *disciplinary perspective on translanguaging* that leverages the synergy between translanguaging and contemporary conceptualizations of content learning. Specifically, we propose that a disciplinary perspective consists of two features: (a) connecting translanguaging practices to disciplinary practices and (b) framing multimodality as essential to constructing disciplinary meaning. We illustrate these features using examples from our research in sixth-grade STEM classrooms. We argue that a disciplinary perspective could address persistent challenges of developing and researching translanguaging pedagogies and contribute to fostering equitable learning experiences for multilingual students.

As both a theory of language and a pedagogical approach, *translanguaging* has captured the attention of bilingual education researchers and practitioners. Translanguaging describes the fluid and dynamic language practices of multilinguals that transcend boundaries between named languages, language varieties, and multimodal resources (Li, 2018). Recently, translanguaging has become more prevalent in bilingual education contexts that integrate content and language learning, including in the Content and Language Integrated Learning (CLIL) movement in Europe and Asia (Lin & Lo, 2017; Nikula & Moore, 2019), K-12 public schooling in North America (Celic & Seltzer, 2011), and English-medium universities across the globe (Mazak & Carroll, 2016). Research on translanguaging has also spanned content areas, including science (Probyn, 2015), mathematics (He, Lai, & Lin, 2017), and English language arts (de los Ríos & Seltzer, 2017). Across these contexts, translanguaging pedagogies promise to transform content classrooms for multilingual students by inviting them to deploy their full repertoire of linguistic and semiotic resources toward the goal of disrupting socially constructed language hierarchies and restrictive language policies (Otheguy, García, & Reid, 2015).

Simultaneously, fundamental shifts have occurred in content teaching and learning. Whereas traditional views emphasized the acquisition of discrete facts and skills, more recent perspectives highlight engagement in *disciplinary practices* (e.g., argumentation) that call on hybrid resources (e.g., language, drawing, gesture, code) to construct disciplinary meaning (Ford & Forman, 2006). This shift toward a practice-oriented and multimodal view of content learning resonates with the shift in bilingual education from a focus on developing discrete named languages to valuing and encouraging translanguaging practices. While a substantial body of research explores the intersection of bilingualism and content

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areas (e.g., Brown & Ryoo, 2008; Garza, 2017a, 2017b; Lin & Lo, 2017), research has only begun to leverage the synergy between translanguageing (from bilingual education) and recent practice-oriented views of content learning (from content area education) due, in part, to researchers working in siloed fields (Grapin, Llosa, Haas, Goggins, & Lee, 2019; National Academies of Sciences, Engineering, & Medicine [NASEM], 2018). As a consequence, we have yet to develop a collective vision of how translanguageing can support and transform teaching and learning in content classrooms.

In this paper, we propose a *disciplinary perspective on translanguageing* that leverages the synergy between translanguageing and contemporary conceptualizations of content learning. This perspective goes beyond positioning translanguageing as “a scaffolding practice” (García & Li, 2014, p. 68; Poza, 2017) to seeing it as integral to engaging in disciplinary work. We begin by describing the theoretical foundation of a disciplinary perspective – the “translanguageing turn” in bilingual education and the “practice turn” in content area education – and providing a brief overview of recent research that explores translanguageing in content classrooms. Then, we describe how a disciplinary perspective on translanguageing could extend current theory and research by (a) connecting translanguageing practices to disciplinary practices and (b) framing multimodality as essential to constructing disciplinary meaning. We illustrate these proposed features of a disciplinary perspective using examples from our design-based research with sixth-grade multilingual students and their monolingual peers¹ in STEM classrooms in the US. Finally, we highlight how a disciplinary perspective could begin to address persistent challenges of developing and researching translanguageing pedagogies.

Theoretical and empirical foundation

A disciplinary perspective on translanguageing is grounded in parallel theoretical shifts in bilingual education and content area education. We focus primarily on mathematics and science classrooms due to the close relationship between these disciplines (Wright & Chorin, 1999) and recent scholarly attention to multilingual students’ STEM learning (NASEM, 2018). Further theoretical and empirical work is needed to understand how this perspective relates to the growing body of research on translanguageing in other content areas, such as language arts (e.g., Smith, Pacheco, & de Almeida, 2017).

Translanguageing turn in bilingual education

There is a long history in bilingual education of conceptualizing named languages as bounded, autonomous systems (Turner & Lin, 2020), which has had real and material consequences for minoritized communities (Makoni & Pennycook, 2007). In schools, this conceptualization has resulted in deficit-oriented views of multilingual students, who are judged as lacking the language (e.g., “English”) or language varieties (e.g., “academic English”) considered prerequisite to participating meaningfully in content classrooms (García, 2020; García & Solorza, 2020). Such monoglossic ideologies often become codified in restrictive language policies, such as English-only programs (Menken & Sánchez, 2019).

In contrast, translanguageing establishes a different starting point: the dynamic and flexible language *practices* of bilingual communities that are “readily observable [and] the normal mode of communication that characterizes communities throughout the world” (García, 2009, p. 44). Translanguageing theory posits that named languages are politically and socially constructed (Ag & Jørgensen, 2013; Canagarajah, 2013; García & Kley, 2016; Makoni & Pennycook, 2007) and that disrupting these political and social constructions calls for the creation of multilingual spaces that privilege versatility and agility over mastery and control (Hemphill & Blakely, 2019; Hornberger & Link, 2012; Poza, 2017). In educational contexts that adopt this theoretical stance, multilingual students are supported to mobilize their full linguistic repertoire as a resource for learning and to extend that repertoire in various directions as they develop new understandings (García, Johnson, & Seltzer, 2017). Ultimately, translanguageing is meant to transform schools and classrooms by empowering multilingual students to challenge socially constructed language hierarchies and restrictive language policies that have been responsible for the oppression of minoritized communities (Otheguy et al., 2015).

Although most closely associated with the notion of *linguistic* repertoire, translanguaging theory emphasizes the *semiotic* repertoire of individuals and communities (Blackledge & Creese, 2017; Kusters, Spotti, Swanwick, & Tapio, 2017; Li, 2018; Lin, 2019). Whereas, in bilingual education, nonlinguistic modes (e.g., visual, actional) have traditionally been viewed as compensatory to language – a *weak version of multimodality* (Grapin, 2019) – translanguaging embraces the *strong version of multimodality*, which starts from the premise that “all semiotic resources are licensed as valuable” (Otheguy et al., 2015, p. 302). Following from social semiotic theories (Bezemer & Kress, 2008; Lemke, 2000), translanguaging recognizes that each mode has distinct affordances (i.e., meaning-making potentials) that shape the semiotic work for which it is best suited. By valuing modes for their communicative (rather than compensatory) function (e.g., Horner, Selfe, & Lockridge, 2015), translanguaging aims to deconstruct hierarchies not only between named languages, but also between modes that have traditionally been valued unequally (e.g., privileging speech and text over gesture and visual representation).

In sum, the translanguaging turn signals a fundamental shift in bilingual education, from a view of bilingualism as the acquisition of bounded, autonomous languages to a focus on empowering bilinguals to challenge monoglossic and logocentric ideologies by drawing on their full multilingual, multimodal repertoire for different purposes and in different contexts. Below, we describe parallel shifts in content area education.

Practice turn in content area education

Traditionally, content classrooms have emphasized the acquisition of decontextualized information and procedures (Duschl, 2008; National Research Council [NRC], 2012b). This image of content classrooms, in which students memorize mathematics theorems or follow a prescribed scientific method, is likely to resonate with some readers' experiences. However, consistent with broader shifts in the psychology of learning (Lave & Wenger, 1991), contemporary thinking in content area education has moved toward a view of learning as participation in the practices of disciplinary communities (Lehrer & Schauble, 2015; Miller, Manz, Russ, Stroupe, & Berland, 2018). The basic premise of this practice turn is that, if learners are to be inducted into disciplinary communities, they must not only acquire content knowledge but also engage in the *disciplinary practices* used to generate that knowledge. For example, in mathematics, students look for patterns and regularities in data to test the truth of mathematical conjectures (Bass, 2011). In science, students work with representations of phenomena and construct and critique evidence-based claims to achieve a best-for-now explanation of nature's behavior (Ford & Forman, 2006). By encouraging students to appropriate and transform disciplinary practices in service of personally meaningful lines of inquiry, the practice turn seeks to cultivate in students an authentic sense of what it means to participate in mathematics and science.

