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# Making mathematics meaningful for culturally and linguistically diverse students with a mathematics learning disability: a focus on culturally responsive practices

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Elements of the Individualized Education Programs (IEP) for culturally and linguistically diverse students with mathematics learning disabilities (CLD-MD) have long been inadequate at capturing the cultural, linguistic, and learning needs of this subset of students. Efforts to address the knowledge gap of understanding of culturally and linguistically diverse (CLD) students within the mathematics community, specifically those focused on mathematics learning disabilities, have typically focused on strategies for specific mathematics concepts and skills such as computation, word-problem solving, or fraction strategies. As the population of CLD students who are identified both as culturally and linguistically diverse and having a specific learning disability in the area of mathematics increases, there have been increased efforts to identify strategies that support the complexity that their identities bring to mathematics instruction. Much of this work is nascent in the field, and as such, this paper provides a variety of evidence-based strategies that provide appropriate whole-class instruction and intensive interventions for CLD-MD students.

## KEYWORDS

culturally responsive, learning disabilities, mathematics, instruction, language, Individualized Education Program

## Introduction

A strong understanding of foundational mathematics skills is a strong predictor of future achievement in adulthood attributing to career options (Cragg et al., 2017). Even though in 2000, the National Council of Teachers of Mathematics shifted the organization's focus to an emphasis on equity, students with learning disabilities continue to be a marginalized group when it comes to mathematics education also referred to as the "invisible 10%" (Gersten et al., 2009; Karp, 2013; Silva et al., 2023). Furthermore, when students experience compounding factors, such as learning disabilities in mathematics with culturally and linguistically diverse backgrounds, these students need instructional methods focused on equity frameworks and asset-oriented approaches (Silva et al., 2023).

In the U.S., over the past decade, the number of culturally and linguistically diverse (CLD) students has increased by more than 300,000, with Spanish being the most prevalent home language representing more than 75% of those from multilanguage homes. The remaining 25% include over 400 languages spoken in the United States, adding a layer of complexity for schools to provide adequate mathematics instructions that reach all learners (Watkins and Liu, 2013; NCES, 2023). CLD students are the fastest-growing demographic in public schools in the United States (Watkins and Liu, 2013; NCES, 2023). In the past, students from linguistically diverse backgrounds have been labeled or identified as “English Language Learners”, “Second Language Learners”, “English as a Second Language Learner”, “Limited English Proficient”, and “Semilinguals”, among other deficit framed labels. Like many researchers focusing on culturally responsive work in education (e.g., Gay, 2000; Hammond, 2015; Tran et al., 2018; Hoover et al., 2019), this paper used CLD as an asset-based descriptor for students who would have likely fallen within these categories in the past and is inclusive of students of color. Office of Special Education (OSEP, 2022) reported that 55% of students who are identified as requiring special education services through an Individualized Education Program (IEP) were students of color, and of those, 16.1% also identified as English Learners. Thus, CLD students face systemic challenges related to language and culture that can impact achievement in English-based mathematics content instruction (Orosco and Reed, 2023).

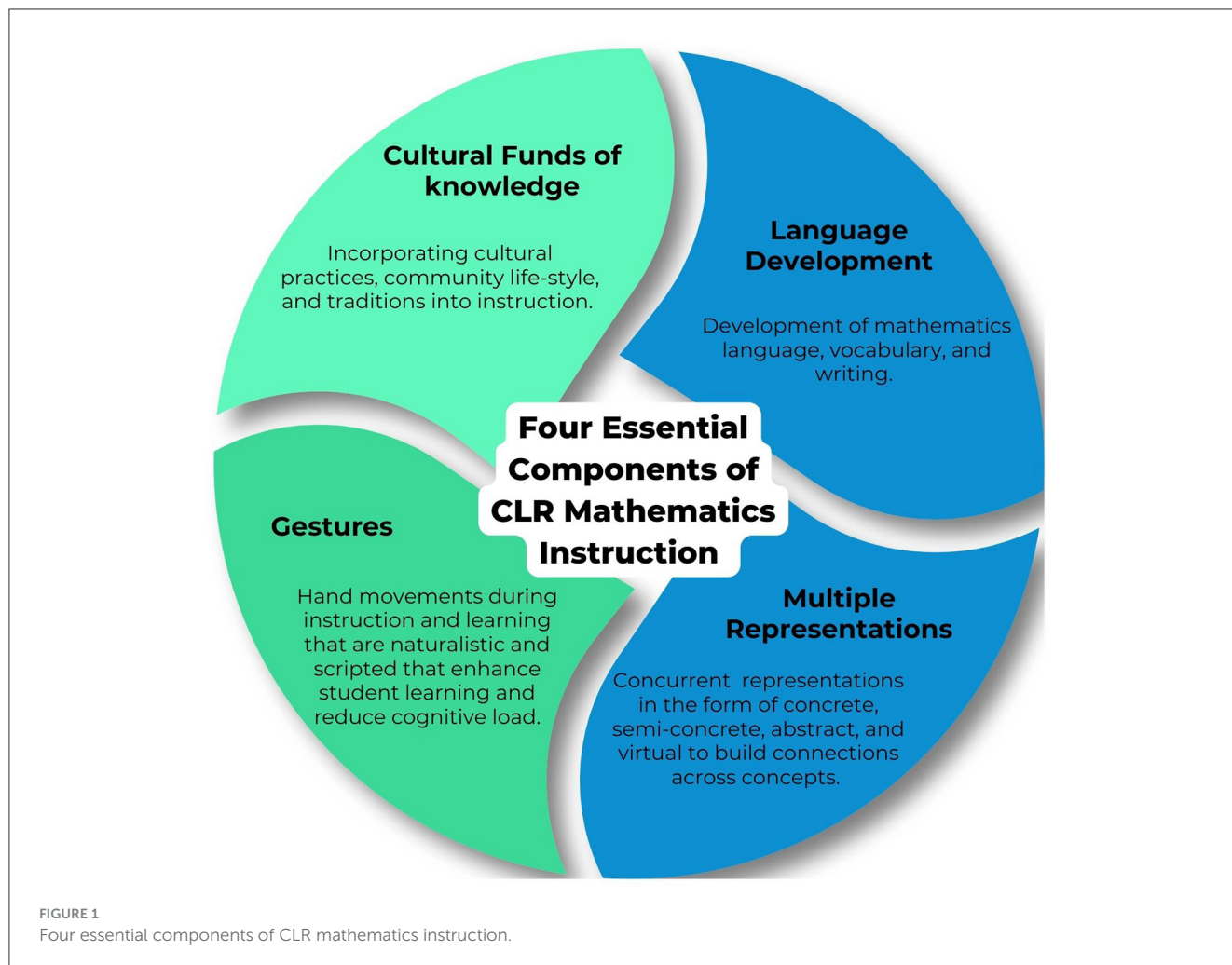
There is a myth that mathematics is believed to be a universal language only based on a series of numbers and symbols, requiring little to no explicit instruction (Cavanagh, 2005; Hoffert, 2009). However, after breaking down the skills needed to perform at the basic or proficient level in mathematics, research suggests that mathematics research is comprised of so much more than numbers, symbols, and computation skills; literacy and language comprehension play a significant role in learning and applying mathematics skills (Hoffert, 2009; Orosco and Abdulrahim, 2017; Orosco and Reed, 2023). For example, starting as early as kindergarten, students encounter word problems that are a crucial component of the mathematics curriculum. These word problems require a combination of complex reading and mathematics skills, all needed to solve one problem, which includes: decoding, comprehending, setting up, and solving algebraic equations using computational skills. Consider the following problem, “Mia has 5 pencils in her pencil box, and her teacher gives her 3 more. How many pencils does Mia have all together?” This word problem requires not only mathematics skills but also language and literacy skills specific to mathematics. Research into culturally responsive research that leverages students’ cultural Funds of Knowledge has highlighted a need to ensure that content area teaching is relational to students’ world which includes mathematics. This type of teaching ensures teaching mathematics is not just narrowed down to memorization of a series of procedures (Moll et al., 1992; Jackson, 2009). Educators have been positioned to use curriculum that lacks a focus on building mathematics literacy or attending to linguistic and reading complexities of solving word problems, this highlights the limited strategies and resources available for educators to use aimed at supporting the linguistic needs of CLD students

(Orosco and Abdulrahim, 2017; Orosco and Reed, 2023). This article attends to the needs and characteristics of culturally and/or linguistically diverse students (i.e., Black, Indigenous, English learners, simultaneous and sequential multilingual students), with a specific learning disability in the area of mathematics or who experience difficulties in mathematics (i.e., consistently performing below grade level in mathematics or receiving Tier II intervention support in mathematics; CLD-MD). Without appropriate support and attention to language needs, CLD-MD students face challenges in overcoming any language barrier and achieving academically (Orosco and Reed, 2023).

