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Emergent Multilingual Learners Use of Multimodal Discursive Resources in Science Journals to Communicate "Doing" and "Learning"

Callie Price
Texas Christian University

Daniella Biffi
Texas Christian University

Molly H. Weinburgh
Texas Christian University

Kathy Horak Smith
Tarleton State University

Cecilia Silva
Texas Christian University

Monica Amylett
Texas Christian University

Antonia Domino
Texas Christian University

ABSTRACT

Sociocultural language learning theory and situated learning theory stress the importance of social interactions and context in both science and language learning. In addition, researchers have highlighted the important role that multimodal language plays in meaning-making and communication in science. The purpose of this study was to examine the multimodal discursive resources emergent multilingual learners (EMLs) used in their journals on the topic of erosion. Thus, we ask "in what ways do multimodal discursive resources differ as EMLs describe doing an investigation (practices) and learning (content) in response to a writing prompt (What I did-What I learned)?" This research, grounded in an interpretive/constructivist paradigm, examined the journals of 18 EMLs who participated in a summer program where they engaged in the social context of scientific practice. Students used the What I Did/What I Learned (WID/WIL) writing prompt to describe the practices used in the classroom investigations and the knowledge resulting from these investigations. The WID/WIL journal entries were examined using template analysis coding. The template consisted of four major categories: writing, mathematical expressions, manual-technical operations, and setting. Findings indicated that EMLs utilized writing and mathematical expressions to communicate their manual technical operations (practice) and knowledge (content) of erosion. EMLs did not use visual representations as part of their multimodal resources. Implications for science teaching and the use of the WID/WIL as a writing prompt are included.

Keywords: multimodal discursive resources, science writing, emergent multilingual learners

Introduction

English learners, also referred to as emergent multilingual learners (EMLs), are the fastest growing student subgroup in US classrooms (National Center for Education Statistics [NCES], 2020). These students, who may already speak several languages, are expected to learn and use English as the medium for content development. Meaning-making and communication in science classrooms are dependent on a students' ability to use academic discourse, including highly technical language in the social context of schooling and science (Brisk & Zhang-Wu, 2017; O'Hara et al., 2012). Academic language can be difficult for students having English as their first language because the linguistic devices and strategies of scientific language are unique (Seah & Chan, 2021). For EMLs this language is particularly difficult. Therefore, it is essential for EMLs to participate in science lessons that scaffold both academic language and conceptual understanding of practice and science content (Lee, 2005; Tang & Rappa, 2021).

Educating EMLs from diverse linguistic, social, and economic backgrounds is increasingly recognized as a key challenge for science education in the US (National Research Council, 2012; NGSS Lead States, 2013). This challenge is evidenced by the pervasive opportunity gap affecting EMLs in science, technology, engineering, and mathematics (STEM; National Academies of Sciences, Engineering, and Medicine, 2018). There is an urgent need for EMLs to be well prepared in STEM to enter our increasingly technology-dependent workforce.

Consequently, more research is needed "on understanding the role of languages and learning environments learners use and engage with in building understanding of science concepts" (Hand et al., 2019, p.110). In pursuit of this understanding, the purpose of this study was to examine the discursive resources EMLs used in their journals to communicate the topic of erosion as they described their scientific practice (did) and their meaning-making (learned). Specifically, we ask in what ways do multimodal discursive resources differ as EMLs describe doing an investigation (practices) and learning (content) in response to a writing prompt (What I did-What I learned)?

Theoretical Framework

Guiding our research is a theoretical framework that combines sociocultural language learning (Eun & Lim, 2009; Mustafa et al., 2017) and situated learning (Gee, 2004; Lave & Wenger, 1991). The overlap of these types of learning provides a space to envision the science language used by EMLs in a socially constructed context of a science class. Within this space, EMLs engage in the practices of science as outlined in the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) over multiple investigations. EMLs also have the opportunity to display conceptual understanding of practice and product of science through multimodal discourse. Thus, the gap being filled by this research is an understanding of how EMLs use multimodal discursive resources, including the use of writing, mathematical expressions, visual, and manual-technical operations, needed to communicate doing and learning science.

