Emerging Bilingual Students and Science Practices: Can Translanguaging Resources be Leveraged to Support Modeling?

Ashlyn Pierson, Vanderbilt University, ashlyn.pierson@vanderbilt.edu
Doug Clark, University of Calgary, douglas.clark@ucalgary.ca

Abstract: All students, including emerging bilingual students, benefit from engaging in authentic disciplinary practices (Lehrer & Schauble, 2015; Moschkovich, 2015; NRC, 2012). Therefore, researchers and educators should support emerging bilingual students in appropriating scientific practices, like modeling (O. Lee, 2005). It is important to do so from a resources perspective to avoid perpetuating deficit narratives (Flores & Rosa, 2015; Mitchell, 2013). Toward these goals, this paper explores parallels between emerging bilingual students' translanguaging resources and the resources involved in scientific modeling. These similarities could serve as points of leverage for practice and research by aiming to support emerging bilingual students in engaging in scientific practices by using resources from their everyday translanguaging practices.

Introduction and significance

Traditionally, research about science learning for emerging bilinguals[1] has focused on language learning, limiting emerging bilingual students' opportunities to engage in science practices like modeling. More recently, research about science education with emerging bilinguals has emphasized the co-development of language learning and science learning. A wealth of research considers the resources that students from non-dominant communities bring to science classrooms (e.g. Gonzalez, Moll, & Amanti, 2005). There is limited research, however, comparing the linguistic practices of emerging bilingual students to the practices of science. There is a critical need to identify these parallels because they could be leveraged by practitioners to support science learning with emerging bilingual students. In response, we identify and highlight parallels between modeling and translanguaging to inform teaching practice and designs for science education with emerging bilingual students. In this way, the paper contributes to ICLS's goal of helping researchers and practitioners unpack the complexity of learning in diverse and social environments.

Historically, science education for emerging bilingual students has characterized language as a gateway for science learning. This perspective has led to an emphasis on English language learning (often focusing on phonology, morphology, vocabulary, and syntax) as a pre-requisite for science learning and learning in other academic disciplines. In contrast, contemporary research promotes engaging emerging bilingual students in language-intensive science practices to simultaneously promote language learning and science learning (O. Lee, 2005; Suarez & Otero, 2014). Prioritizing science content and language learning simultaneously represents significant progress because this approach provides increased opportunities for emerging bilinguals to engage with science content. Still, critical scholars warn that in implementation, this approach has the potential to unintentionally perpetuate deficit narratives of emerging bilingual students because it emphasizes the "appropriateness" of language and academic registers (Flores & Rosa, 2015). Additionally, they caution that solutions designed to benefit "all" students could inadvertently allow some teachers to dismiss responsibility for emerging bilingual students (Mitchell, 2013). Academic discourse is a social and political construct (García, 2009), and prioritizing the development of standardized English skills can unintentionally conflate emerging bilinguals with deficiency unrelated to objective linguistic practices (Flores & Rosa, 2015; O. Lee, 2005).

In the context of mathematics, for example, Moschkovich (2015) demonstrates that knowledge of academic English is neither necessary nor sufficient for learning. She argues that mathematical communication goes beyond fluency with academic register, because it also involves participating in mathematical practices, and she shows that emerging bilingual students use hybrid resources (including languages other than English, drawings, and gestures) in order to engage in complex and rigorous mathematical reasoning (2015). As Moschkovich demonstrates, students can engage in sophisticated reasoning with hybrid resources. Further research should therefore explore emerging bilingual students' practices as resources and assets for deep disciplinary thinking in science regardless of their English proficiency. Such research might expand the impact of current teaching practices by more fully leveraging emerging bilingual students' full range of resources in service of their learning and success.

Literature review and synthesis

In this section, we review literature related to modeling practices and translanguaging practices. Then, we

synthesize these two bodies of literature by exploring parallels between modeling and translanguaging practices.