This article will highlight the implications of developing effective math-focused individualized educational programming for CLD-MD students. Individualized Education Program (IEP) can serve as an instructional tool that documents the strategies CLD-MD students regularly utilize to access the curriculum and demonstrate their knowledge exceeding the minimum compliance standards under the law (Tran et al., 2018). Longitudinal research studies highlight that proficient mathematics skills in early elementary grades strongly predict success in high school and beyond into adulthood achievement (Watts et al., 2014). Therefore, the mathematic interventions implemented with CLD-MD students should rely on evidence-based practices paired with culturally and linguistically responsive (CLR) practices. CLR practice is defined as the integration of the student’s cultural experiences, native language skills, and prior experiences to make learning experiences more relevant and effective for students while demonstrating respect for the student’s personal and community identity (Ladson-Billings, 1995; Gay, 2000; Hammond, 2015; Caires-Hurley et al., 2020; Tran et al., 2021). Incorporating CLR practices in the curriculum means going beyond translating a word problem into a student’s native language or swapping out subject names for culturally popular names while ensuring the context remains relevant.

When planning for CLR mathematics instruction for CLD-MD we suggest utilizing these four essential evidenced-based instructional elements: (a) cultural funds of knowledge, (b) language development, (c) gestures, and (d) multiple representations. All four essential components embed evidence-based mathematics instruction and CLR pedagogy for CLD-MD students. The components focus on CLR pedagogy to validate the CLD-MD students’ home community culture, and varying linguistics abilities, and integrate students’ cultural experiences and background knowledge (Moll et al., 1992; Ladson-Billings, 1995). Figure 1, provides a brief overview of the four essential components of CLR instruction. For each instructional element, we describe why the component is important, what is included in each component, and how to teach using the component within instruction.

These instructional elements will allow the educator to plan for varying abilities and provide opportunities to determine the instructional conditions that increase access to the content and expression of knowledge for the CLD-MD student. These shifts are particularly important for students with a disability as this provides valuable information to document in a student’s Individualized Education Program (IEP). Not only does the IEP serve as a legal document for delivering services, but when the IEP incorporates



CLR information, it serves as the blueprint for adequate and effective intervention for CLD students with disabilities.

## Essential components of CLR mathematics instruction: what, why, and how?

### Cultural funds of knowledge

#### What are cultural funds of knowledge?

The development of Funds of Knowledge (FoK) originated out of a need to understand and embrace the “historically accumulated and culturally developed” (González et al., 2005) foundation of knowledge that culturally and linguistically diverse students and families embodied. In 2014, Moll clarified that understanding FoK required three related elements: (1) Ethnographic home-based research in which reciprocity and trust (*confianza*) between educators and the families support the identification of cultural FoK; (2) Classroom Practices analysis; and (3) study groups used for the reflective practice of study (González et al., 2005, p. 1; Llopart and Esteban-Guitart, 2018). Educators can use a Funds of Knowledge Inventory (González et al. 2005) to document and

support their understanding of families’ FoK. In combination with culturally responsive pedagogy, which attends not only to meeting the needs of CLD students but also leans on the cultural experiences and assets they bring into the classroom and mathematics lessons daily (Ladson-Billings, 1995; Gay, 2000; Hammond, 2015; Tran et al., 2021). CLR pedagogy intertwined with FoK creates CLR practices are the bridge that connects CLD students’ culture, languages, and experiences with what they learn in school.

Within this article, cultural FoK combines culturally responsive approaches to education and funds of knowledge, as both are responsive to the culture and knowledge students bring with them to the learning space. Cultural FoK are the reservoirs of knowledge that individuals and communities have accumulated over time through their historical and cultural experiences. These funds are deeply rooted in the productive and exchange activities within households, reflecting the values, traditions, and ways of life of various cultural groups (Moll et al., 1992; González et al., 2005). Validating and utilizing each student’s cultural, familial, and linguistic wealth of knowledge opens doors to inclusive, effective, and engaging pedagogical approaches.

Mathematics is often considered a universal subject that rarely centers on cultural or linguistic practices as effective content area needs. However, a CLD-MD student’s true mathematics

achievement potential is unlocked when it resonates with their real-life experiences. Educators can make the subject relevant and meaningful for CLD-MD students by incorporating cultural funds of knowledge into mathematics lessons. Understanding how mathematics connects to their daily lives, cultural practices, and traditions enhances their learning motivation and strengthens their conceptual understanding and problem-solving abilities (Caires-Hurley et al., 2020). Research involving mathematics and FoK has successfully identified that families used the five National Council of Teachers of Mathematics standards for the practices of problem-solving, reasoning and proof, communication, connection, and representation with their children. This was seen through “questioning and discussion, providing experiences, and promoting practice” (Andrews et al., 2005; Williams et al., 2020).

### Why are cultural funds of knowledge important?

A pivotal consideration when assisting CLD-MD students involves the utilization of support systems aimed at enriching their grasp of mathematical concepts. The significance of fostering student learning by bridging the gap between mathematical concepts and real-world applications permeates the existing body of literature (Fuchs et al., 2014; Kong and Orosco, 2016). It is imperative to recognize that students bring an array of experiences and diverse cultural and linguistic backgrounds to the educational setting, which significantly influences their pre-existing mathematical knowledge and comprehension. Harnessing and capitalizing on their culture (FoK) presents a means to infuse authenticity and relevance into mathematical content, rendering it a true reflection of students’ lived experiences and attention to additional languages spoken (Aguirre et al., 2013; Freeman-Green et al., 2021).

### How to teach using cultural funds of knowledge?

In creating Table 1, a Culturally and Linguistically Relevant (CLR) Framework and Features within Mathematics Instruction, we identified prominent frameworks used in both FoK and CLR pedagogy and those specific to CLD-MD students, such as Kong et al. (2022), who found that there were specific ways that mathematics instruction could be approached through culturally responsive ways that provided an instructional framework for CLD-MD students specifically. This framework has five sections: (1) Cultural Context in Word Problems and Examples, (2) Culturally Relevant Resources & Connect Mathematics to Cultural Artifacts and Celebrations, (3) Provide Multilingual Support, (4) Culturally Responsive Assessment & Personalized Learning Pathways, and (5) Ethnomathematics Exploration & Celebration of Cultural Contributions to Mathematics. The framework summarizes each section and provides informative practices that support CLR features. Additionally, there is guidance on ineffective ways of supporting CLD-MD students that should be avoided.