Although engaging in disciplinary practices involves using language, these practices are rarely accomplished through language alone. The multimodal nature of disciplinary practices is supported by extensive studies of professional mathematicians and scientists (Goodwin, 2018; Nersessian, 2008). For example, to investigate electromagnetism, Michael Faraday moved flexibly and strategically across hybrid representations (e.g., concrete objects, sketches) that combined multiple modes (e.g., visual, linguistic; Gooding, 2006). Importantly, multiple modes and representations not only offered *more* channels for communicating ideas, but each mode or representation also offered a *unique perspective* on the phenomenon under study. In a similar manner, a student in a mathematics classroom who re-represents a word problem as an algebraic function could uncover novel ways of making sense of and solving that problem (Moschkovich, 2015). Likewise, developing embodied or computational models in science could foreground dynamic or emergent aspects of phenomena (e.g., diffusion of particles) that might not otherwise be apparent from a static diagrammatic model (Pierson & Brady, 2020). Given the distinct affordances of different modes and representations, engaging in disciplinary practices requires strategic decisions about when, how, and why to deploy various meaning-making resources.

Recently, the practice turn has been adopted by international educational reform movements (Harris, Krajcik, Pellegrino, & DeBarger, 2019). In the US, the latest college and career-ready standards foreground disciplinary practices. For example, the Common Core State Standards (CCSS) for mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) articulate eight mathematical practices that “describe varieties of expertise that mathematics educators at all levels should seek to develop in their students” (p. 6). Likewise, the Next Generation Science Standards (NGSS) view science as “not just a body of knowledge” but “also a set of practices used to establish, extend, and refine that knowledge” (NRC, 2012a, p. 26). Accordingly, the NGSS identify eight science and engineering practices that reflect the actual practices of scientists and engineers and are intended to be used iteratively as students work together in their classroom communities to explain phenomena in the natural world (NGSS Lead States, 2013). Although disciplinary practices in the latest standards have been described as language-intensive (Hakuta, Santos, & Fang, 2013), these practices are inherently multimodal (Grapin, 2019; Grapin & Llosa, 2020). As students engage in mathematics and science practices, they draw strategically from visual, actional, and linguistic modes to construct disciplinary meaning (Bezemer & Kress, 2008; Moschkovich, 2015).

Just as translanguaging calls for disrupting language hierarchies, in the past decade, STEM education researchers have begun to critically evaluate disciplinary practices represented in the CCSS and NGSS. Specifically, these scholars warn that calls to “broaden participation” in STEM have been taken up in prescriptive ways that privilege canonical disciplinary practices over the everyday practices of minoritized students (Bang et al., 2018; Barton & Tan, 2018; Medin & Bang, 2014). In response to this concern, researchers have intensified efforts to recognize and amplify students’ everyday practices, which are shaped by their experiences in and out of school (Warren, Vossoughi, Rosebery, Bang, & Taylor, 2020). We propose that inviting translanguaging into practice-oriented content classrooms is one way of bringing together everyday practices and canonical disciplinary practices (Gutiérrez & Jurow, 2016) to create new forms of knowledge and promote more equitable learning for multilingual students.

In sum, the practice turn in content area education signals a fundamental shift in content learning, from a focus on acquiring discrete knowledge and skills to engaging in classroom versions of disciplinary practices. This practice turn in content area education parallels the translanguaging turn in bilingual education in two key ways. First, the translanguaging turn reflects the practices of bilingual communities, and the practice turn reflects the practices of disciplinary communities. Second, both turns emphasize how students draw strategically from multimodal resources to make meaning. Based on these parallels, emerging research in content classrooms has explored ways to leverage synergy between translanguaging and multimodal disciplinary practices, as described next.

Emerging research on translanguaging and multimodal disciplinary practices

Substantial research demonstrates that multilingual students benefit from deploying their full range of meaning-making resources in content classrooms (e.g., García & Kleyn, 2016; Smith, Pacheco, & Khorosheva, 2020). For example, in science classrooms, translanguaging can promote language development, higher-order thinking, and conceptual understanding (Oliveira, Weinburgh, McBride, Bobowski, & Shea, 2019; Poza, 2018), thus contributing to more equitable learning environments for multilingual students (Karlsson, Nygård Larsson, & Jakobsson, 2019; Probyn, 2015). In light of the practice turn in content area education (Ford & Forman, 2006), researchers have also begun to consider how translanguaging can support engagement in multimodal disciplinary practices to make sense of phenomena (Brown & Ryoo, 2008).

In science classrooms, researchers have explored connections between students’ linguistic practices and the disciplinary practice of argumentation (e.g., Hudicourt-Barnes, 2003; Infante & Licona, 2018; Reigh & Miller, 2020). For example, Licona and Kelly (2019) show how teachers can draw on students’ full linguistic repertoires to help them understand nuanced dimensions of argumentation, such as the

role of reasoning. This research also suggests that linking translanguaging and language-intensive disciplinary practices like argumentation can support students classified as English learners (ELs) in science. However, as Reigh and Miller (2020) have recently pointed out, less attention has been paid to connections between translanguaging and science practices other than argumentation (for an exception focused on the science practice of modeling, see Suárez, 2020).

In addition to connecting translanguaging practices to disciplinary practices, researchers have emphasized multimodality in content learning with multilingual students, especially in mathematics (e.g., Barwell, 2018; Razfar, 2013). For example, Moschkovich (2015) has characterized multilingual students' multimodal resources as mathematically productive. Specifically, she illustrates how multilingual students use drawings to indicate a mathematical result and gestures to describe patterns in data. Though not explicitly focused on translanguaging, this research shows that multilingual students engage in mathematical practices by drawing on their "full communicative and multimodal repertoire – not only written text but also other inscriptions, oral communication, gestures, and objects" (Moschkovich, 2015, p. 45).

Similar work has extended into other STEM disciplines, such as computer science (e.g., Radke, Vogel, Hoadley, & Ma, 2020; Vogel, Hoadley, Ascenzi-Moreno, & Menken, 2019). Radke et al. (2020) describe an instructional design in which students used a multilingual, multimodal programming environment to understand a personally meaningful phenomenon – the effects of Hurricane María on Puerto Rico. This design invited students' multimodal resources, cultures, and experiences by engaging them in statistical modeling practices while also exploring "human stories of migration . . . in less quantitative formulations" (p. 1371). Thus, integrating translanguaging with multimodal STEM practices supported students in reasoning from everyday and disciplinary perspectives.

In sum, existing research has begun to explore connections between translanguaging and some disciplinary practices (e.g., argumentation), yet further research is needed to identify potential connections to other disciplinary practices. Moreover, while research has begun to explore how multimodality can be leveraged as part of translanguaging to support disciplinary learning, further research is needed to understand how multimodality can support meaning-making within specific content areas.

A disciplinary perspective on translanguaging

Building on the emerging body of research described above, we propose a disciplinary perspective on translanguaging that leverages the synergy between translanguaging and contemporary conceptualizations of content learning. In proposing this perspective, we aim to extend the contributions of recent theory and research and to chart a path toward a coherent research agenda on translanguaging in content areas.