Sociocultural Language Learning

Influential studies on learning by Bandura (1986, 1997) pushed against the emphasis on conditioning and reinforcement as seen in behavioral learning theory. Instead, Bandura proposed a social cognitive theory that emphasized the role of social interactions in cognition and asserted that people can reproduce acts they observe being conducted by others. Similarly, Vygotsky's (1978) theory of sociocultural learning stressed "the interaction of interpersonal (social), cultural-historical, and individual factors as the key to human development" (Schunk, 2020, p. 331) and learning. Both theories underscored learning as highly dependent on context and interaction with others.

Mustafa et al. (2017) pointed out that sociocultural theories of language differ from other theories of language because they emphasize that the "social environment is not the context for, but rather the source of, mental development" (p. 1170) and take into "account the complex interaction between the individual acting with mediational means and the sociocultural context" (p. 1170). Thus, a sociocultural theoretical lens would predict that language learning does not occur in isolation, but in connection to particular experiences, social interactions, and cultural norms (Martinez & Mejia, 2020). Researchers have examined the social aspect of learning as it applies to language acquisition (Knain, 2015; Lantolf et al., 2015). Lantolf et al. (2015) stated that "language in all its forms is the most pervasive and powerful cultural artifact that humans possess to mediate their connections to the world, to each other, and to themselves" (p. 211). Ma (2020) stated that "cognitive and linguistic development, as an integrated entity, is possible only when the meaning contained in the sign system is interpreted by the individual" (p. 171). In sociocultural theory, the social activity of mediation "transforms unmediated behavior into higher mental processes through tools" (p. 171) which can be symbolic, material, and cognitive.

Sociocultural theory helps explain early language development which is centered within the home where children develop their primary discourse. This language develops without significant instruction and is the result of physical maturation, social interactions, and cultural norms. As with all social activities, community norms are passed from the more advanced or knowledgeable member to the novice. Secondary discourses develop as children are socialized into schools and other institutions beyond the home community and are more focused and highly specialized. In addition to receiving explicit instruction about discourse practices, students observe and imitate the discursive practices of others. This learning involves change that is "demonstrated based on what people say, write, and do" (Schunk, 2020 p. 4). Thus, a proxy (text, drawings, symbols, speech, etc.) is used to denote that learning has occurred.

Situated Learning

Situated learning theory also emphasizes the active role of contexts in knowing and learning (Lave & Wenger, 1991). From this perspective, all members, and the resources (e.g., ideas, norms, tools) of the group, are part of the context. As individuals are enculturated into the situated practice of a social group or community, change takes place. The construction of knowledge and skills occurs in the space defined by authentic activities that allows for the influence and refinement of the domain-specific tools. Therefore, learning cannot be divorced from the situation in which the learning develops.

Building on earlier research by psychologists and educators, Klassen (2006) criticized the decontextualized and tedious way science is often taught. He proposed five contexts (i.e., practical, theoretical, social, historical, affective) for teaching. Overall, the five contexts advocate for moving away from science teaching in which students learn facts but very little about how ideas were developed (historical and social), their position within the bigger picture (theoretical), and their appeal to students (affective). Klassen (2006) suggested a science teaching where students, in contextualized experiences, become emotionally involved and stay motivated by conducting authentic (practical) science investigations in groups (social).

From the position of the overlap of these two theories, we would expect students to use the academic discourse that is both explicitly introduced and intentionally modeled during the investigations. In addition, the theories suggest that students will use language that is specific to the situation and represents the investigation being conducted.

Literature Review

EMLs and Multimodal Science Discourse

Lemke's work (1990, 2002, 2004) posited the discourse of science as a hybrid of four interconnected communication modes: natural language, mathematical expressions, visual representations, and manual-technical operations. In his work, Lemke highlighted the importance and limitations of natural language. With this line of conceptualization, the diverse forms of representation can be considered 'modes', which are "… organized, regular, socially specific means of representation" (Jewitt et al., 2001, p. 5).