## Language development

### What is language development?

When considering CLD-MD students, it is essential to identify specific language development needs that arise for

both CLD and MD perspectives in each field. For CLD students, a focus on mathematics language (i.e., technical mathematics vocabulary, terms with multiple meanings, and multiple mathematics meanings) and literacy (i.e., reading word problems, comprehension, decoding) alongside the content instruction is essential for full engagement in the topic. We identify critical areas of language development that need to be addressed when teaching mathematics. Language practices in education encompass various verbal and written communication methods to enhance teaching and learning experiences. Seminal research heavily influences these practices, highlighting the significance of the integration of effective language development in mathematics instruction.

One such seminal research piece is the work of Vygotsky and Cole (1978), who emphasized the role of language in cognitive development and learning. Vygotsky’s theory of social constructivism highlights the importance of social interactions and language use in shaping a student’s understanding of concepts and skills. Furthermore, Cummins (1981) introduced the concept of “BICS” (Basic Interpersonal Communication Skills) and “CALP” (Cognitive Academic Language Proficiency) to differentiate between everyday language and language proficiency required for academic success. This research emphasized the importance of supporting students in developing both language skills. However, in recent iterations, the collective understanding of BICS and CALP evolved from being two distinct categories to a holistic approach that integrates the two and focuses on social and academic language (Halbach, 2012). Researchers like Gibbons (2002) have extensively discussed integrating language practices in education. Her research on language and content teaching emphasized the need for language support across various subjects, particularly for CLD students. The focus on multilingualism and language diversity has recently gained attention. García and Li (2014) examined the concept of translanguaging, where students draw upon their entire linguistic repertoire to communicate and learn effectively. This research has highlighted the value of embracing students’ native languages and promoting multilingualism in education. Additionally, the work of Swain (1985) emphasized the importance of providing students with opportunities to use language actively and meaningfully in classroom settings. Her research on language output and language production underscored the significance of engaging students in conversations and collaborative language learning.

These seminal research works have greatly influenced language practices in education and have led to the development of pedagogical strategies that cater to the diverse language needs of classroom students. Understanding the role of reading, writing, and oracy in mathematics is crucial to implementing effective CLD-MD mathematics strategies.

### Reading

The simple view of reading (Hoover and Gough, 1990) posits that reading comprehension is a function of decoding skills and linguistic comprehension. The term decoding refers to recognizing and pronouncing words by applying knowledge of letter-sound relationships and word patterns. In contrast, linguistic comprehension is understanding and interpreting meaning from written language. When students effectively comprehend text, they demonstrate an understanding of relationships between ideas, draw

TABLE 1 CLR framework within mathematics instruction.

CLR framework	Summary	CLR features
Cultural context in word problems and examples	Understand the context of the community and include problems that are unique to the local community and native traditions. Provide background knowledge and explanations for the contexts from different cultures and societies (Frankenberg, 2009). This enables students to connect more deeply with the problem and see its relevance in their own lives (Gutiérrez, 2002).	<p>Do:</p> <ul style="list-style-type: none"> <li>• Create word problems using scenarios and examples that reflect the cultural experiences and contexts of their students (e.g., open markets, soccer, pinatas, lucky envelopes, flowers, food).</li> <li>• Allow students to create their own word problems to solve.</li> <li>• Create opportunities for collaborative problem-solving that fosters mathematical and cultural discussions.</li> </ul> <p>Avoid:</p> <ul style="list-style-type: none"> <li>• Changing out character names for cultural names while the context remains the same (e.g., Jose for Joe, Ahmid for Aaron).</li> <li>• Assumptions about how place and space are used by the community (e.g., assuming that because you live in Colorado, all children will relate to the mountains or skiing)</li> <li>• Misrepresent cultural representations and stereotypes</li> </ul>
Culturally relevant resources & connect mathematics to cultural artifacts and celebrations	Engage students by leaning on culturally resources to highlight the cross-disciplinary nature of knowledge (D'Ambrosio, 2001). Use cultural artifacts to teach mathematical concepts. Embed cultural artifacts, celebrations, and events into mathematical concepts and instruction (NCTM, 2000; Gutiérrez and Rogoff, 2003; Lillard, 2016).	<p>Do:</p> <ul style="list-style-type: none"> <li>• Integrate culturally relevant resources, such as literature, art, music, and historical examples, to illustrate mathematical concepts.</li> <li>• Use artifacts that are representative of their culture (e.g., sarape instead of quilt, lanterns instead of flashlights, pastry or baked goods instead bagel or muffin).</li> </ul> <p>Avoid:</p> <ul style="list-style-type: none"> <li>• Focusing only on fun, fiesta, food and ensure you are talking authentically about cultural celebrations.</li> </ul>
Provide multilingual support	Recognize and embrace multilingualism in the classroom (Moschkovich, 2002).	<p>Do:</p> <ul style="list-style-type: none"> <li>• Determine the student's native strengths and how it impacts their learning.</li> <li>• Provide support and explanations in students' native languages when possible, helping them understand mathematical concepts more effectively.</li> <li>• Provide sentence stems to support oracy around mathematics for linguistic learners.</li> <li>• Word walls and student created mathematics glossaries with multiple representations.</li> </ul> <p>Avoid:</p> <ul style="list-style-type: none"> <li>• Direct translation.</li> <li>• English only environments</li> </ul>
Culturally responsive assessment & personalized learning pathways	Design assessments that consider students' cultural backgrounds and experiences Moss (2016). Tailor instruction to students' individual needs and interests, considering their cultural backgrounds. This approach values and builds upon students' strengths while addressing their unique challenges (Gay, 2000).	<p>Do:</p> <ul style="list-style-type: none"> <li>• Provide opportunities use native language when appropriate.</li> <li>• Allow alternative forms of knowledge assessments.</li> </ul> <p>Avoid:</p> <ul style="list-style-type: none"> <li>• Using true/false questions.</li> <li>• Questions that are a test of language skills to decipher.</li> <li>• Assessment questions that require understanding of one particular culture that might disadvantage certain groups.</li> </ul>
Ethnomathematics exploration and celebration of cultural contributions to mathematics	Introduce students to ethnomathematics, which explores the mathematical practices and concepts within diverse cultural communities (D'Ambrosio, 1985). This helps students recognize that there are multiple valid ways of approaching mathematical challenges. Explore and celebrate the mathematical achievements of diverse cultures throughout history (D'Ambrosio, 2001). This helps students see themselves as contributors to the field of mathematics.	<p>Do:</p> <ul style="list-style-type: none"> <li>• Provide opportunities for students to recognize their own mathematics abilities within their world (e.g., video game time allotment, elapsed time for outings, money for purchases, measurement for cooking).</li> <li>• Provide opportunities for students to explore how mathematics is used in their community (e.g., construction workers calculate area and perimeter, shop owners calculate product supplies to order or profit/loss, chefs use measurement to determine correct ratio for flavor)</li> <li>• Consider worldviews and historical foundation (e.g., use of number zero within calculations was developed by a mathematician in India).</li> </ul> <p>Avoid:</p> <ul style="list-style-type: none"> <li>• Only celebrating student achievement based on standardized measures and district assessments (e.g., ranking of student achievement, pass/fail)</li> </ul>

conclusions, and utilize existing background knowledge to make sense of their reading. Without adequate development of either of these components (i.e., decoding or linguistic comprehension), a student's overall reading ability will be insufficient (Carter and Dean, 2006). A significant challenge experienced by practitioners is the variability in students' acquisition and application of reading comprehension skills in mathematics and their understanding of mathematics language. In some cases, particularly concerning mathematics word-problem solving, students may be able to read the text (i.e., decode) and struggle to decipher meaning from what was read (i.e., comprehend).