Modeling practices

In parallel to science education for emerging bilingual students, science education for all students has historically emphasized content knowledge and vocabulary over the appropriation of scientific practices for sense-making (Duschl, 2008). Recently, science education research and K-12 science standards have shifted away from a focus on conceptual development and an accumulation of skills toward conceptualizing science as practice (Erduran & Jiménez-Aleixandre, 2007; National Research Council [NRC], 2012). From this perspective, science classrooms should provide students with opportunities to engage in disciplinary activity as a way of building scientific knowledge understanding (Ford & Forman, 2006; Duschl, 2008).

In professional practice, scientific modeling is complex. Though models, in their simplest form, are analogies (Lehrer & Schauble, 2015), they often represent relationships across domains and modalities (Collins & Gentner, 1987; Nersessian, 2017). These hybrid representations can shape mental or physical experiments and analyses designed to test predictions about scientific concepts and relationships (Gooding, 2006). In the process, material agency shapes scientists' understanding and their future research (Pickering, 1995).

To support the development of modeling in classrooms, students should be positioned as epistemic agents. In an attempt to support engagement in science practices, many designs for learning provide students with a series of steps to follow or actions to take. However, emphasizing skills separate from the context of a scientific phenomenon can lead to rote performance (Ford & Forman, 2006). Alternatively, providing students with opportunities to engage in the epistemic elements of science practices can support the development of generative resources for sense-making. Therefore, learning environments designed to support modeling should include opportunities for creating and revising several types of models in response to shifting epistemic aims (Gouvea & Passmore, 2017). Engaging in modeling in a variety of ways supports the development of meta-representational competence, because it provides students with opportunities to flexibly appropriate modeling practices as resources for sense-making (diSessa, Hammer, Sherin, & Kolpakowski, 1991).

In summary, providing students with opportunities engage in modeling in service of sense-making can position students as epistemic agents and promote the development of meta-representational competence. In these environments, students have opportunities to attend to correspondence and salience as they map observations from the natural world or classroom constructions onto two-dimensional representations or runnable experiments or simulations. We argue that resources developed through translanguaging practices could potentially facilitate emerging bilingual students' engagement in these modeling activities. In the next section, we will describe translanguaging practices in order to identify similarities between K-12 modeling practices and translanguaging practices.

Translanguaging practices

Translanguaging theory posits that emerging bilinguals should not be viewed as double-monolinguals, but rather as learners with unique opportunities and challenges, because emerging bilingual students engage in translanguaging practices that are distinct from their monolingual peers' languaging practices (Daniel & Pacheco, 2016; García, 2009). Translanguaging provides a theoretical lens for understanding how bi- and multilingual individuals communicate and make meaning by moving flexibly across semiotic resources, like languages, registers of speech, and gestures (García, 2009).

Bi- and multilingual students frequently participate in practices that require metalinguistic awareness, such as identifying cross-language connections, using bilingual dictionaries to identify salient words, discussing English texts in other languages, and translating or language brokering for family members (Daniel & Pacheco, 2016). Language brokering is defined as interpreting and translating in everyday situations by bilinguals with no special training. Brokering is different from simple linguistic decoding because it involves making meaning from words, cultural context, and register and then re-representing the meaning and context in another form (Tse, 1996). Practices like brokering, interpreting, and translating typically involve source-to-target mapping between named languages (Malakoff & Hakuta, 1991). In this sense, emerging bilingual individuals are mapping back and forth between domains, with emerging bilinguals serving as the bridge between domains.

Though practices like language brokering involve monoglossic speech, other translanguaging practices encourage the use of bilinguals' full linguistic repertoires simultaneously. When speaking, emerging bilinguals often engage in code-switching by drawing on linguistic resources in ways that combine more than one named language (Jorgensen, 2008). Some researchers have pejoratively described this type of speech as "crutch-switching," implying that students use resources from one language to fill gaps in their knowledge of another language. However, Martínez (2010) found that students' hybridization of language resources is deliberate, identifying intentional conversational functions for the use of "Spanglish," such as clarifying utterances,

shifting voices in response to audience, and communicating subtle nuances of meaning. In written text, students engage in a practice that Canagarajah (2013) calls codemeshing, which involves drawing on multiple languages, registers of speech, and modalities. Some of these texts are created are for personal use; for example, Daniel and Pacheco (2011) describe students taking notes or drafting essays using text from more than one language. Others are more publicly shared; Canagarajah (2013) describes essays and songs that integrate components from multiple languages in ways that are rhetorically and contextually motivated.