Multimodal communication has been studied from different foci (Jewitt, 2017; Jornet & Roth, 2015; Kress et al., 2001). Studies can be found that examine natural language (Brown & Ryoo, 2008; Cervetti et al., 2012; Fang et al., 2010; Lee, 2005), mathematical expression (Friel et al., 2001; Olivares, 1996; Osterholm, 2005), visual representations (Kress & van Leeuwen, 2006; Roth, 2002; Tytler & Hubber, 2016; van Leeuwen, 2014) and manual-technical operations (Roth & Lawless, 2002; Siry et al., 2012) in science education. Muna et al. (2020) stated that "developing proficiency in the visual and symbolic/mathematical modes is a protracted process" (p. 2744), just as proficiency is in written and oral language. Weinburgh et al. (2018) also pointed out that the manual-technical mode develops over time with multiple engagements. More recently, researchers have expanded Lemke's four-mode interpretation by positing other forms of communication (e.g., gestures) (Bezemer & Kress, 2016; Kang & Tversky, 2016).

The notion of multimodality positioned language is a tool for participating in communities of practice (Wenger, 1999). However, this tool is not equally accessible to all students. Additional scaffolds are needed for EMLs to fully participate in these communities. Woolfolk (2014) described scaffolds as tools that allow "teachers and students (to) make meaningful connections between what the teacher knows and what the students know and need in order to help the student learn more" (p. 393). For example, when a new concept is introduced, the teacher might provide students with some information so that the students can focus on a specific part. That support would gradually be reduced as students become more proficient.

The linguistic demands of science present challenges to EMLs in understanding text, communicating ideas, and presenting written responses (Bunch, 2013; Echevarria et al., 2011; Lee, 2005). These challenges vary given the linguistic and cultural diversity among EMLs (Allexsaht-Snider et al., 2017; Freeman & Freeman, 2009). Thus, scaffolding language and science content can help with student success. For EMLs, capitalizing on the multimodal communication patterns in the science classroom increases their opportunity to access information and construct meaning (Hand et al., 2016; Weinburgh et al., 2019).

A growing body of research indicated that when EMLs engage in context-rich, student-active science, both conceptual understanding and language competencies result (Lee, 2005; Lee et al., 2005; Wilmes & Siry, 2018). The use of observable events and/or manipulatives helps to reduce the cognitive load associated with science. In addition, allowing students to use language that is familiar can facilitate entry into the science experience (Brown, 2011; Brown et al., 2017).

Journaling

The process of writing allows for an engagement in "intensive meaning-making related to the larger process of making meaning as we experience ourselves in the world" (Yagelski, 2009, p. 13). It has been argued that writing science is not only an essential product of science literacy, but it is also an opportunity to attain science literacy (Hand et al., 2001). Journaling in science is considered an important component of learning to use language, as writing promotes the development of scientific vocabulary, grammar, spelling, punctuation, argument construction, and technical writing (Hand et al., 2001). For EMLs, writing can be especially constructive for vocabulary development since writing takes more time than talking and students can experiment with new words turning *passive* vocabulary into *active* vocabulary (Dikilitaş & Bush, 2014). Several studies documented the power of science notebooks for verifying students' thoughts, ideas, and investigations (Huerta et al., 2016; Varelas et al., 2012). Wu et al. (2019) explicitly investigated Lemke's notion of hybrid language to demonstrate knowledge of science found in journals. Recently, journals have been deemed semiotic and social spaces, and not as mere products, where students construct ideas based on diverse resources (Wilmes & Siry, 2020).

In addition, journals provide a space for communication through mathematical computation and expressions. Lemke (2003) pointed out that "the history of mathematical speaking and writing is a history of the gradual extension of the semantic reach of natural language into new domains of meaning" (p. 217). Discrete (typological) meanings are found in the natural language domain while continuous (topological) meanings are found in the mathematical domain. Mathematical expressions have the power to establish meaning (Moschkovich, 2010) and inclusion of these expressions in journals can extend the student's concept of communication. Using mathematical symbols and mathematical syntax during writing appears to increase overall mathematical literacy (Hillman, 2014). Lemke (1990) underscored that "learning science entailed learning how to communicate in the language of science and act as a member of the scientific community" (p. 1).