CLD-MD students may further struggle when linguistic complexity problems increase, requiring more robust vocabulary knowledge (Graves et al., 2013). Difficulties associated with the language of mathematics include (a) words that have multiple meanings, but the mathematics meaning is more precise (e.g., measuring the volume of a cylinder vs. a volume of work); (b) words that are used in everyday language as well as in mathematics, but differ depending on context (e.g., data table vs. table in a kitchen); (c) words that are homonyms (e.g., weight vs. wait); (d) words often used informally and imprecisely in mathematics class (e.g., break apart vs. decompose); and (e) words that have technical meanings that are unique to mathematics (e.g., zero pair, ratio, coefficient; Livers and Elmore, 2018; Kroesch et al., 2022). Though research on language acquisition indicates that students will indirectly acquire vocabulary over time, the most effective way to build CLD-MD students' language, and improve comprehension, is through careful, intentional lesson planning that involves explicit instruction and a collaborative approach with equal attention to reading, writing, and oracy (Escamilla et al., 2014). Additionally, students should have ample opportunities to engage authentically with the content through practice and application.

## Writing

In mathematics, written expression constitutes an integral facet of language proficiency. Within this context, students engage in mathematical writing through the representation of numbers (e.g., 3, 25, 1/3) and symbols (e.g., %, >, \$, +). The act of inscribing numbers and symbols holds paramount importance as it empowers students to articulate their mathematical concepts and address inquiries pertaining to mathematics. However, the scope of mathematical writing surpasses mere numerical and symbolic representation. Students are also tasked with transcribing mathematical concepts into verbal form. This includes using words to designate units of an answer (e.g., 11 additional cherries or  $\frac{3}{4}$  of a pie slice). Moreover, students employ words within sentences and paragraphs, particularly during instances of extensive mathematical composition.

Mathematical writing manifests through the use of writing instruments such as pencils or markers on conventional paper, graph paper, or whiteboards. Furthermore, in the contemporary educational landscape, typing has become a significant mode of mathematical inscription, with numerous students employing computers or tablets for their mathematical endeavors. An intriguing feature of mathematical writing is its bidirectionality—students not only engage in producing written content within the realm of mathematics, but they also undertake the task of deciphering and comprehending the written expressions inherent

to mathematical discourse. This interpretive facet of mathematical writing often necessitates reading, thereby establishing a profound interconnection between writing and reading within the context of mathematics.

## Why is language development important?

Language and literacy are embedded in all areas of daily life activities (e.g., science, history, cooking, driving), and a robust intersectional relationship exists among culture, language, teaching, and learning, which drives the purposefulness of CLR practices. The understanding that language and literacy are present within mathematics is a critical component of mathematics learning that should be considered when teaching CLD-MD students. Social language develops quicker through implicit learning, in contrast to academic language which requires systematic and explicit instruction (Cummins, 1981). Both social and academic language play an essential role in mathematics development for CLD-MD students, therefore, there is a need for mathematics language development within the mathematics curriculum (Escamilla et al., 2014). Mathematics language is the ability to understand and use technical mathematics vocabulary, symbols, and procedures to communicate one's thoughts (Riccomini et al., 2015). Due to the complexity of mathematics language and barriers, it, in turn, creates challenges for educators to support CLD-MD students. Barriers that arise when not attending to the language of mathematics can prevent CLD-MD students from accessing and expressing their knowledge in mathematics. When CLD-MD students have the opportunity to practice language orally aloud, reading it and writing it consistently, it activates working memory, and learning occurs (Orosco, 2014). Undoubtedly, literacy instruction plays a critical role in developing students' mathematics proficiency (August and Shanahan, 2008). Educators of CLD-MD students must weave literacy instruction within mathematics content-area instruction intentionally. Doing so involves more than simply asking students to read problems. Instruction must prioritize numerous opportunities for students to interact with the content and deepen their understanding of concepts.

## How to teach language?

### Explicit vocabulary instruction

Enhancing CLD-MD students' vocabulary holds the potential to significantly bolster comprehension for all students grappling with mathematical challenges. While vocabulary acquisition might occur indirectly over time, the most efficacious avenue to cultivate students' vocabulary knowledge and understanding is by means of explicit vocabulary instruction coupled with avenues for utilizing mathematical language. In this context, the term "explicit" signifies a methodical approach to instruction that encompasses vocabulary modeling, guided practice, and constructive feedback (Archer and Hughes, 2010).

When embarking on the explicit instruction of vocabulary, educators should commence each lesson by introducing the target vocabulary words along with user-friendly definitions tailored to students' comprehension (Plonsky and Zhuang, 2019). It is important to note that some mathematical vocabulary consists of

individual words, while others comprise multi-word terms. These student-friendly definitions should be lucid, incorporating familiar terms and everyday language accessible to the students.

Subsequently, reinforce the definitions with visual depictions of the vocabulary words or terms. Visual representations offer students diverse perspectives through which to perceive and comprehend the terms (Klingner and Eppolito, 2014; Freeman-Green et al., 2021). Lastly, afford students the opportunity to observe specific examples and counterexamples of the terms within the context of mathematics. During this process, ensure that students are provided opportunities to bridge new information with their pre-existing mathematical knowledge. This can be facilitated through various means, such as partner discussions regarding their existing familiarity with a term (e.g., think-pair-share), whole-group discourse, or the incorporation of graphic organizers to document ideas (e.g., K-W-L chart or word maps).

Regarding writing, students should be granted occasions in which mathematical writing is explicitly modeled alongside embedded practice sessions. For crafting sentences and paragraphs, which might pose challenges for certain students, especially those with limited general writing skills, educators should designate dedicated time within their mathematical instruction to focus on honing mathematical writing abilities (Graham et al., 2020). Educators should provide avenues for students to engage in diverse forms of mathematical writing, encompassing explanatory and argumentative writing (Colonnese, 2020). Moreover, educators should guide students in practicing mathematical writing through varied approaches, such as journaling, blog composition, or letter writing (Peng et al., 2022).

### Language development strategies

Another strategy for developing mathematics language and vocabulary is oral language practice. This allows CLD-MD students various opportunities to verbalize mathematics language and vocabulary aloud, moving it from short-term memory into working memory (Orosco, 2014). Show the students the word in written form while they are practicing the word orally. Have the students say the word aloud together and independently several times. Break down the word into phonetic pronunciation and syllables for the students to see and hear the term segmented. Have CLD-MD students practice verbalizing the syllables within each word (Orosco and Klingner, 2010). Provide a student-friendly definition with an example and visual image, both written and oral. Additionally, model and guide the student for appropriate language development through meaning, while scaffolding conversation. Then follow up with using the term in a sentence that portrays how the student would hear the word used in context. When applicable, provide a culturally responsive example, this will not apply to all mathematics vocabulary. The oral language development cycle is illustrated in Figure 2, the components of the process are a linear progression. Components may be repeated, expanded, and paired with other components at any point to provide extra practice of oral language. An extension activity is included to illustrate an example of how to expand oral language practice beyond the initial isolated vocabulary development to cross-mathematical skills connections. This demonstrates how to expand on the use of oral language development with concepts similar and related to the current topic. When CLD-MD students

can see visual representations of how the individual concepts relate to the previous and future topics it provides them an opportunity to translate the skill to application (Orosco and Klingner, 2010).

### Graphic organizers

Utilizing graphic organizers proves to be a potent technique for cultivating vocabulary comprehension among CLD-MD students, concurrently fostering avenues for linking to prior knowledge (Dexter and Hughes, 2011). The Frayer model, a distinctive graphic organizer variant, is a particularly effective vehicle for nurturing vocabulary acquisition. It prompts students to discern key attributes of the vocabulary word, devise their own instances and counterexamples, and craft a personalized definition of the term (Dunston and Tyminski, 2013). An inherent advantage of the Frayer model lies in its adaptability, rendering it suitable for a spectrum of grade levels and proficiency tiers. Refer to Figure 3 for an illustrative example.