We propose that a disciplinary perspective on translanguaging consists of two key features: (a) connecting translanguaging practices to disciplinary practices and (b) framing multimodality as essential to constructing disciplinary meaning. To illustrate these features, we present an example from our research. The first author, Ashlyn, in collaboration with a teacher (Ms. S), designed a 9-week ecology unit for Ms. S's sixth-grade STEM classroom. We describe this unit as one possible application of a disciplinary perspective on translanguaging, because it embodies and instantiates the features described above: (a) connecting translanguaging practices to *STEM modeling practices* and (b) framing *multimodal modeling* as essential to constructing disciplinary meaning.

First, our design focused on connecting translanguaging practices to STEM modeling practices. Modeling is the practice of creating, using, or revising representations (e.g., diagrams, computer simulations) that correspond in some ways (but not others) to a referent phenomenon (Lehrer & Schauble, 2015). Modeling is central to science and mathematics and is featured prominently in U.S. science and mathematics standards (NGA Center for Best Practices & CCSSO, 2010; NGSS Lead States, 2013). Although students engaged in other disciplinary practices in the unit, we emphasized modeling as a key STEM practice with similarities to translanguaging. Both translanguaging and modeling emphasize fluid movement across representations – translanguaging between socially constructed named languages and

modeling between multiple model types and their referent phenomena. Just as multilingual individuals select semiotic resources from their repertoire in response to purpose and context, scientists and mathematicians develop models that foreground aspects of phenomena in response to their questions and lines of inquiry. Furthermore, in both translanguaging and modeling, no language or model is inherently “right” or “more appropriate” – each is useful for different purposes of meaning-making and expression in different contexts (Flores & Rosa, 2015; Lehrer & Schauble, 2015). Our design leveraged these parallels by making explicit connections between translanguaging and modeling.

Second, our design framed multimodal modeling as essential to constructing disciplinary meaning. Throughout the unit, students developed four types of models: physical, embodied, diagrammatic, and computational (Figure 1). Each model type makes use of different modes and therefore has different affordances for constructing disciplinary meaning. For example, whereas diagrammatic models make use of drawings and symbols to highlight the relationships between system components (e.g., arrows to indicate energy transfer among organisms in an ecosystem), computational models make use of computer code and dynamic visualization to test causal explanations underlying phenomena (e.g., testing effects of different population sizes on species in an ecosystem). A focus on multimodality deepens the connection between translanguaging and modeling practices, as both involve moving flexibly across modes (including languages) to make meaning.

We conjectured that, by (a) connecting translanguaging practices to STEM modeling practices and (b) framing multimodal modeling as essential to constructing disciplinary meaning, we could legitimize students’ multilingual, multimodal practices that are often marginalized in schools. In addition to fostering more equitable learning experiences for multilingual students, we conjectured that this design would contribute to the broader goal of promoting value for linguistic and representational

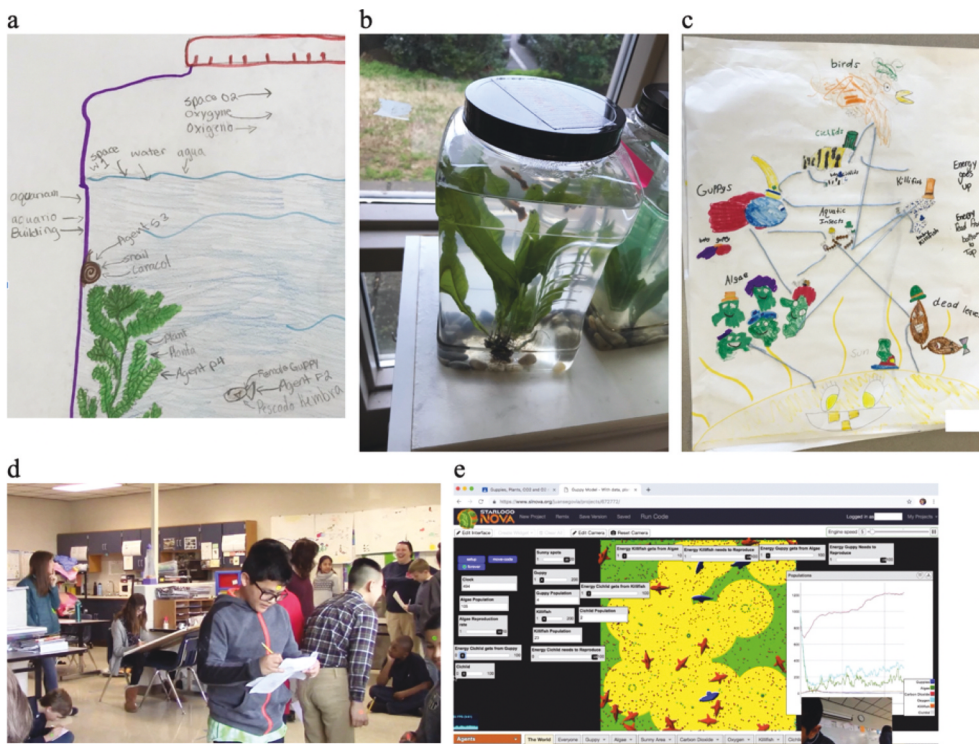


Figure 1. Examples of student models used during the unit: (a) diagrammatic model – ecosystem plan, (b) physical model – ecosystem jar, (c) diagrammatic model – food web, (d) embodied model – guppy ecosystem, (e) computational model – guppy ecosystem.

diversity, including among students traditionally considered monolingual. Below, we describe the research context in more detail and provide classroom snapshots to illustrate how this design helped students recognize multilingual, multimodal practices as valuable for STEM.

Research context

We present data from an iterative design-based study that was part of a larger research program (Lee, Llosa, Grapin, Haas, & Goggins, 2019; NSF DRL#1742138). The study was conducted in a public middle school in a small suburban school district in the southeastern US in collaboration with Ms. S, who was in her 26th year of teaching. By participating in the study, Ms. S hoped to develop equitable STEM curricula that integrated programming and computational modeling.

Ms. S and the first author, Ashlyn, codesigned and cotaught all lessons, which took place 3 times per week during Ms. S's 9-week STEM class. Ms. S and Ashlyn, who are both white, monolingual English speakers, were interested in promoting multilingual and multimodal STEM learning based on their experiences as teachers of linguistically diverse students. During the fourth iteration of the design, Ashlyn suggested focusing on translanguaging to explicitly challenge monoglossic norms in the classroom and legitimize and value multilingual resources.

Following a design-based approach (Cobb, Confrey, di Sessa, Lehrer, & Schauble, 2003), we iteratively developed, implemented, and revised an ecology unit focused on the flow of energy and matter in ecosystems. Design-based research was appropriate, because it allowed us to explore an innovative instructional design with the goal of advancing theory and practice (Cobb et al., 2003). Details of the design and related findings are reported in other publications. Specifically, we have closely analyzed how students interacted with computational models as participants in inquiry (Pierson, Brady, & Clark, 2020), how embodied modeling created more equitable learning opportunities by building on students' multimodal resources (Pierson & Brady, 2020), and how translanguaging supported new kinds of STEM learning and transformed what counts as legitimate and valuable participation in STEM (Pierson, Clark, & Brady, 2021). Here, we highlight findings from these studies that illustrate the promise of a disciplinary perspective on translanguaging for multilingual students and their monolingual peers in content classrooms.

Data included student artifacts, classroom videos, and end-of-unit student interviews. These data were collected during seven successive implementations of the ecology unit in Ms. S's classroom. During any given implementation cycle, between two and five students were classified by their school as ELs. All of these students identified as bi/multilingual and as speakers of Spanish and English, although they described their linguistic resources in different ways (e.g., some students identified as speakers of "Mexican" or "Honduran" Spanish). In addition to students classified as ELs, other students in Ms. S's classes identified as bi/multilingual, including speakers of Spanish, Hindi, Korean, Chinese, Hebrew, and Castellano. Still, most students (and Ms. S) identified as monolingual English speakers. Our data therefore offer insight into how to promote translanguaging in predominantly monolingual settings that have privileged English over other linguistic and semiotic resources.