Methodology

Our research is grounded in an interpretive/constructivist paradigm (Guba & Lincoln, 1994). Within this paradigm, we investigated the social phenomenon of language used by EMLs to communicate practice and product of science. We, like Shah and Al-Bargi (2013), entered the research with the assumption that meaning-making is an act of interpretation, language derives its meaning from context and from the relationship of words to one another, and realities exist in the system of numerous and intangible mental constructions. Thus, our epistemological stance recognizes the multiple assemblies of knowledge. Our ontological stance considers the scientific canon while holding to the subjectivity of reality. Our axiological stance questions the ethical issue of research by recognizing that we bring biases into the research. For this study, we define multimodal discursive resources as the semiotic practices that are expressed through writing, mathematical expression, visual representations, or manual-technical operations.

Context

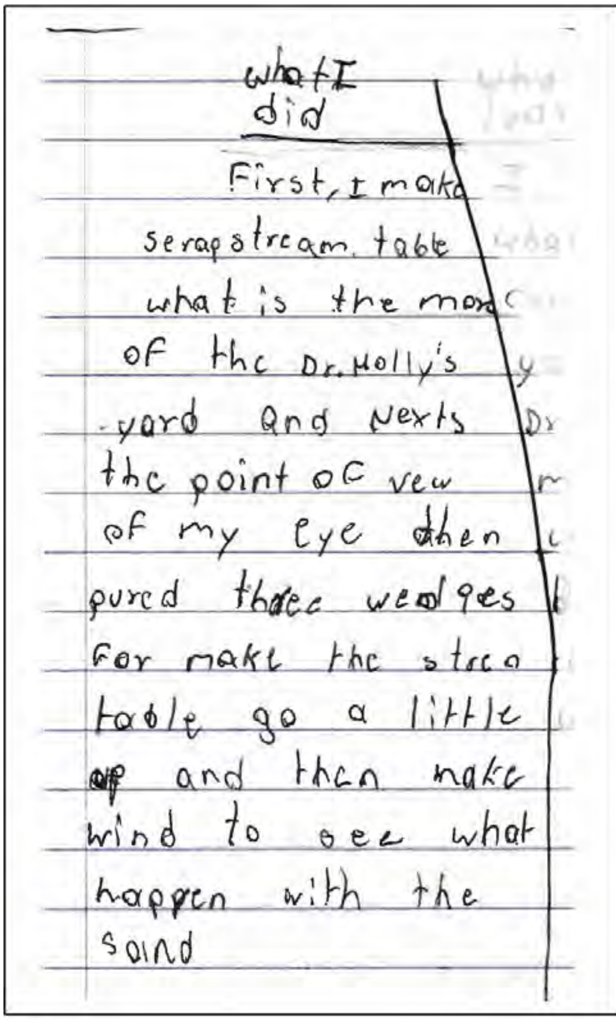
A southwestern university and a local school district collaborated for 12 years to provide a summer experience to newcomers for whom English was an emerging language. The experience was conducted at the university for 16 days in June and was taught by three college professors and two district teachers (see Silva et al., 2008 for details). The philosophical stance for the program centered on the integration of mathematics, science, and language (MSL). The underlying decision for the science topic had more to do with providing a transdisciplinary understanding of investigations (NGSS practices) and the engagement in multimodal communication than with the specific content.

Fostering Multimodal

To avoid lexical and grammatical features from becoming barriers that "mask the depth of students' science understandings" (Wilmes & Siry, 2020, p. 1000), the instructors participating in the summer experience invited students to focus on meaning-making and communication (see Figure 1 for examples).

Figure 1

Examples of Student's Original Entries and Re-written Entry Showing Conventional Writing



What I
did

First, I make
serap [set up] stream table
what is the **more** [model]
of the Dr. Molly's
yard and nexts
the point of **vew** [view]
of my eye then
pured [poured] three wedges
for make the **strea** [stream]
table go a little
up and then make
wind to see what
happen with the
saind [sand]

Note. Misspelled words are in bold. The text in brackets indicates the correct spelling of the words.