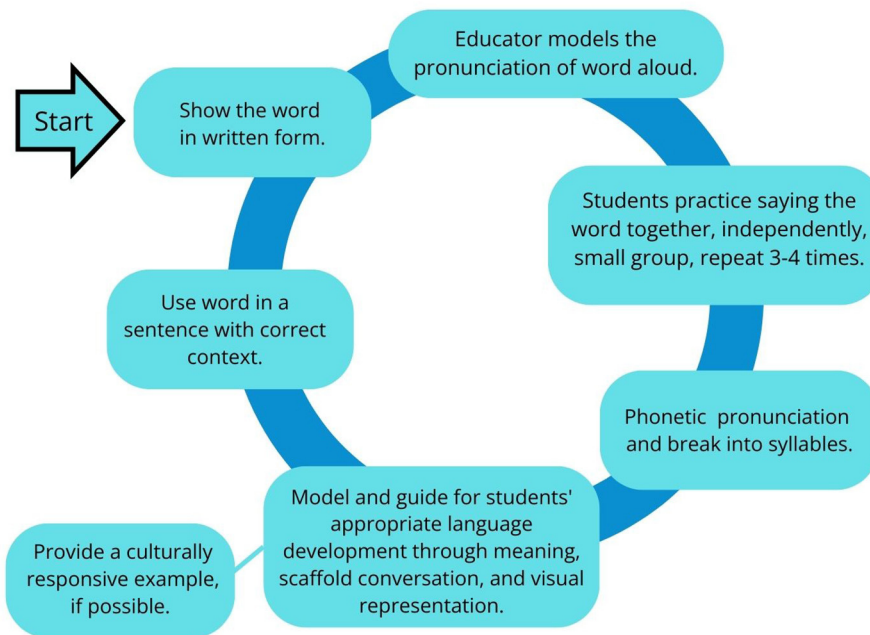
### Anchor charts

Anchor charts are used strategically for learners in dual language and general education classroom settings to support language development (Escamilla et al., 2014). When used in classrooms, anchor charts provide a classroom and content artifact for students to refer to regularly during their learning. These charts are co-constructed by students and teachers during the direct instruction of the content. They are displayed to remind students of their prior learning and support their continued learning of the content. Figure 4 provides an example of how anchor charts within the mathematics content might be seen in the classroom setting. Additional anchor charts designed to facilitate 'how to engage in mathematical writing' can offer substantial benefits when considering the linguistic complexity of certain mathematics problems or features. For example, an anchor chart featuring a mnemonic for simplifying mathematical writing could prove particularly valuable (Gupta, 2019).

Another chart that could significantly enhance writing endeavors is a vocabulary wall (Gupta, 2019). Collaboratively established by educators and students, these charts find their place within the classroom environment. As students embark on writing tasks, they are presented with a tangible point of reference delineating crucial terms to be incorporated into their compositions, along with guidelines on accurate spelling and usage.

### Student-created reference materials

An additional approach that can effectively bolster continuous vocabulary acquisition for CLD-MD students involves integrating student-generated reference materials, exemplified by tools like vocabulary cards or a comprehensive glossary of terms (Manyak et al., 2021). The creation of student-generated vocabulary cards affords an avenue for students to visualize concepts, establish associations, and cultivate an enriched understanding of vocabulary. This participatory involvement also grants students a sense of ownership in generating a resource that serves as an enduring aid for reinforcing their learning. Each vocabulary card comprehensively encompasses the term, its definition, synonyms, antonyms, contextual usage, visual depictions, symbolic



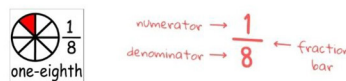
**Sample oral language practice with term: denominator**

Educator model: "denominator"

Say: "denominator"

Phonetic pronunciation: "duh-naa-muh-nay-tr"

Math definition: "The term in a fraction that tells the number of equal parts in a whole."



Sentence: "The denominator of one-eighth is 8."

⊘ Non-example: "The bottom number of the fraction is 8. One over eight."

**Extension practice**

$$\frac{1}{8} \text{ "is the same as"} 0.125 \text{ "is the same as"} 12.5\%$$

"one-eighth"                      "one hundred twenty-five thousandths"                      "twelve and five tenths percent"

Educator model: "one-eighth", "one hundred twenty-five thousandths", "twelve and five-tenths"

Say: "The fraction **one-eighth** is the same as the decimal **one hundred twenty-five thousandths** and is the same as **twelve and five-tenths percent**."

FIGURE 2  
Oral language development cycle.

representations, and instances illustrating the term within sentences or exemplary mathematical problems (Minetola et al., 2013).

Alternatively, educators can guide students in the formulation of a personally crafted mathematics glossary. This glossary serves as a communal repository, facilitating the storage and tracking of pivotal terms, their corresponding definitions, and illustrative examples that reinforce the acquired vocabulary throughout the academic year. For our CLD-MD students, both these strategies present a remarkable opportunity to foster connections with their individual cultural and linguistic

backgrounds. This is accomplished through the incorporation of culturally pertinent contextual instances (conjoined with word explanations) and the provision of native language support (such as word translations and cognates; Gunn et al., 2021). Note that some CLD-MD students may require accommodations and assistance to create their own glossary such as, but not limited to, scribe or printed terms and student-friendly definitions for them to paste in their glossary rather than handwritten depending on their level of English proficiency, disability, and fine motor. See Figure 5 for an example of a student-created glossary.



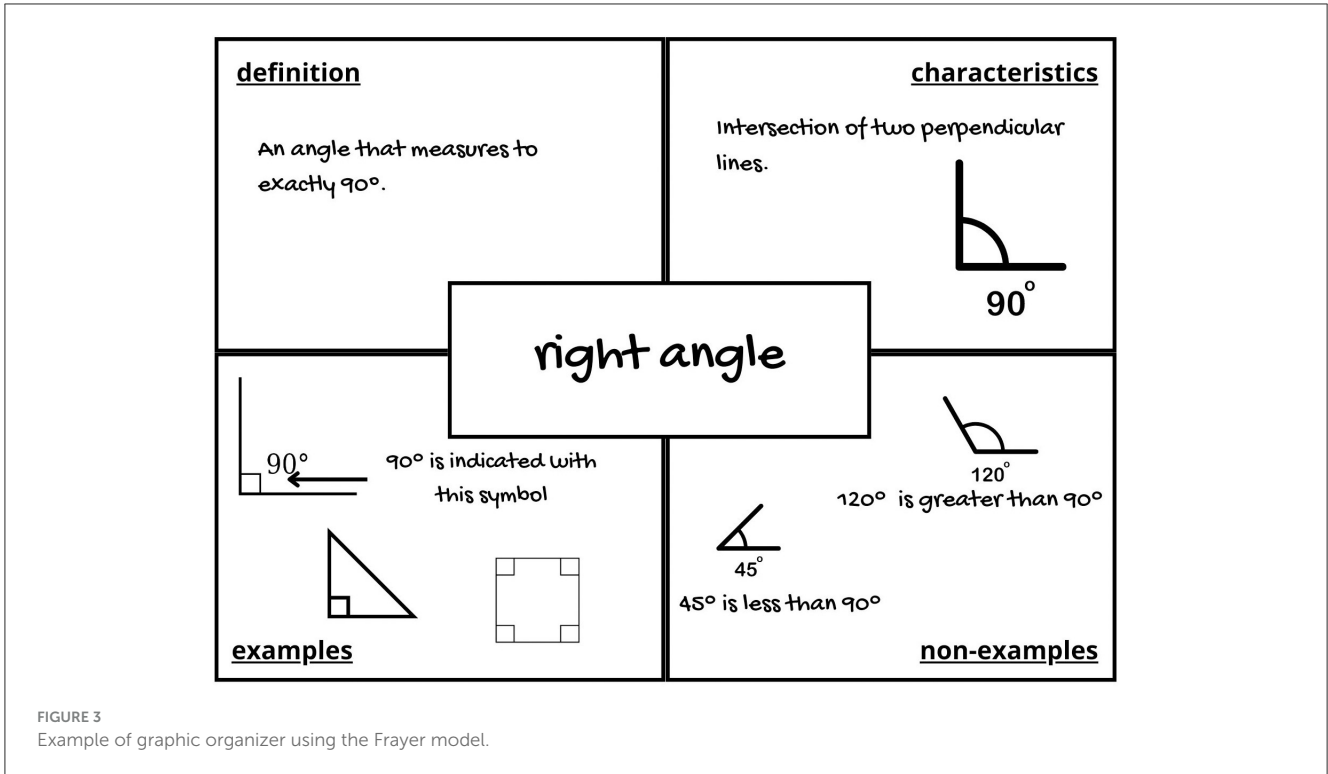


FIGURE 3 Example of graphic organizer using the Frayer model.