Design

The design emphasized the features outlined above: (a) connecting translanguaging practices to STEM modeling practices and (b) framing multimodal modeling as essential to constructing disciplinary meaning. The unit focused on using models to explain the phenomenon of how guppies survive in rivers with different amounts of predators. Throughout the unit, students created physical, embodied, diagrammatic, and computational models to understand aspects of the guppies' environments (Figure 1). These model types were selected for the broad range of modes they integrate, including material resources (physical models); embodied actions and spoken language (embodied models); drawings, symbols, and written language (diagrammatic models); and programming languages and dynamic visualization (computational models). Although the model types were chosen by Ms. S and

Ashlyn, students were encouraged to choose the modes and languages they used in their models. Thus, the design offered students opportunities to iteratively represent the guppies' environment with increasing complexity by deploying a range of multilingual and multimodal resources.

To explicitly connect translanguaging to modeling, Ms. S launched the unit by framing modes and models as “languages” essential for meaning-making in STEM fields. To introduce this idea, she projected an image of a student’s computational model (similar to Figure 2) on the board with the question, “What ways are ideas represented here?” Students responded by identifying and describing modes within the model. For example, they pointed out the simulation could show “more plants than guppies,” the graph could show how “population numbers are decreasing,” and the clock could show “how long the code has run.” After students shared ideas, Ms. S said, “Those are all like different languages.”

Then, Ms. S asked students whether certain ideas are represented differently across languages. After Ms. S shared examples, multilingual students shared their own. For example, Eli, Jesús, and Carlos each shared examples of foods with names in Korean or Spanish that are difficult to describe in English. Ms. S also asked students to describe how and when they used languages. Some students described “combining” languages when studying (e.g., using linguistic resources from one named language to make sense of words in another) or when interacting with different people (e.g., when shopping in a grocery store, using different linguistic resources with family members versus employees). Some students described using languages separately, especially when communicating with monolingual speakers.

Ms. S connected these examples to multimodal models. She explained that scientists rely on different “languages” (broadly conceived as including linguistic and nonlinguistic modes) in their work. As an example, she prompted students to compare canonical STEM languages, like tables and graphs. Students noticed that these representations were useful for different purposes because they showed similar ideas in different ways; students observed that tables were useful for displaying exact numbers, while graphs were useful for making “big picture” trends visible.

During the next class, Ms. S launched a discussion with, “Why would it be good to use different languages in our models?” Students offered multiple reasons, including “communicating information with *others* who speak different languages” and “helping *ourselves* make connections between ideas and come up with new ideas.” These discussions established a connection between translanguaging and multimodal modeling that Ms. S continued to strengthen throughout the unit.

Classroom snapshots

Below, we provide classroom snapshots to illustrate how Ms. S legitimized and valued translanguaging through modeling activities that (a) connected translanguaging practices to STEM modeling practices and (b) framed multimodal modeling as essential to constructing disciplinary meaning.

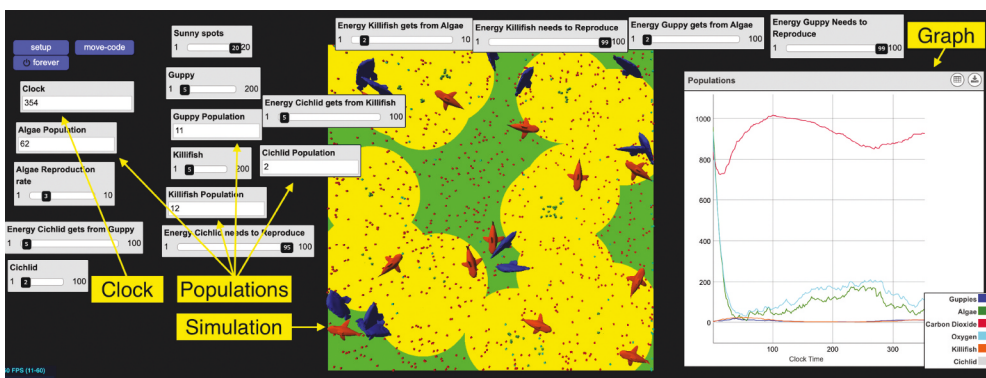


Figure 2. Computational model of guppy ecosystem.

Connecting translanguaging to STEM modeling

After explicitly connecting translanguaging to modeling, Ms. S encouraged students to use multiple languages in their models. Students interpreted this task in different ways. Some groups translated each term (Figure 3). Other students, like Luis, moved more fluidly between linguistic resources. When Luis added text to his diagrammatic model (Figure 4), he wrote primarily in Spanish, and he drew on English resources when he did not know Spanish words for English terms he learned in class. For example, he wrote, “El pes agara su comida de la planta y el *algae* y oxígeno” (“The fish gets its food from the plant and the *algae* and breathes oxygen”)², blending English and Spanish words and spellings (e.g., “oxígeno” rather than “oxygen” or “oxígeno”).

The opportunity to use multiple languages also allowed students to build their understanding by seeing phenomena from different perspectives. For example, in end-of-unit interviews, multilingual students reported that using different languages in their models changed their thinking. Jennifer explained:

In English, it's like “food chain” and you know, like, it has to be connected to something because of the word “chain,” and in Spanish you have to think of, like, multiple words to describe the food chain because, like, in Spanish there's not really a word to describe food chain, so you have to, like, a sentence will describe a food chain, not just like saying two words.

Even though Jennifer did not know “a word to describe food chain” in Spanish, considering how to translate “food chain” created an opportunity to unpack and explore the meaning of this term and how it is useful for describing the connections between organisms in ecosystems. In other words, for students like Jennifer, translanguaging as part of modeling was not only about communicating ideas but also about making sense of those ideas.

In addition to using resources from multiple named languages (e.g., Spanish and English), students *invented* terms to describe phenomena that emerged as important in their classroom. For example, 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 the ecosystem was stable. As this pattern became central to students' discourse, Ms. S asked students to nominate English, Spanish, and invented terms to describe the pattern. The nominated terms captured what was, for students, salient about the pattern. For example, Eli shared an invented term: “Flectorate. It sounds like fluctuate, and it means the rates are changing.” Luis used 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.” These examples illustrate the wealth of resources that students brought to interpreting and describing the pattern in their models. Importantly, these invented terms emerged from the classroom community rather than being handed down from an authoritative voice. For students in this STEM classroom, the project of disinventing languages (i.e., challenging the notion of languages as bounded, autonomous systems; Makoni & Pennycook, 2007) involved inventing new terms that were useful for their own personally meaningful lines of inquiry.

In sum, as students in this classroom used translanguaging practices to engage in STEM modeling practices, they were not just encoding the same ideas in different ways. Rather, they were deploying resources from multiple named and invented languages to make sense of the phenomena they were studying and, more broadly, the worlds they were inhabiting.