"Rather than privileging the language of schooling over other forms of language, the MSL team emphasized language as a tool for communicating within and across contexts and with and between various audiences" (Griffith et al., 2014, p. 342). Viewing language as an epistemic tool (Hand, 2017), they believed that increased linguistic sophistication is the result of scaffolded opportunities for EMLs to engage in conceptual activity that requires specific uses of language (Heritage et al., 2015).

Mathematics as a communication tool (NGSS Lead States, 2013) provides students with the ability to be more descriptive and precise. This aligns with Klassen's (2006) suggestion of a context in which students are emotionally involved and are motivated by seeking solutions or answers to real problems. Visuals, produced for and by the students, were used to provide alternative ways of meaning-making and of communicating understanding. In addition, the philosophy emphasized the importance of engaging with natural material as events by which the mode of manual-technical operations could be the focus. To this end, students were provided with reoccurring opportunities to manipulate scientific materials. Throughout the program, the students engaged in language-intensive instruction targeted at science communication as part of inquiry-based instruction (Lemmi et al., 2019; NGSS Lead States, 2013).

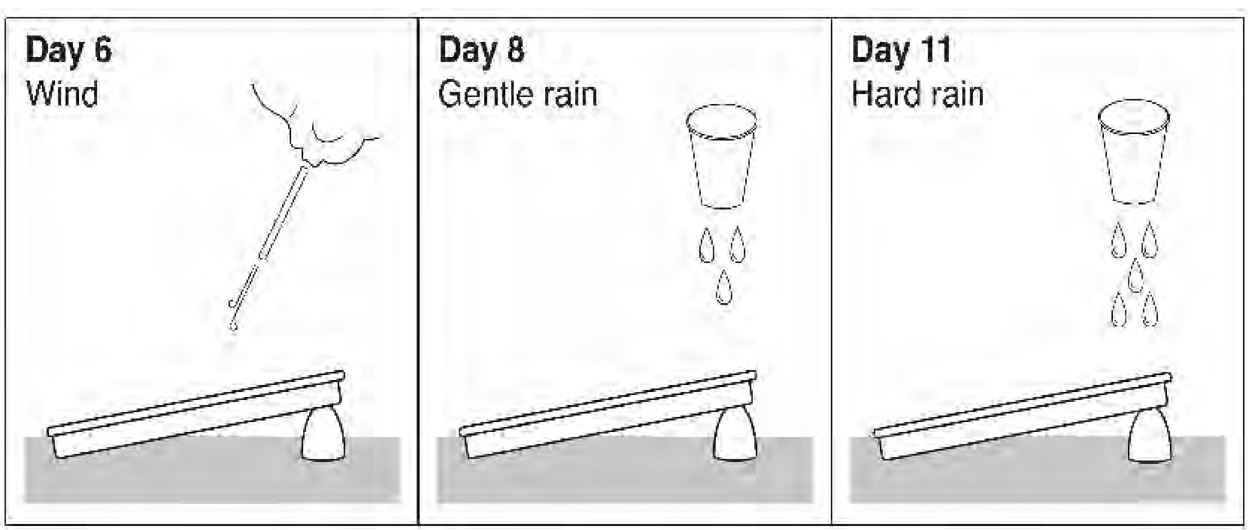
Erosion Unit

The students in this study participated in a unit on erosion. The science and mathematics content were grade level appropriate as they were aligned with the state's science and mathematics standards. Students used dynamic models to investigate the results of changing only one variable at a time (i.e., wind, gentle rain, hard rain) as they developed a concept of erosion as an earth process. Students kept a journal and were encouraged to record their investigations in words, symbols, and visuals. The journal served as a space for the students to document each event of the investigation through drawings, tables, and other notations that they felt were important.