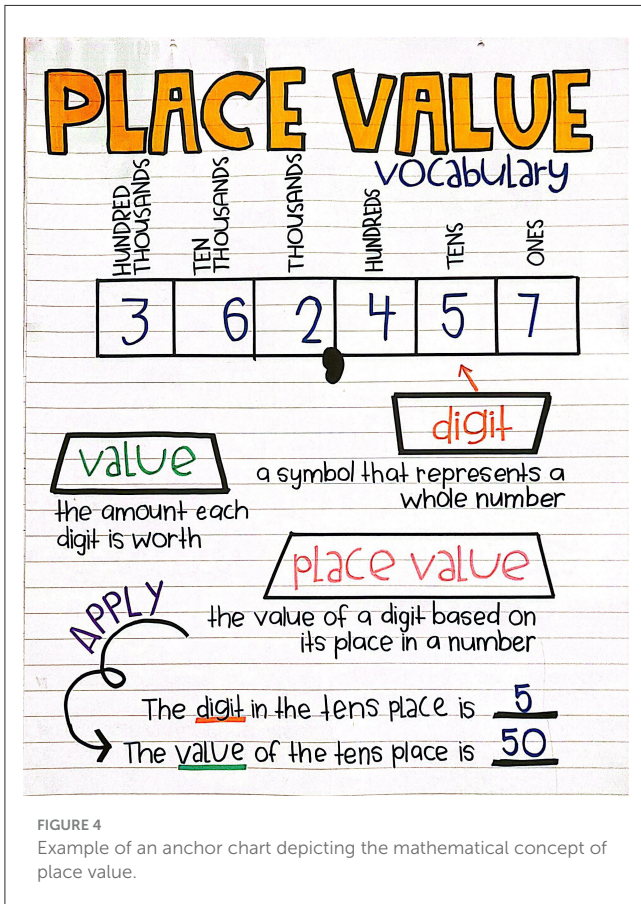


FIGURE 4 Example of an anchor chart depicting the mathematical concept of place value.

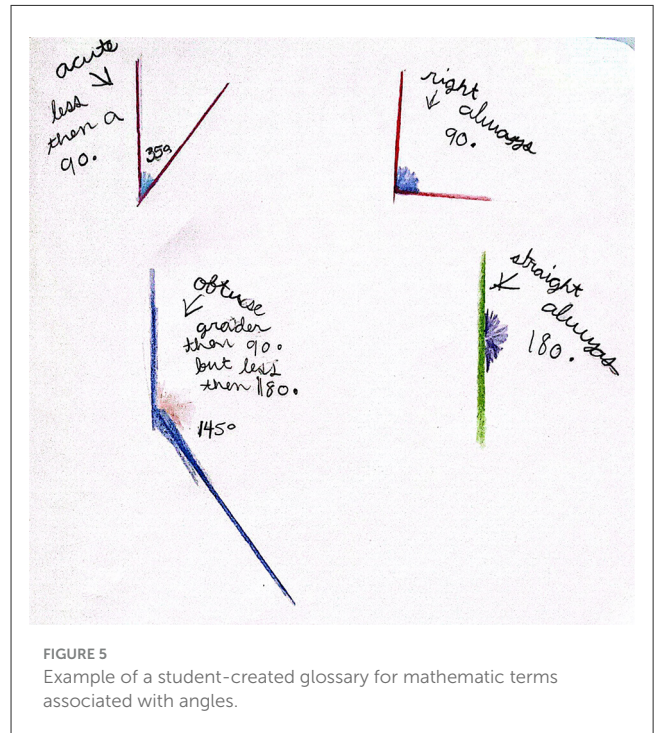


FIGURE 5 Example of a student-created glossary for mathematical terms associated with angles.

Use of a mnemonic for self-regulated strategy protocol for writing mathematical writing. To illustrate, Hughes and Lee (2020) introduced the PRISM Check strategy, wherein students

self-employ the acronym to navigate through the sequential stages of PRISM: P for the problem, R for representation, I for I do, S for state, say, and share, M for my answer, and C for check. PRISM guides the students step by step through the essential elements for constructing coherent written mathematical explanations. Students may refer to a guided handout with PRISM illustrated or they may write out the acronym at the top of their paper as a checklist.

## Gestures

### What are gestures?

Gestures are defined as the movement of the hands that convey meaning. For example, pointing, sweeping of hands to show change, or even fingers held up to show quantity. Gestures are often used simultaneously with speech to enhance meaning to the context (Martinez-Lincoln et al., 2018). People of all ages use gestures all day, every day while speaking, and as they are learning and trying to make sense of the information received. In fact, many educators naturally gesture during instruction and casual conversations with students across grade levels, though gestures are used more consistently and prominent at the elementary level (Alibali et al., 2014). Gestures are categorized as either naturalistic or scripted for ease of educator use in this list of strategies. Naturalistic gestures are those naturally occurring done without prior preparation or intention of use. For example, a naturalistic gesture to represent the numerical value of five would be to hold up five fingers. Most educators do this naturally as they are building number sense with young children. Other examples of a single naturalistic gesture include: pointing, a handshape, or tracing. (Goldin-Meadow et al., 2001; Alibali et al., 2014). Scripted gestures are carefully selected hand movements that are used consistently to accompany a specific mathematics topic. For example, when students are developing an understanding that both sides of the equal sign are balanced expressions. Educators may use the gesture of holding both arms out (i.e., holding something heavy) with one arm tilted higher than another to indicate that one side has more than the other.

### Why are gestures important?

Research emphasizes the use of gestures by educators enhances the transfer and retention of content for students (Cook et al., 2013, 2017). This is particularly true when the gestures provide additional information. When gestures are paired with spoken instruction, students' mathematical performance increases (Singer and Goldin-Meadow, 2005). Not only is the use of gestures by educators impactful for student learning and retention, but when students use gestures, it supports their transition from learning to understanding mathematical concepts, especially during mathematical discussions (Broaders et al., 2007). Studies have proven that overall students perform higher on mathematics tasks when they gestured than when students did not. In addition, researchers have observed the use of gestures when CLD students struggle to determine the word or phrase during their mathematical explanation as a way to fill in the missing parts to illustrate meaning (Domínguez, 2005; Ping and Goldin-Meadow, 2010;

Mainela-Arnold et al., 2011; Shein, 2012; Rosborough, 2014; Martinez-Lincoln et al., 2018). The use of gestures increases CLD student's working memory in turn, reduces the cognitive load, leading to an increase in mathematical achievement including mathematical concepts, language, comprehension, and expression (Goldin-Meadow et al., 2001; Cook et al., 2008, 2012; Ping and Goldin-Meadow, 2010; Martinez-Lincoln et al., 2018; Clough and Duff, 2020). Additionally, understanding the role of cognitive load for language learners has been studied in language learning broadly [i.e. foreign language learning (Chen and Chang, 2009; Roussel et al., 2017)] and second language acquisition specifically (Mayer et al., 2014; Sweller, 2017; Azamnouri et al., 2020). Overall, when both educators and students use gestures during mathematics instruction and learning, it has a positive impact on CLD-MD students' mathematical performance.