Using multimodal models to construct disciplinary meaning

In addition to using multiple languages as part of modeling, students also moved between multimodal models. For both multilingual and monolingual students, this offered new perspectives, enabling them to understand ecological phenomena in increasingly nuanced ways. For example, students began the unit by writing a list of components they planned to include in their ecosystem (e.g., guppies, algae). Then, they represented their ecosystem in a diagrammatic model. This shift from the written to the visual mode foregrounded two new variables that could affect guppies' survival: space and interaction. Tensions between these variables arose as students visually represented their ecosystems and shared their plans. For example, Nora noticed that Carlos's plan included one fish (Figure 4), while Jennifer's plan included two fish (Figure 3). Nora asked Jennifer about her decision:

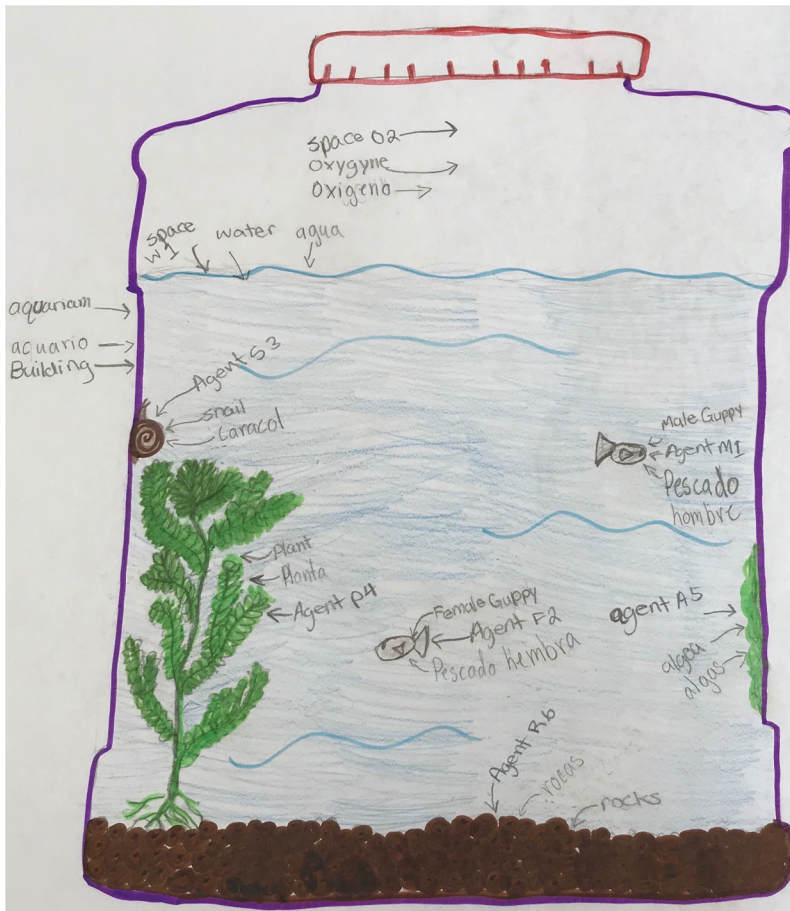


Figure 3. Group 1 (Jennifer, Jesús, Becca) – ecosystem plan.

Nora: Is there a reason for two fish?

Jennifer: It said they're better off living in pairs so we decided to get two to be more at home.

Nora: Yeah, I know some groups did one [Carlos's plan], because they said the guppy needs space, and other groups did two [Jennifer's plan], because they need to not be lonely.

Shifting to a visual representation foregrounded behavioral factors ("guppy needs space") and social factors ("[guppies] need to not be lonely") that could affect guppies' survival. These factors emerged from a unique affordance of the visual mode for showing the spatial relations among entities (Bezemer & Kress, 2008). Thus, multimodality did not simply allow students represent the same ideas in different ways. Rather, it helped students recognize aspects of phenomena that they may not have otherwise considered. This is similar to how different named and invented languages (e.g., unpacking "food chain," inventing "flectorate") helped students make sense of phenomena.

Beyond creating multimodal representations, Ms. S also encouraged students to put modes and models "in conversation." During modeling activities, Ms. S prompted students to identify languages within their models and consider what their models might "say to" or "learn from" each other. Students used this connection to conversation to examine how meaning shifts between and within multimodal models. For example, in the end-of-semester interview, Carlos explained how modes "talk to each other" within his computational model (Figure 2):

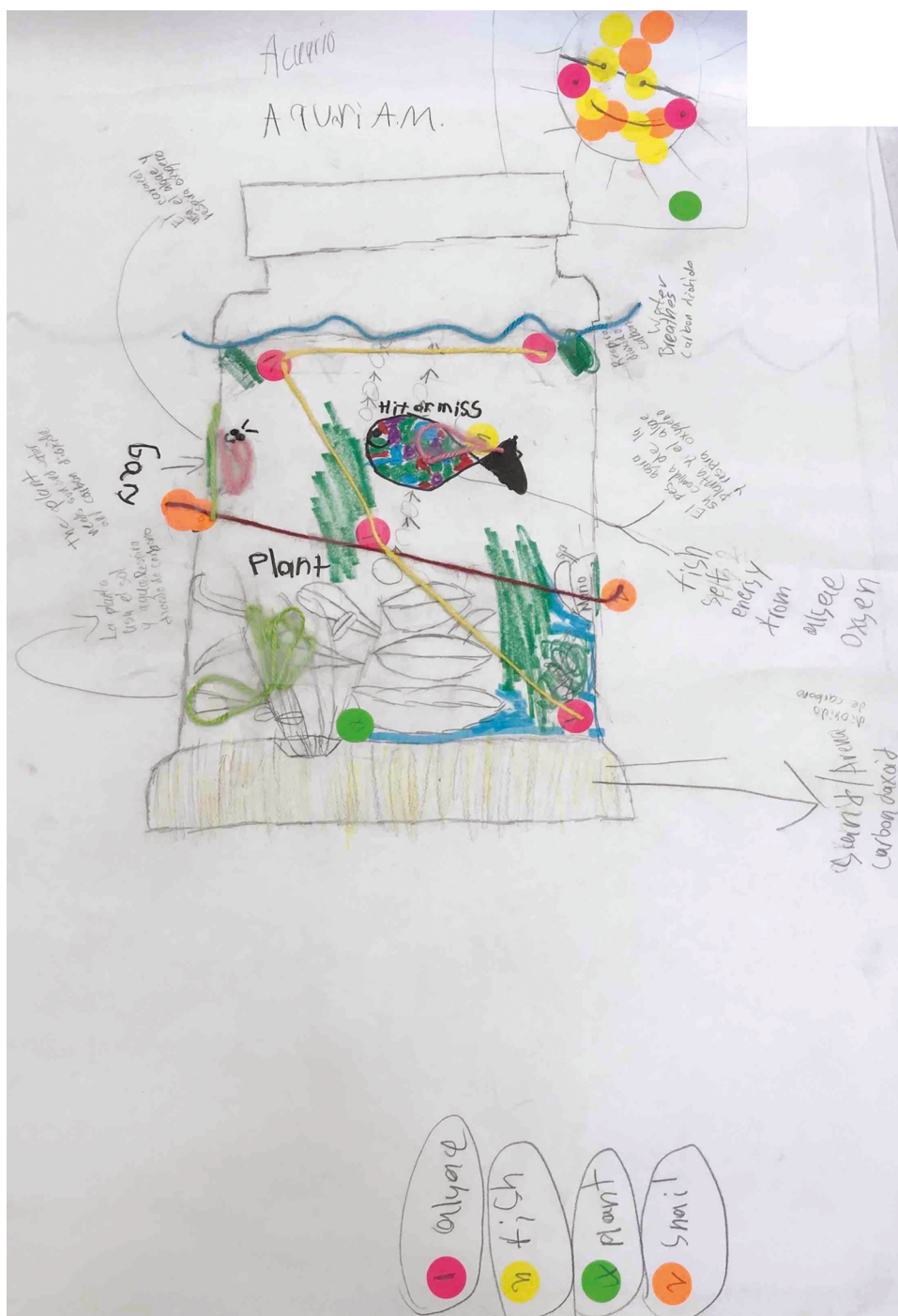


Figure 4. Group 3 (Luis, Carlos, Sean) – ecosystem plan.

They talk to each other and combine to each other because if you look at this [the graph] it will show all the, the algae went down fast, so did the oxygen, oh but the algae went up again because the death of the guppies, and then it shows that the cichlids are almost dead, died out, and the clock speaks because if you could tell the model, if you set it up again, it starts at 1 and the population is 2, and those speak together because every time they move you could see, "Oh, there's six cichlids, oh there's six guppies, oh it's been barely 17 or 18, 19 seconds."