Cognitive psychology research suggests that bilinguals and emerging bilinguals who engage in the translanguaging practices described above demonstrate increased metalinguistic awareness (Bialystok & Barac, 2012) and domain-general executive control (Bialystok, 2011). On performance tasks involving salient conflicts (like the Stroop task), bilingual children, adolescents, and adults outperformed their monolingual peers (Bialystok, 2011). Bialystok and colleagues attribute this difference to bilinguals' frequent need to differentiate between several representations of an object or idea as they choose among linguistic representations. Bialystok, Craik, Green, and Gollan (2009) explain that though bilingual and monolingual children tend to know similar numbers of words overall, bilingual children often know fewer words in each language than their monolingual peers. As a result, bilingual children tend to demonstrate less fluency, yet greater metalinguistic awareness, than monolingual children. While monolingual children rely on the heuristic that unknown words match unknown objects, multilingual children are less likely to assume a one-to-one correspondence between objects and names, because they know several names for the same object. This research suggests that though bilingual children may appear deficient in tasks that assess fluency or single-language vocabulary, they may have access to unique resources related to executive control and meta-linguistic awareness stemming from translanguaging practices.

In summary, emerging bilingual children tend to develop a variety of meta-cognitive resources through engagement in translanguaging practices. In the next section, we argue that parallels exist between modeling and translanguaging practices. From a resources perspective, these parallels provide a new lens for educators, researchers, and curriculum designers as they aim to support emerging bilingual students in science classrooms.

Parallels between translanguaging and modeling

Our review of modeling and translanguaging identifies 3 parallels between these seemingly disparate domains: (a) source-to-target mapping, (b) correspondence and salience, and (c) meta-representational awareness.

Source-to-target mapping

Translanguaging and modeling practices both involve mapping ideas from source to target domains. With practices like translating, students map lexical, syntactic, and semantic knowledge from one language to another in service of sense-making (Jiménez et al., 2015). At a lexical level, this involves considering multiple meanings for words and explicit relationships between words across languages, like cognates. When a word does not map directly from one language to another, students achieve fit between source and target languages by using descriptions or synonyms. These practices go beyond simple decoding. To address idiomatic or figurative language, students attempt to capture larger ideas within the source language and apply those abstracted ideas to the target language.

This is similar to analogical reasoning in modeling practices. When modeling, scientists attempt to map source domains onto target domains. Though the attributes within the domains may not correspond directly, scientists attend to relational similarities between domains to make sense of phenomena. For example, in the modeling section above, we described how Faraday abstracted patterns from optical illusions to make sense of microscopic aquatic rotifers (Gooding, 2006). Modeling involves attending to aspects of source domains that can be mapped directly to target domains, as well as determining which aspects do not translate directly from one domain to another. Emerging bilingual students may be able to use their experience with source-to-target mapping during translating as a resource for making sense of epistemic practices involving source-to-target mapping in science.

Correspondence and salience

Translanguaging and modeling practices both require students to attend to correspondence and salience in their representations. Particularly with practices such as language brokering, students must determine the meaning of an utterance or text and re-represent salient features. These practices require students to not only recognize what it important to communicate, but also to attend to audience and register. For example, Harris and Sherwood (1978, p. 157) describe a daughter language brokering for her father during bargaining sessions. When the father became angry and asked his daughter to "Digli che é imbecile," ("Tell him he's a nitwit,") the daughter said, "My father won't accept your offer." In this case, the daughter determined that it was important to convey that her father was unwilling to accept the bargain. Simultaneously, the daughter attended to the cultural context of

the interaction by relaying this message without insulting the other party. In this case, the daughter re-represented what was salient about her father's communication with attention to register and audience.

Modeling also requires attention to correspondence and salience. Above, we presented an example of scientists creating hybrid devices to stand in for vascular and neural systems (Nersessian, 2017). To ensure that their work was ethical and controlled, the scientists had to choose aspects of the systems to amplify or reduce. Therefore, it was critical for these scientists to identify and preserve the most salient aspects of these systems. Though this practice is common within professional science communities, it is particularly difficult for young children, who typically privilege literal and complete representations (Schwarz, Reiser, Archer, Kenyon, & Fortus, 2012). Emerging bilingual students who regularly engage in language brokering may have unique resources for attending to salience and correspondence that could be leveraged to support modeling practices.