### How to teach gestures?

To support CLD-MD students' retention of mathematics concepts and engage in the transfer of knowledge to application, research encourages both educators and CLD-MD students to use gestures. The gestures naturally used or carefully selected should complement the spoken language for it an effective tool (Cook, 2011).

#### Naturalistic gestures

During instruction, educators should take note of the gestures that naturally occur and decide if they need to increase, decrease, or remain the same, and if the gestures match their spoken information. When lesson planning, educators can take a moment to review the content and guided practice to select meaningful gestures to accompany the instruction to enhance the CLD-MD student's understanding. Encourage CLD-MD students to use gestures naturally when transitioning from learning to understanding (Martinez-Lincoln et al., 2018). Educators should embed time for guided student practice using mathematical language with gestures while checking in for understanding of mathematical concepts. Provide CLD-MD students multiple opportunities to engage in mathematical discussions using gestures with verbal explanations throughout the lesson with their peers.

#### Scripted gestures

Create or use an existing single gesture or a sequence of gestures to illustrate or convey the mathematical concept that will accompany a verbal prompt. The gestures should enhance the CLD-MD student's conceptual understanding of the concept. Both the CLD-MD students and all educators should be trained on the gestures, especially focused on how to use the gestures appropriately with the mathematic concept and when to use the scripted gestures.

## Multiple mathematical representations

### What are multiple mathematical representations?

Multiple mathematical representations are observable and tangible ways to depict mathematical concepts (e.g.,

manipulatives, diagrams, dice) with the intention that educators and students use the representation to explore, acquire, or investigate (Bartolini and Martignone, 2014; Goldin, 2014). Frequently multiple representations are referred to in terms of concrete, semi-concrete, abstract, and more recently a virtual representation category was created to capture the digital representations. Concrete representations are three-dimensional materials that can be physically manipulated such as base-10 blocks, two-color counters, a sphere, or skip-counting chains (Goldin, 2014). Recently, educators have added a new category, virtual representations which is a subcategory of concrete representations. Virtual representations are digital representations of concrete manipulatives (e.g., virtual base ten blocks, fraction tiles, or balance scale) for interaction on a computer, tablet, or digital screen by moving it in different ways (e.g., rotating, clicking, dragging, and dropping; Bartolini and Martignone, 2014; Bouck et al., 2020). Semi-concrete representations are drawings or pictures of mathematics materials or concepts or two-dimensional pictorials that include drawings of base-10 blocks, diagrams, number lines, or a picture of a triangle. This also includes pictures of a three-dimensional object; the representation is still considered semi-concrete due to the format in which students interact with the mathematical representation. Abstract representations are written numbers, symbols, mathematical ideas, expressions, or equations such as  $3x + 5 = 20$ ,  $10 > 3$ , or  $9 - 2$ .

### Why are multiple mathematical representations important?

The use of multiple representations within mathematics instruction enhances students' knowledge and conceptual understanding of symbols and quantities. The enhancement of this knowledge around symbols is important because there is a strong predictor between a student's early symbolic and arithmetic knowledge and their mathematics achievement in later grades (Courtier et al., 2021). Multiple representations are beneficial for CLD-MD students' learning because they can be used to represent a single mathematical concept in multiple ways and demonstrate connections across concepts which strengthens mathematical understanding. Not only can multiple representations be used to build conceptual understanding, but it is a two-way relationship that bridges CLD-MD students' receptive and expressive knowledge (Goldin, 2014). Allowing students to demonstrate their mathematical knowledge through a self-selected representation allows for educators to determine a CLD-MD student's level of understanding. Researchers caution when one mathematical representation is introduced in isolation at the beginning, often students assign a particular meaning and retain the definition as the only fundamental interpretation of the concept. When students are attempting to build on mathematical concepts for more complex problem-solving, it is difficult for them to evolve their mathematical understanding or transfer to new concepts (Goldin, 2014).

### How to teach with multiple mathematical representations?

#### Explicit instruction

When using multiple representations to engage CLD-MD students in interaction with mathematical concepts, it should be done through systemic and explicit instruction. Explicit instruction includes a sequence of behaviors that must be included: (a) educator models the use of multiple representations specifically for each concept especially when using the same representations for another mathematic skill, (b) educator incorporates ample guided practice opportunities, (c) check student understanding briefly and consistently, (d) educator provides feedback on mathematical concept knowledge and use of multiple representations, and (e) students engage in independent practice (Doabler and Fien, 2013). CLD-MD students can develop an understanding of how to use the materials effectively and optimize the use of multiple representations to build mathematical understanding and use the representations to demonstrate their knowledge.

#### Multiple formats

Use a variety of representations to represent the same mathematical concept and even the same mathematical problem for CLD-MD students to understand the correspondence between the symbols and quantities (Strickland, 2016). For example, when teaching CLD-MD students multiplication facts for 5s, it can be represented with skip counting chains, where students would stop after every 5th bead and place a piece of paper above the bead to indicate the quantity (i.e., 5, 10, 15, 20) then at a later time add the multiplication fact associated with the grouping of beads (e.g.,  $5 \times 3 = 15$ ). The CLD-MD students can engage with the mathematical concept both with concrete and abstract representation throughout the activity to develop a conceptual understanding of multiplication. See Figure 6 for examples of multiple representations across concepts.

#### What multiple representations to use

Use objects that are representative of the CLD-MD student's community such as rocks or buttons for counting instead of bright plastic bears or traditional blankets to see weaving patterns for geometric angles. Similar to the discussion of FoK, this is an opportunity to celebrate and utilize the cultural artifacts that the students are familiar with within the mathematics curriculum, but also bridge to explicit explanations for those they are not familiar with the artifacts (Lillard, 2016). Use this opportunity to share with CLD-MD students the similarities and differences of representations among different cultures. In addition to cultural artifacts, when selecting representations with specific mathematic concepts use evidence-based materials such as base-ten blocks, fraction tiles, two-color counters, or angle legs. Figure 7 provides a visual illustration of two CLD students calculating four-digit addition with the use of multiple representations.

#### What multiple representations to avoid

Avoid using idiomatic speech (two-strikes and you're out, looks like a million bucks, etc), culture-specific analogies or metaphors (e.g., crab claw for solving binomial expansion, alligator eats more for greater or less than, etc.), or non-evidence-based

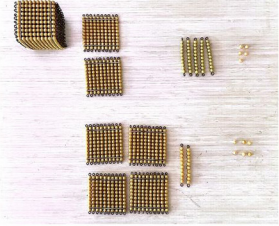
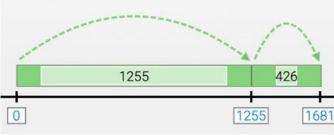

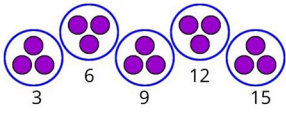
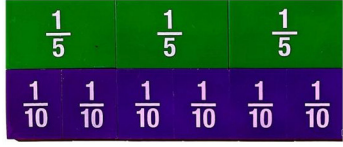
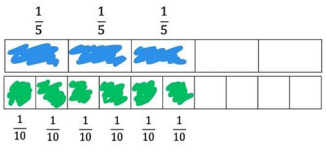
Concrete	Semi-concrete	Abstract
		$\begin{array}{r} 1255 \\ + 426 \\ \hline \end{array}$ $1255 + 426 = \underline{\quad}$
		$\begin{array}{r} 3 \\ \times 5 \\ \hline 15 \end{array}$ $3 \times 5 = 15$
		$\frac{3}{5} = \frac{6}{10}$

FIGURE 6 Examples of multiple representations across selected mathematic concepts.

materials (alligator made of popsicle sticks). When introducing these concepts, specifically those with linguistic features or those with direct cultural and language connections, it is most beneficial to do so by explicitly teaching the language feature itself before the introduction of the content-specific connection (Escamilla et al., 2014). For example, one of the most popular representations of greater than and less than is the use of the alligator eating the side that has more. Some educators may argue that use of concrete (i.e., alligator made of popsicle sticks) or semi-concrete (i.e., picture) representation of the alligator, CLD-MD students are creating a visual of the mathematical concept of greater than, less than, or same as. However, CLD-MD students are more likely to be literal in visualizing an animal coming to eat the side that has more until they get a stomach ache and want less, this metaphor in particular may or may not transition to the understanding of the greater than and less than symbols (i.e., <, >). There is a mismatch of the mathematics concept, representation, and language that could act as a barrier to the development of conceptual knowledge (Orosco and O'Connor, 2014).