Framing modeling as conversation, Carlos attended to several dynamic modes to understand complex interactions. Specifically, he coordinated observations from two dynamic lines on the *graph* (“the algae went up again because of the death of the guppies”), the *simulation* (“it shows that the cichlids are almost dead”), and the *clock* and *population* data boxes, which “speak together” to report the time and the population of each species. In this way, putting modes and models in conversation helped students make sense of multimodal representations and how they were useful (separately and collectively) to explain the guppies’ survival. Framing modeling as conversation also contributed to students’ linguistic and representational knowledge, as they considered the affordances of modes and model types for constructing disciplinary meaning.

Overall, these data suggest the promise of a disciplinary perspective for legitimizing linguistic and representational diversity in STEM classrooms. Importantly, this perspective positions translanguaging as a way to *support* canonical disciplinary practices but also to *transform* those practices in personally meaningful ways (Gutiérrez & Jurow, 2016; Warren et al., 2020). For example, rather than relying exclusively on technical science terms (e.g., “population dynamics”) – what Lemke (1990) called “the exclusive property of an initiated elite” (p. 6) – students in this classroom nominated terms (“flectorate”) that were useful in their own communities for describing a pattern in their models. By framing disciplinary practices not as rigid prescriptions but as flexible tools that students can imbue with their own meanings and intentions, this disciplinary perspective seeks to advance the social justice agenda of translanguaging and leverage its “transformative capacity” (García & Li, 2014, p. 32).

Summary and implications

In this paper, we have proposed a disciplinary perspective on translanguaging grounded in parallel theoretical shifts in bilingual education and content area education. This perspective consists of two features: (a) connecting translanguaging practices to disciplinary practices (in our design, STEM modeling) and (b) framing multimodality as essential to constructing disciplinary meaning (in our design, multimodal models). We have proposed this perspective to stimulate further theoretical and empirical work that strengthens connections between translanguaging and multimodal disciplinary practices within and beyond STEM, with the ultimate goal of fostering equitable learning experiences for multilingual students in content classrooms.

Although further research is needed, we propose that a disciplinary perspective could begin to address some persistent challenges of developing and researching translanguaging pedagogies in schools. As the research literature on translanguaging is becoming more mature, we join others (e.g., Jaspers, 2018; Poza, 2017) who have surfaced emerging challenges related to translanguaging and promising avenues for addressing them. The challenges we highlight here include (a) confronting monoglossic ideologies that permeate educational institutions, (b) promoting translanguaging in classrooms with both multilingual and monolingual students and teachers, and (c) developing principles for translanguaging in instructional designs.

One challenge involves confronting monoglossic ideologies that permeate educational institutions (Holdway & Hitchcock, 2018; Pacheco, Kang, & Hurd, 2019). While a disciplinary perspective is not a panacea for addressing this systemic challenge, we propose that it offers a novel entry point: the nature of academic disciplines. Rather than approaching translanguaging from a purely sociolinguistic perspective, which may be unfamiliar to content teachers and overpowered by ideologies about language learning, a disciplinary perspective starts from the premise that using hybrid resources to make sense of the world is the norm in disciplinary communities. From this starting point, which is likely to resonate with content teachers’ preparation and experiences, the notion of hybridity can be expanded to include how bilinguals also draw on hybrid resources “to make sense of their bilingual worlds” (García, 2009, p. 45). By anchoring discussions with educators in their “academic homes,” a disciplinary perspective can support educators in understanding translanguaging as a powerful sociolinguistic theory and applying it in ways that foster more equitable learning for multilingual students in content classrooms.

A second challenge involves promoting translanguaging in classrooms with both multilingual and monolingual students. In these contexts, multilingual students may be reluctant to use languages other than English if they do not see these languages as part of the (academic) language valued in school or are concerned about distancing themselves from monolingual peers (Cole, David, & Jiménez, 2016). A disciplinary perspective begins to address this challenge by framing translanguaging as something *all students* do as they pursue disciplinary work. In the classroom snapshots above, both multilingual and monolingual students invented terms to describe phenomena and imagined conversations between multimodal models that “spoke” to one another. By positioning translanguaging as a set of practices advantageous for all students rather than as a scaffold for students classified by their schools as ELs, a disciplinary perspective seeks to legitimize linguistic and representational diversity and, ultimately, destabilize English-only practices in content classrooms (García & Kleifgen, 2019).

A final challenge involves developing principles for translanguaging in instructional designs (Celic & Seltzer, 2011). We propose that design-based research could play an important role in developing and refining design principles that inform curriculum and instruction from a disciplinary perspective. With dual goals of advancing theory and practice, design-based research allows researchers to operationalize high-level theories (e.g., translanguaging, practice-oriented views of content learning) and everyday practices of participants into design principles through iterative cycles of development, implementation, and revision (Gutiérrez & Jurow, 2016). Although design-based research is grounded in local contexts (Barab & Squire, 2004), it calls for consideration of why a design is successful and how it could be adapted to new contexts (Cobb et al., 2003). This attention to context could offer insight into how a disciplinary perspective might work differently across content areas, classroom compositions (more or less linguistically diverse), and schools and communities.

Regardless of the methodological approach (whether design-based or otherwise), a disciplinary perspective on translanguaging will require collaboration between researchers and teachers in different fields. For example, the authors, Ashlyn and Scott, came to this collaboration with formal training in STEM education and bilingual education, respectively, and the larger research team in which they work includes researchers and teachers with expertise ranging from computer science to applied linguistics. Because a disciplinary perspective calls for a principled understanding of content, bilingualism, and the synergy between the two, collaboration between content area education and bilingual education will be essential.

Conclusion

As a theory and a pedagogical approach, translanguaging has fundamentally transformed conceptualizations of language in bilingual education. At the same time, content area education has shifted to emphasize participation in disciplinary practices that emerge within and are transformed by classroom communities. Yet, research that capitalizes on synergy between translanguaging and this vision of content learning is relatively nascent. We propose a disciplinary perspective on translanguaging that connects translanguaging practices (from bilingual education) to multimodal disciplinary practices (from content area education). In doing so, we seek to initiate a dialogue between historically separate fields (Grapin et al., 2019; NASEM, 2018). This dialogue will require bilingual education researchers to engage more deeply with contemporary conceptualizations of content learning and content area researchers to engage more deeply with students’ linguistic and semiotic practices. Through this mutual understanding between the fields, translanguaging can realize its transformative potential of fostering more equitable learning environments for multilingual students in content classrooms.

Notes

1. From the perspective of translanguaging, “multilingual” and “monolingual” are socially constructed; there is no threshold of linguistic knowledge that distinguishes between monolingual and multilingual students. Still, these categories are important in discussions of social identity and sociolinguistic behavior (Otheguy et al., 2015). In

this paper, we use “multilingual” to describe students who identified as bilingual or multilingual and used more than one named language (in or out of school), including students who were classified as “English learners” by their school. We use “monolingual” for students who did not identify as bilingual or multilingual and used English almost exclusively for speaking and writing.