Meta-representational awareness

Both translanguaging and modeling practices promote and depend on awareness of meta-representational structures. Translanguaging practices promote the development of meta-linguistic awareness because they require students to compare, reflect on, and manipulate language components and structures (Malakoff & Hakuta, 1991). As a result, emerging bilingual students demonstrate greater meta-linguistic awareness than their monolingual peers (Bialystok & Barac, 2012; Bialystok et al., 2009). Jiménez et al. (2015) describe how translanguaging practices, like translating, help students become aware of the structural elements of languages, increasing their understanding of how different languages function.

Similarly, modeling relies on and supports the development of meta-representational awareness (diSessa et al., 1991). Modeling practices involve selecting among multimodal representations to make sense of natural phenomena (Gooding, 2006; Nersessian, 2017), and recognizing the affordances and constraints of different representations is a crucial epistemic practice within the scientific community (Gouvea & Passmore, 2017). Emerging bilinguals who regularly engage in meta-cognitive reflection through translanguaging practices may have resources for meta-representational thinking that could be leveraged as they engage in modeling.

Interventions: opportunities and challenges

Researchers and practitioners recommend increasing K–12 students' engagement in authentic scientific practices such as modeling (NRC, 2012). All students, regardless of their future participation in the scientific community, benefit from appropriating such practices as tools for problem solving and building understanding (Lehrer & Schauble, 2015). Yet, instruction in schools for emerging bilingual students often ends up emphasizing the development of vocabulary and grammar rather than providing opportunities for authentic engagement in science practices (Flores & Rosa, 2015).

In order to provide equitable and accessible science learning environments for emerging bilingual students, it is important to identify and leverage these students' linguistic resources as well as their resources for modeling in science education more broadly. These parallels are an opportunity for educators to frame emerging bilingual students' languaging practices as assets, whereas emerging bilingual students' languaging practices have historically been characterized as deficits (Mitchell, 2013). Additionally, supporting students in leveraging these resources can provide students with opportunities for authentic engagement in science practices, as recommended by the NRC (2012) and researchers internationally (e.g. Erduran & Jiménez-Aleixandre, 2007).

Still, there is much to learn about supporting students in using translanguaging practices as resources for modeling. Students are unlikely to recognize the connections between translanguaging and modeling practices automatically. Researchers are beginning to investigate how students engage in translanguaging in science classrooms (e.g. Suarez & Otero, 2014), but little is known about how translanguaging practices can support specific science practices, such as modeling.

We conjecture that educators could leverage the parallels between modeling and translanguaging in several ways. At the most basic level, encouraging translanguaging in science classrooms allows students to leverage their full linguistic repertoires for science learning. A wealth of research demonstrates that the use of heritage languages supports classroom learning (e.g. Daniel & Pacheco, 2016). Yet even at this level, designing classroom interventions is complex. Cole, David, and Jiménez (2016) find that students' language identities shift across time, space, and interaction, and that students may be unwilling to take up identities as speakers of their heritage language in school settings. Thus, future research is needed to explore ways of framing heritage language resources as valid resources for disciplinary engagement.

Another way of leveraging these parallels is by designing learning environments that aim to support emerging bilingual students in recognizing implicit resources developed through translanguaging practices as explicit resources for engaging in modeling. One learning environment design could invoke emerging bilingual students' translanguaging resources to help them develop a sense of self-efficacy related to scientific modeling.

Affirming students' bilingual identities and making connections between their in-school and out-of-school experiences can motivate emerging bilingual students by helping them feel pride in their unique linguistic resources (Suarez & Otero, 2014). By emphasizing that emerging bilingual students already engage in sophisticated practices paralleling modeling, this approach could provide an entry point into scientific practices that could otherwise appear unfamiliar or daunting. Essentially, helping emerging bilinguals understand that they "already do things like this" could increase self-efficacy and engagement. Relating emerging bilingual students' everyday translanguaging practices to scientific modeling practices could position these students as capable in science classrooms.