On Day 3, students were given a description of Dr. M's yard—a hill that sloped to the road, grass removed during landscaping, very sandy soil—and were asked to decide how the class could study the yard. In teams of four, students developed a plan for a model of the yard and shared it with the class. Consensus resulted in using a prefabricated stream-table and a prescribed amount of sand to scale the model to the dimensions of the hill. On Day 6, students were presented with a question: *What will happen to Dr. M's yard if it is a very windy day, as forecasted in the local weather report*? The variable of 'wind' was manipulated, data collected, and information recorded in the journals. Later in the program (Day 8 and Day 11), students were asked: *What will happen to Dr. M's yard if there is gentle rain and hard rain* (see Figure 2)? With each investigation, one variable was manipulated, and the results recorded.

Figure 2

Diagram of the Model of Dr. M's Yard and Variables Manipulated by Day



The program alternated between days of science and days of mathematics with language always at the forefront. During the mathematics sessions, students spent a significant amount of time discussing the importance of mathematics communication, and its use in the mathematics classroom, other content areas (especially science), and real-world settings. Thus, mathematical content was systematically selected to support the science investigations and to communicate the findings (NGSS Lead States, 2013).

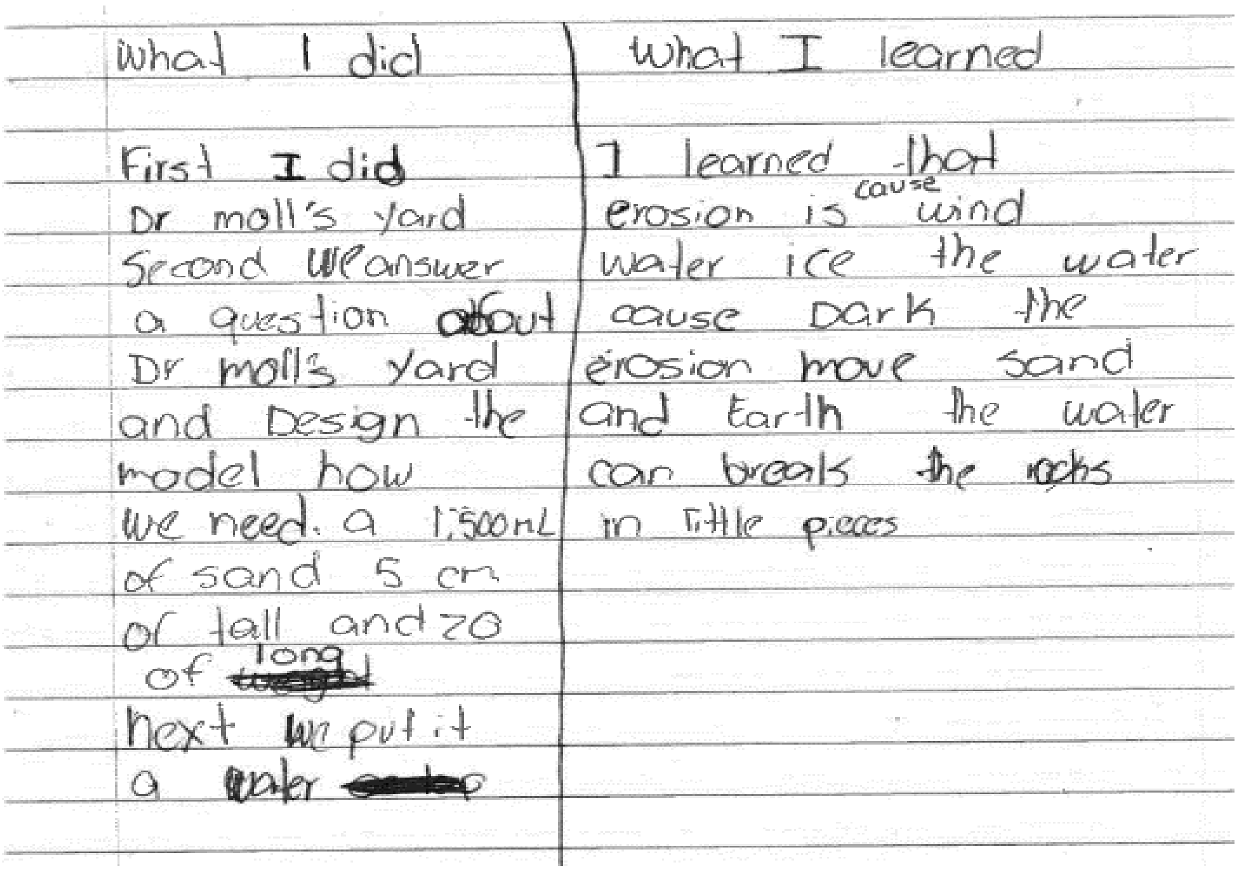
Similarly, students engaged in discussions and activities comparing features and usage of informal and academic language in the science classroom. Instruction included scaffolds to support the development of science-based discourse. For example, EMLs were introduced to, and supported in using, relevant general and specialized vocabulary within the context of the investigations. As they engaged in related reading and writing activities, they examined features associated with science text (e.g., signal words, text features, common genres). The science topic varied each summer (i.e., erosion, wind turbines, crime scene investigation) but the general format was constant.