2. In our data, we preserve students’ spelling and grammar.

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References

- Ag, A., & Jørgensen, J. N. (2013). Ideologies, norms, and practices in youth poly-language. *International Journal of Bilingualism*, 17(4), 525–539. doi:10.1177/1367006912457275
- Bang, M., Marin, A., & Medin, D. (2018). If Indigenous peoples stand with the sciences, will scientists stand with us? *Daedalus*, 147(2), 148–159. doi:10.1162/DAED_a_00498
- Barab, S., & Squire, K. (2004). Design-Based research: Putting a stake in the ground. *The Journal of the Learning Sciences*, 13(1), 1–14. doi:10.1207/s15327809jls1301_1
- Barton, A. C., & Tan, E. (2018). *STEM-Rich maker learning: Designing for equity with youth of color*. New York, NY: Teachers College Press.
- Barwell, R. (2018). From language as a resource to sources of meaning in multilingual mathematics classrooms. *The Journal of Mathematical Behavior*, 50, 155–168. doi:10.1016/j.jmathb.2018.02.007
- Bass, H. (2011). Vignette of doing mathematics: A meta-cognitive tour of the production of some elementary mathematics. *The Mathematics Enthusiast*, 8(1), 3–34.
- Bezemer, J., & Kress, G. (2008). Writing in multimodal texts: A social semiotic account of designs for learning. *Written Communication*, 25(2), 166–195. doi:10.1177/0741088307313177
- Blackledge, A., & Creese, A. (2017). Translanguaging and the body. *International Journal of Multilingualism*, 14(3), 250–268. doi:10.1080/14790718.2017.1315809
- Brown, B. A., & Ryoo, K. (2008). Teaching science as a language: A “content-first” approach to science teaching. *Journal of Research in Science Teaching*, 45(5), 529–553. doi:10.1002/tea.20255
- Canagarajah, S. (Ed.). (2013). *Literacy as translanguaging practice: Between communities and classrooms*. New York, NY: Routledge.
- Celic, C., & Seltzer, K. (2011). *Translanguaging: A CUNY-NYSIEB guide for educators*. New York, NY: City University of New York.
- Cobb, P., Confrey, J., di Sessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32(1), 9–13. doi:10.3102/0013189X032001009
- Cole, M. W., David, S. S., & Jiménez, R. T. (2016). Collaborative translation: Negotiating student investment in culturally responsive pedagogy. *Language Arts*, 93(6), 430–443.
- de los Ríos, C. V., & Seltzer, K. (2017). Translanguaging, coloniality, and English classrooms: An exploration of two bicoastal urban classrooms. *Research in the Teaching of English*, 52(1), 55–76.
- Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, 32(1), 268–291.
- Flores, N., & Rosa, J. (2015). Undoing appropriateness: Raciolinguistic ideologies and language diversity in education. *Harvard Educational Review*, 85(2), 149–171. doi:10.17763/0017-8055.85.2.149
- Ford, M. J., & Forman, E. A. (2006). Redefining disciplinary learning in classroom contexts. *Review of Research in Education*, 30(1), 1–32. doi:10.3102/0091732X030001001
- García, O. (2009). *Bilingual education in the 21st century: A global perspective*. West Sussex, UK: Wiley-Blackwell.
- García, O. (2020). The education of Latinx bilingual children in times of isolation: Unlearning and relearning. *MinneTESOL Journal*, 36(1), 1–7.

- García, O., Johnson, S., & Seltzer, K. (2017). *The translanguaging classroom: Leveraging student bilingualism for learning*. North York, ON: Caslon.
- García, O., & Kleifgen, J. A. (2019). Translanguaging and literacies. *Reading Research Quarterly*, 55(4), 1–19.
- García, O., & Kley, T. (2016). *Translanguaging with multilingual students: Learning from classroom moments*. New York, NY: Routledge.
- García, O., & Li, W. (2014). *Translanguaging: Language, bilingualism and education*. Hampshire, UK: Macmillan.
- García, O., & Solorza, C. (2020). Academic language and the minoritization of U.S. bilingual Latinx students. *Language and Education*, 1–17. doi:10.1080/09500782.2020.1825476
- Garza, A. (2017a). A translanguaging mathematical space: Latino/a teenagers using their linguistic repertoire. In P. Ramirez, C. Faltis, & E. De Jong (Eds.), *Learning from emergent bilingual Latinx learners in K-12* (pp. 139–156). New York, NY: Routledge.
- Garza, A. (2017b). “Negativo por negativo me va dar un . . . POSITivo”: Translanguaging as a vehicle for appropriation of mathematical meanings. In J. Langman & H. Hansen-Thomas (Eds.), *Discourse analytic perspectives on STEM education: Exploring interaction and learning in the multilingual classroom* (pp. 99–116). Basel, Switzerland: Springer.
- Gooding, D. C. (2006). From phenomenology to field theory: Faraday’s visual reasoning. *Perspectives on Science*, 14(1), 40–65. doi:10.1162/posc.2006.14.1.40
- Goodwin, C. (2018). *Co-Operative action (Learning in doing: Social, cognitive, and computational perspectives)*. New York, NY: Cambridge University Press.
- Grapin, S. E. (2019). Multimodality in the new content standards era: Implications for English learners. *TESOL Quarterly*, 53(1), 30–55. doi:10.1002/tesq.443
- Grapin, S. E., & Llosa, L. (2020). Toward an integrative framework for understanding multimodal L2 writing in the content areas. *Journal of Second Language Writing*, 47, 1–8. doi:10.1016/j.jslw.2020.100711
- Grapin, S. E., Llosa, L., Haas, A., Goggins, M., & Lee, O. (2019). Precision: Toward a meaning-centered view of language use with English learners in the content areas. *Linguistics and Education*, 50, 71–83. doi:10.1016/j.linged.2019.03.004
- Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *The Journal of the Learning Sciences*, 25(4), 565–598. doi:10.1080/10508406.2016.1204548
- Hakuta, K., Santos, M., & Fang, Z. (2013). Challenges and opportunities for language learning in the context of the CCSS and the NGSS. *Journal of Adolescent & Adult Literacy*, 56(6), 451–454. doi:10.1002/JAAL.164
- Harris, C. J., Krajcik, J. S., Pellegrino, J. W., & DeBarger, A. H. (2019). Designing knowledge-in-use assessments to promote deeper learning. *Educational Measurement: Issues and Practice*, 38(2), 53–67. doi:10.1111/emip.12253
- He, P., Lai, H., & Lin, A. M. (2017). Translanguaging in a multimodal mathematics presentation. In C. M. Mazak & K. S. Carroll (Eds.), *Translanguaging in higher education: Beyond monolingual ideologies*. Bristol, UK: Multilingual Matters.
- Hemphill, D., & Blakely, E. (2019). English language learning in globalized third spaces: From monocultural standardization to hybridized translanguaging. In D. Macedo (Ed.), *Decolonizing foreign language education: The misteaching of English and other colonial languages* (pp. 220–240). New York, NY: Routledge.
- Holdway, J., & Hitchcock, C. H. (2018). Exploring ideological becoming in professional development for teachers of multilingual learners: Perspectives on translanguaging in the classroom. *Teaching and Teacher Education*, 75, 60–70. doi:10.1016/j.tate.2018.05.015
- Hornberger, N. H., & Link, H. (2012). Translanguaging and transnational literacies in multilingual classrooms: A biliteracy lens. *International Journal of Bilingual Education and Bilingualism*, 15(3), 261–278. doi:10.1080/13670050.2012.658016
- Horner, B., Selfe, C., & Lockridge, T. (2015). *Translinguality, transmodality, and difference: Exploring dispositions and change in language and learning*. Louisville, KY: Enculturation Intermezzo.
- Hudicourt-Barnes, J. (2003). The use of argumentation in Haitian Creole science classrooms. *Harvard Educational Review*, 73(1), 73–93. doi:10.17763/haer.73.1.hnq801u57400l877
- Infante, P., & Licona, P. R. (2018). Translanguaging as pedagogy: Developing learner scientific discursive practices in a bilingual middle school science classroom. *International Journal of Bilingual Education and Bilingualism*, 24(7), 913–926.
- Jaspers, J. (2018). The transformative limits of translanguaging. *Language and Communication*, 58, 1–10. doi:10.1016/j.langcom.2017.12.001
- Karlsson, A., Nygård Larsson, P., & Jakobsson, A. (2019). Multilingual students’ use of translanguaging in science classrooms. *International Journal of Science Education*, 41(15), 2049–2069. doi:10.1080/09500693.2018.1477261
- Kusters, A., Spotti, M., Swanwick, R., & Tapio, E. (2017). Beyond languages, beyond modalities: Transforming the study of semiotic repertoires. *International Journal of Multilingualism*, 14(3), 219–232. doi:10.1080/14790718.2017.1321651
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
- Lee, O., Llosa, L., Grapin, S. E., Haas, A., & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education*, 103(2), 317–337. doi:10.1002/sce.21498

- Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. In R. M. Lerner (Ed.), *Handbook of child psychology and developmental science* (7th ed., pp. 371–388). Cambridge, UK: Cambridge University Press.
- Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.
- Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity*, 7(4), 273–290. doi:10.1207/S15327884MCA0704_03
- Li, W. (2018). Translanguaging as a practical theory of language. *Applied Linguistics*, 39(1), 9–30. doi:10.1093/applin/amx039
- Licona, P. R., & Kelly, G. J. (2019). Translanguaging in a middle school science classroom: Constructing scientific arguments in English and Spanish. *Cultural Studies of Science Education*, 15(2), 485–510. doi:10.1007/s11422-019-09946-7
- Lin, A. M. (2019). Theories of trans/language and trans-semiotizing: Implications for content-based education classrooms. *International Journal of Bilingual Education and Bilingualism*, 22(1), 5–16. doi:10.1080/13670050.2018.1515175
- Lin, A. M. Y., & Lo, Y. Y. (2017). Trans/language and the triadic dialogue in content and language integrated learning (CLIL) classrooms. *Language and Education*, 31(1), 26–45. doi:10.1080/09500782.2016.1230125
- Makoni, S., & Pennycook, A. (2007). *Disinventing and reconstituting languages*. Bristol, UK: Multilingual Matters.
- Mazak, C. M., & Carroll, K. S. (2016). *Translanguaging in higher education: Beyond monolingual ideologies*. Bristol, UK: Multilingual Matters.
- Medin, D. L., & Bang, M. (2014). *Who's asking? Native science, western science, and science education*. Cambridge, MA: MIT Press.
- Menken, K., & Sánchez, M. (2019). Translanguaging in English-only schools: From pedagogy to stance in the disruption of monolingual policies and practices. *TESOL Quarterly*, 53(3), 741–767. doi:10.1002/tesq.513
- Miller, E., Manz, E., Russ, R., Stroupe, D., & Berland, L. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the Next Generation Science Standards. *Journal of Research in Science Teaching*, 55(7), 1053–1075. doi:10.1002/tea.21459
- Moschkovich, J. N. (2015). Academic literacy in mathematics for English learners. *The Journal of Mathematical Behavior*, 40, 43–62. doi:10.1016/j.jmathb.2015.01.005
- National Academies of Sciences, Engineering, and Medicine. (2018). *English learners in STEM subjects: Transforming classrooms, schools, and lives*. Washington, DC: National Academies Press.
- National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for English language arts and literacy*. Washington, DC: Author. Retrieved from <http://www.corestandards.org/ELA-Literacy/>
- National Research Council. (2012a). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.
- National Research Council. (2012b). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. Washington, DC: National Academies Press.
- Nersessian, N. J. (2008). *Creating scientific concepts*. Cambridge, MA: MIT Press.
- Next Generation Science Standards Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.
- Nikula, T., & Moore, P. (2019). Exploring translanguaging in CLIL. *International Journal of Bilingual Education and Bilingualism*, 22(2), 237–249. doi:10.1080/13670050.2016.1254151
- Oliveira, A. W., Weinburgh, M., McBride, E., Bobowski, T., & Shea, R. (2019). Teaching science to English language learners: Current research and practices in the field of science education. In *The Handbook of TESOL in K-12* (pp. 277–290). West Sussex, UK: Wiley-Blackwell.
- Otheguy, R., García, O., & Reid, W. (2015). Clarifying translanguaging and deconstructing named languages: A perspective from linguistics. *Applied Linguistics Review*, 6(3), 281–307. doi:10.1515/applirev-2015-0014
- Pacheco, M. B., Kang, H. S., & Hurd, E. (2019). Scaffolds, signs, and bridges: Language ideologies and translanguaging in student-teaching experiences. *Bilingual Research Journal*, 42(2), 194–213. doi:10.1080/15235882.2019.1596179
- Pierson, A. E., & Brady, C. E. (2020). Expanding opportunities for systems thinking, conceptual learning, and participation through embodied and computational modeling. *Systems*, 8(4), 1–31. doi:10.3390/systems8040048
- Pierson, A. E., Brady, C. E., & Clark, D. B. (2020). Balancing the environment: Computational models as interactive participants in a STEM classroom. *Journal of Science Education and Technology*, 29(1), 101–119. doi:10.1007/s10956-019-09797-5
- Pierson, A. E., Clark, D. B., & Brady, C. E. (2021). Scientific modeling and translanguaging: A multilingual and multimodal approach to support science learning and engagement. *Science Education*, 105(4), 776–813. doi:10.1002/sce.21622
- Poza, L. (2017). Translanguaging: Definitions, implications, and further needs in burgeoning inquiry. *Berkeley Review of Education*, 6(2), 101–128. doi:10.5070/B86110060
- Poza, L. E. (2018). The language of ciencia: Translanguaging and learning in a bilingual science classroom. *International Journal of Bilingual Education and Bilingualism*, 21(1), 1–19. doi:10.1080/13670050.2015.1125849

- Probyn, M. (2015). Pedagogical translanguaging: Bridging discourses in South African science classrooms. *Language and Education*, 29(3), 218–234. doi:[10.1080/09500782.2014.994525](https://doi.org/10.1080/09500782.2014.994525)
- Radke, S., Vogel, S., Hoadley, C., & Ma, J. (2020) Representing percents and personas: Designing syncretic curricula for modeling and statistical reasoning. *Proceedings of the International Conference of the Learning Sciences*, 3, 1365–1372, Nashville, TN: International Society of the Learning Sciences.
- Razfar, A. (2013). Multilingual mathematics: Learning through contested spaces of meaning making. *International Multilingual Research Journal*, 7(3), 175–196. doi:[10.1080/19313152.2012.665204](https://doi.org/10.1080/19313152.2012.665204)
- Reigh, E., & Miller, E. (2020). Viewing science as practice: Implications for the language development and inclusion of English Learners. *Proceedings of the International Conference of the Learning Sciences*, 4, 2269–2272, Nashville, TN: International Society of the Learning Sciences.
- Smith, B. E., Pacheco, M. B., & de Almeida, C. R. (2017). Multimodal codemeshing: Bilingual adolescents' processes composing across modes and languages. *Journal of Second Language Writing*, 36, 6–22. doi:[10.1016/j.jslw.2017.04.001](https://doi.org/10.1016/j.jslw.2017.04.001)
- Smith, B. E., Pacheco, M. B., & Khorosheva, M. (2020). Emergent bilingual students and digital multimodal composition: A systematic review of research in secondary classrooms. *Reading Research Quarterly*, 56(1), 33–52. doi:[10.1002/rrq.298](https://doi.org/10.1002/rrq.298)
- Suárez, E. (2020). “Estoy explorando science”: Emergent bilingual students problematizing electrical phenomena through translanguaging. *Science Education*, 104(5), 791–826. doi:[10.1002/sce.21588](https://doi.org/10.1002/sce.21588)
- Turner, M., & Lin, A. M. (2020). Translanguaging and named languages: Productive tension and desire. *International Journal of Bilingual Education and Bilingualism*, 23(4), 423–433. doi:[10.1080/13670050.2017.1360243](https://doi.org/10.1080/13670050.2017.1360243)
- Vogel, S., Hoadley, C., Ascenzi-Moreno, L., & Menken, K. (2019). The role of translanguaging in computational literacies: Documenting middle school bilinguals' practices in computer science integrated units. *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, Minneapolis, MN, 1164–1170.
- Warren, B., Vossoughi, S., Rosebery, A. S., Bang, M., & Taylor, E. V. (2020). Multiple ways of knowing: Re-Imagining disciplinary learning. In N. S. Nasir, C. D. Lee, R. Pea, & M. McKinney de Royston (Eds.), *Handbook of the cultural foundations of learning* (pp. 277–294). New York, NY: Routledge.
- Wright, M., & Chorin, A. (1999). *Mathematics and science*. Alexandria, VA: National Science Foundation.