Another learning environment design might focus on developing heuristics for engaging in translanguaging and modeling. In the TRANSLATE pedagogy, Jiménez and colleagues (2015) find that reducing translanguaging practices to heuristics effectively supports students' use of those resources. Following from this framework, one possibility is to distill specific translanguaging and modeling practices to heuristics and support students in recognizing similarities across these heuristics. It is important to note that this approach was successful for TRANSLATE because the design aimed to support students in a specific translanguaging task: making sense of small pieces of English language text using translation. Because we aim to broadly support translanguaging and modeling, this approach risks oversimplifying and proceduralizing students' rich and varied translanguaging and modeling practices. Still, this approach could potentially provide a useful scaffold for initial introduction and engagement with modeling practices.

In contrast to the top-down approach described in the previous paragraph, a ground-up learning environment design might build on Carol Lee's cultural modeling framework (2006). This framework involves examining points of synergy between problem solving practices that emerge in students' everyday experiences and in disciplinary contexts. This approach could involve researchers or teachers explicitly identifying points of synergy and naming them for students. An even more effective variant of this approach might support classrooms in developing their own descriptions of resources for modeling grounded in students' translanguaging practices. Essentially, engaging classrooms in developing their own descriptions, rather than externally providing those points of synergy to classrooms, might allow students to engage even more authentically in the meta-representational practices emphasized across both domains.

Beyond a focus on specific learning environment designs, a more general focus on the parallels between translanguaging and modeling practices at a curricular level could help researchers, teachers, and students shift language and science curricula further from a focus on vocabulary to a focus on developing linguistic and scientific practices. Historically, science education has often been reduced to vocabulary acquisition for both monolingual and bilingual students, limiting students' opportunities for engaging in scientific practices. Similarly, language learning for emerging bilingual students has often been reduced to vocabulary acquisition rather than authentic engagement in languaging practices. By recognizing that emerging bilingual students engage in higher-order thinking skills and sophisticated practices as they participate in translanguaging, and by identifying the value of these practices as resources for engaging in modeling, we hope to shift the perception of emerging bilingual students in science classrooms further away from a deficit framing to instead emphasize the unique resources that these students bring to science classrooms.

Endnotes

(1) Emerging bilingual students are often referred to as English Learners (ELs). Following critical scholars (García, 2009; K. Gutiérrez & Orellana, 2006), we use the term "emerging bilingual" to celebrate these students' languaging resources rather than privileging English over other languages.

References

Bialystok, E. (2011). Reshaping the mind: The benefits of bilingualism. *Canadian Journal of Experimental Psychology/Revue Canadienne De Psychologie Expérimentale*, *65*(4), 229-235.

Bialystok, E., & Barac, R. (2012). Emerging bilingualism: Dissociating advantages for metalinguistic awareness and executive control. *Cognition*, *122*(1), 67-73.

Bialystok, E., Craik, F. I. M., Green, D. W., & Gollan, T. H. (2009). Bilingual Minds. *Psychological Science in the Public Interest*, *10*, 89-129.

Canagarajah, S. (2013). *Translingual practice: Global Englishes and cosmopolitan relations*. New York, NY: Routledge.

Cole, M. W., David, S. S., & Jiménez, R. T. (2016). Collaborative Translation: Negotiating Student Investment in Culturally Responsive Pedagogy. *Language Arts*, *93*(6), 430.

Collins, A., & Gentner, D. (1987). How people construct mental models. In D. Holland & N. Quinn (Eds.). *Cultural Models in Language and Thought* (pp. 243-265). New York, NY: Cambridge University