## Action and reflection

### Instructional conditions

One of the essential features of an IEP is it provides educators with instructional conditions statements, which clearly define and describe the strategies, tools, and instructional methods that the CLD-MD students need and use to assess the content and demonstrate their knowledge to reach their annual goal (Tran et al., 2018; Hoover et al., 2019). The three main IEP sections to incorporate the CLR instructional conditions include (a) the present levels of academic achievement and functional performance (PLAAFP) statements, (b) annual measurable goals, and (c) accommodations and modifications. The PLAAFP statements build a picture of the CLD-MD student, current performance in specific content areas, their strengths, areas of growth, and the support the CLD-MD student needs to access the curriculum and learn. Goals clearly describe the mathematics skill addressed in the intervention, the measure to evaluate their progress, and how the CLD-MD student will achieve the goal. Accommodations address the CLD-MD

student’s needs and provide guidance as to how to increase their access to the content and express knowledge. In each section, consider and document how the CLD-MD student’s mathematics disability and cultural attributes are addressed (e.g., increase explicit vocabulary instruction, use of gestures, or multiple representations) and how the learner will express their knowledge.

### Data-based decision making

Another important factor following the implementation of these strategies, it becomes imperative for educators to engage in informed decision-making regarding the CLD-MD student’s progress. This is where the utilization of data-driven decision-making techniques assumes paramount significance. Employing data-based decision-making, educators engage in the continuous assessment of student advancement. This assessment can take diverse forms, ranging from informal exit tickets, observational insights, and surveys, to more structured evaluations encompassing computational assessments or real-world applications. Regular collection of such data, ideally on a bi-weekly or monthly basis, enables educators to discern the trajectory of student development across weeks and months.

Guided by the amassed data, educators deliberate on the efficacy of classroom instruction (such as explicit word-problem guidance) for their students. Through the graphical representation of data trends, educators can discern patterns of student performance (i.e., upward or downward shifts) and promptly institute decisions aimed at refining instructional strategies. The significance of data-based decision-making is particularly pronounced for students with mathematical challenges, especially those classified under the umbrella of CLRP (Complex Learning and Related Disabilities), as they might already be grappling with mathematics below grade-level standards. In the realm of mathematics, where setbacks can impede progress, educators are compelled to remain adaptable and prompt in modifying instructional approaches as circumstances dictate. A failure to make timely instructional adjustments risks allowing an entire semester or school year to transpire without addressing the inadequacies of the original instruction.

In instances where an educator identifies the inadequacy of a CLD-MD student’s current instructional program, a plethora of adaptations can be employed. The term “adaptations” aptly encapsulates the idea that educators often tweak the instructional framework rather than entirely overhauling it. These adaptations



FIGURE 7 Students using concrete base-ten blocks with abstract representations to add four-digit numbers.

TABLE 2 CLR features for IEP components with specific recommendations for mathematics.

	Mathematics PLAAPF statements include:	Annual goals include:	Accommodations and modifications address:
Cultural funds of knowledge	<ul style="list-style-type: none"> <li>• Description of culture and community.</li> <li>• How student’s culture influences their daily life.</li> <li>• Student’s perception of mathematics strengths and contribution.</li> </ul>	<ul style="list-style-type: none"> <li>• Use of CLR assessment measures.</li> <li>• Description of the mathematic skill(s) to be addressed in direct intervention.</li> <li>• Description of <i>how</i> the goal will be achieved.</li> <li>• Description of method(s) for demonstration of knowledge that supports the disability and CLD background.</li> </ul>	<ul style="list-style-type: none"> <li>• Validation of cultural and linguistic differences.</li> <li>• Access to the content that supports disability and CLD background</li> <li>• Method for demonstration of knowledge that supports disability and CLD background.</li> </ul>
Language development	<ul style="list-style-type: none"> <li>• Native language abilities specific to mathematics.</li> <li>• English proficiency level.</li> <li>• Background knowledge and current need for mathematics language development.</li> </ul>	<ul style="list-style-type: none"> <li>• If and how native and English language are factors.</li> </ul>	<ul style="list-style-type: none"> <li>• Supports that bridge the native and English language skills.</li> <li>• Mathematics Language Development</li> </ul>
Gestures	<ul style="list-style-type: none"> <li>• Description of the gestures use by students and educator that impact learning.</li> </ul>	<ul style="list-style-type: none"> <li>• Description of method(s) for demonstration of knowledge.</li> </ul>	<ul style="list-style-type: none"> <li>• Description of the appropriate and effective strategies for access and demonstration of knowledge.</li> </ul>
Multiple representations	<ul style="list-style-type: none"> <li>• Descriptions of multiple representations use.</li> </ul>	<ul style="list-style-type: none"> <li>• Description of <i>how</i> the goal will be achieved with use of multiple representations.</li> </ul>	<ul style="list-style-type: none"> <li>• Description of the appropriate and effective strategies for access and demonstration of knowledge.</li> </ul>

may encompass augmenting instructional duration (e.g., increasing daily minutes), fostering transfer learning (i.e., elucidating how simpler problems relate to complex ones), or refining the mathematical content itself (e.g., employing diverse manipulatives, elevating emphasis on mathematical language).

In essence, the process of continuous data-based decision-making ensures that educators remain attuned to the evolving needs of their students and remain agile in their instructional methodologies, ultimately fostering a dynamic and responsive learning environment. Once the IEP team has made a determination it is important to share with professionals that interact with the CLD-MD students and document within the IEP.

## Implications for Individualized Education Program development

Given the importance of mathematical skills as a strong predictor of future achievement for all students in education, it is important to incorporate the four CLR essential components of effective mathematics instruction into the daily instruction for CLD-MD students. These four essential components extend beyond implementation within the daily instruction. They also need to be documented in the CLD-MD student's IEP, as it serves as the foundation for effective and adequate services. Table 2 illustrates select CLR examples to incorporate into the development of PLAAFP statements, annual goals, and accommodations and modifications sections of an IEP.

## Conclusion

For CLD-MD students, it is essential to use evidence-based mathematics instruction starting in the early years to build a strong foundation that will carry with them into the upper grades. Each of these four essential instruction elements, (a) cultural funds of knowledge, (b) language development, (c) gestures, and (d) multiple representations are appropriate to integrate into instruction as early as preschool and through high school. It is highly recommended that educators incorporate one or all of these elements in daily mathematics instruction throughout every unit.

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Once the instructional plan is created, educators should select a data collection method and implementation timeline. Once data is collected, use the data to make decisions and engage in discussion about what is working well for CLD-MD students and what kind of adaptations need to be made.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

LT: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. OC: Conceptualization, Writing – original draft, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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