What I Did/What I Learned Writing Prompt

A ubiquitous artifact used to document the process and product of science investigation is the lab report. The typical format requires students to state the problem/question, outline the procedures (maybe list equipment), explain the results, and justify a conclusion. Rather than use some more elaborate reporting template (e.g., Science Writing Heuristic; Keys et al., 1999), we used the *What I Did/What I Learned* (WID/WIL) writing prompt. This organizer uses the familiar T-chart form to invite students to write a summary of the classroom activities (i.e., what I did) on the left and their new knowledge (i.e., what I learned) on the right (see Figure 3).

Figure 3

Page from Student Journal Showing What I Did and What I Learned Displayed in the T-chart.



What I did	What I learned
First I did	I learned that
Dr moll's yard	erosion is cause wind
Second We answer	water ice the water
a question about	cause Dark the
Dr moll's yard	erosion move sand
and Design the	and Earth the water
model how	can breaks the rocks
we need. a 1,500mL	in little pieces
of sand 5 cm	
of tall and 20	
of long	
next we put it	
a water	

For EMLs, this writing prompt provided a scaffold not only for expressing science understanding but also for thinking about the type of language (genre) needed for communicating certain tasks. Researchers (Hand et al., 2001; Klein, 2004; Townsend, 2015) have provided evidence that organized writing may assist students in thinking critically and constructing new knowledge by exploring the connection between ideas. Also, writing may help transform undeveloped ideas into more coherent and structured forms.

The *What I Did* section of the T-chart represents a summative writing task. In general, summative writing is considered a basic task since it is grounded on memory and recall (Lamb et al., 2019). However, and especially for EMLs, summative writing that details scientific activities presents many challenges (Beck et al., 2013). Writing summaries involve complex cognitive processes like choosing salient concepts, removing details, and connecting ideas (Gelati et al., 2014).

The *What I Learned* section of the T-chart is regarded as a reflective writing task since reflection deals with the reorganization of the knowledge one already has in order to achieve an outcome (Moon, 2006; Rodgers, 2002). An advantage of introducing the reflection task with the "what I learned" prompt, is that instructors avoid confusing students about what is expected.

Participants and Data Collection

Eighteen seventh grade students' journals were used for this study. School A participants (*N* = 8; six males and two females) were enrolled in the district's newcomer program and received English as Second Language (ESL) instruction, as well as content and elective classes in English. School B participants (*N* =10; three males and seven females) were enrolled in a bilingual school (Spanish and English), where they also studied additional languages. All students spoke a language other than English at home and were identified as *English learners* using the state-approved English language testing criteria (Texas Education Agency, n.d.). The program's objective was to provide continued development in English as well as academic content. Data consisted of 46 written WID/WIL entries from Day 6, 8, and 11. We selected the WID/WIL entries as they captured the students' ability to recount practice as well as describe learning and have been used for assessing students' knowledge after a single lesson (Hartweg et al., 2017; Pearce et al., 2020). Overall, this writing prompt provided a space for students to display their 'take-away' message from the activities conducted in the classroom.