Press.
Daniel, S. D., & Pacheco, M. B. (2016). Translanguaging practices and perspectives of four multilingual teens. *Journal of Adolescent & Adult Literacy*, 1-11.
diSessa, A., Hammer, D., Sherin, B., & Kolpakowski, T. (1991). Inventing graphing: Meta-representational expertise in children. *Journal of Mathematical Behavior*, *10*(2), 117–160.
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.
Erduran, S., & Jiménez-Aleixandre, M. P. (2007). Argumentation in science education: Perspectives from classroom-based research. Dordrecht, Netherlands: Springer.
Flores, N., & Rosa, J. (2015). Undoing appropriateness: Raciolinguistic ideologies and language diversity in education. *Harvard Educational Review*, *85*(2), 149-171.
Ford, M. J., & Forman, E. A. (2006). Redefining disciplinary learning in classroom contexts. *Review of Research in Education*, *30*, 1–32.
García, O. (2009). *Bilingual Education in the 21st Century: A Global Perspective*. Malden, MA: Wiley-Blackwell.
González, N., Moll, L. C., & Amanti, C. (2005). Funds of knowledge: Theorizing practices in households, communities, and classrooms. Mahwah, NJ: L. Erlbaum Associates.
Gooding, D. C. (2006). From phenomenology to field theory: Faraday's visual reasoning. *Perspectives on Science*, *14*(1), 40-65.
Gouvea, J., & Passmore, C. (2017). Models of versus Models for. *Science & Education*, *26*(1-2), 49–63.
Gutiérrez, K. D., & Orellana, M. F. (2006). At last: The "problem" of English learners: Constructing genres of difference. *Research in the Teaching of English*, *40*(4), 502-507.
Harris, B., & Sherwood, B. (1978). Translating as an innate skill. In D. Gerver & H. W. Sinaiko (Eds.), *Language interpretation and communication* (pp. 155-170). New York: Plenum Press.
Jiménez, R. T., David, S., Fagan, K., Risko, V. J., Pacheco, M., Pray, L., & Gonzales, M. (2015). Using translation to drive conceptual development for students becoming literate in English as an additional language. *Research in the Teaching of English, 49*(3), 248-271.
Jorgensen, J. N. (2008). Polylingual languaging around and among children and adolescents. *International Journal of Multilingualism, 5*, 161-176.
Lee, C. D. (2006). “Every good□bye ain’t gone”: analyzing the cultural underpinnings of classroom talk. *International Journal of Qualitative Studies in Education*, *19*(3), 305–327.
Lee, O. (2005). Science education and English language learners: Synthesis and research agenda. *Review of Educational Research, 75*(4), 491-530.
Lehrer, R., & Schauble, L. (2015). The development of scientific thinking. In R. M. Lerner (Ed.), *Handbook of Child Psychology and Developmental Science* (pp. 1–44). Hoboken, NJ: Wiley.
Malakoff, M., & Hakuta, K. (1991). Translation skill and metalinguistic awareness in bilinguals. In E. Bialystok (Ed.), *Language processing in bilinguals*. New York: Cambridge University Press.
Martínez, R. A. (2010). "Spanglish" as literacy tool: toward an understanding of the potential role of Spanish-English code-switching in the development of academic literacy. *Research in the Teaching of English*, 124-149.
Mitchell, K. (2013). Race, difference, meritocracy, and English: Majoritarian stories in the education of secondary multilingual learners. *Race Ethnicity and Education*, 16(3), 339-364.
Moschkovich, J. N. (2015). Academic literacy in mathematics for English learners. *The Journal of Mathematical Behavior, 40*, 43-62.
National Research Council. (2012). A framework for K-12 science education. *A framework for K-12 science education: Practices, crosscutting concepts, core ideas.* Washington, DC: National Academies Press.
Nersessian, N. (2017). Hybrid devices: Embodiments of culture in biomedical engineering. In K. Chemla & E. F. Keller (Eds.), *Culture without Culturalism* (pp. 117-144). Durham, NC: Duke University Press.
Pickering, T. (1995). The mangle of practice: Time, agency and science. In *American journal of sociology.* Chicago: University of Chicago Press.
Schwarz, C., Reiser, B. J., Achér, A., Kenyon, L., & Fortus, D. (2012). MoDeLS: Challenges in Defining a Learning Progression for Scientific Modeling. In A. Alonzo & A. W. Gotwals (Eds.), *Participant observation*. The Netherlands: SensePublishers, Rotterdam.
Tse, L. (1996). Language brokering in linguistic minority communities: The case of Chinese-and Vietnamese-American students. *Bilingual research journal*, *20*(3-4), 485-498.