Data Interpretation

Template Development

We examined the journals through template analysis (King & Brooks, 2017) for evidence of multimodal discourse resources. The template was developed in steps. First, we listed the *categories* based on Lemke's (2004) four modes of hybrid language of science (natural language, mathematical expression, visual representations, manual-technical operations) and added the category of 'setting'. Because our theoretical framework included situated learning, the addition of where the students located their understanding of the scientific concepts seemed necessary.

Second, we subdivided each category into *codes* (King & Brooks, 2017). See Table 2 for information on the categories and codes. The codes were grounding in the literature we found within language (Schleppegrell, 2004), the mathematics standards (National Council of Teachers of Mathematics, 2014), and manual-technical operations (Weinburgh et al., 2019). After applying the template to the journals, we eliminated visual representation because no graphics were found in the WID/WIL part of the student journals.

Table 2

Categories and Codes

Natural Language		Manual-Technical Operations		Mathematical Expressions		Setting	
academic word	[L:aca]	measuring	[MT:mea]	measurement	[M:mea]	general	[S:gen]
signal word	[L:sig]	tool	[MT:too]	numbers	[M:num]	specific	[S:spe]
learned about	[L:abo]	set up	[MT:set]	topology	[M:top]		
cause & effect	[L:cau]	transfer	[MT:fer]	typology	[M:typ]		
comparison	[L:com]	transport	[MT:port]				
example	[L:exa]						
explanation	[L:exp]						
observation	[L:obs]						
procedure	[L:pro]						
synthesis	[L:syn]						
learned that	[L:tha]						

Coding

The codes were first applied to journals not included in the data set. The research team discussed discrepancies and rules were developed for each of the codes. When coding collaboratively, researchers have suggested interpretive convergence or inter-coder alignment (Guest & MacQueen, 2008). However, Saldaña (2009) states that there is no standard agreement of the percentage of overlap (but suggest 85%) and that consensus in qualitative research is often the goal. We selected to use consensus after intensive discussions.

Data Analysis

Other researchers have noted that most of the multimodal communication of the science classroom is embedded within oral or written text (Gunel et al., 2016; Lemke, 1998). Thus, examining the written WID/WIL entries in the student journal still allowed for a multimodal analysis. Using the template, the team coded all 46 entries. This provided a way to look for patterns and relationships within and across 'doing' and 'learning'. These were then used to develop explanations of how EMLs used multimodal discursive resource.

Trustworthiness

Although only one data source (i.e., students' journal entries of WID/WIL) was used, trustworthiness was increased by the application of the pyramid approach. Each researcher coded individually and then came together as an insider/outsider team. The insider involved one of the professors and the outsider was a graduate student who had not participated in the summer program. Simple mismatches in coding were corrected (e.g., missing the coding of a word or utterance). More substantial discrepancies (e.g., using a different code) were reconciled. If a team continued to disagree, the whole research team was consulted.

Findings

In answering the research question (in what ways do multimodal discursive resources differ as EMLs describe doing an investigation (practice) and learning (content) in response to a writing prompt?), we organize the findings by multimodal discursive resources (natural language [writing], mathematical expression, manual-technical operations) and setting; first discussing practice (as found in the WID) and then content (as found in WIL). Students' entries selected as examples are in italics and followed by the students' initials, the prompt, and day. The codes assigned are in brackets (see Table 2 for a list of categories and codes). Strikethroughs show texts that students wrote and then crossed out.

Writing

Two codes were prevalent in the analysis of the WIDs. Students' entries were organized around a series of step-by-step actions (*procedures*) taken to accomplish the task at hand. In their writing, the students used *signal words* (e.g., first, second, next) when introducing the steps. For example, one student wrote:

> *Next*[L:sig] *we used a cup with a hole in the bottom and we fill it with water* [L:pro].
> *Then*[L:sig] *we went for our water and put it on our cloud but first we set_up the ruler and the cloud* [L:pro].
> *Finally*[L:sig] *we put more water for trial_2 and it made a big river, holes, alluvial_fan, gullys and etc.* [L:pro]. GAI (WID - Day 11)

Another student wrote:

> *First*[L:sig] *I did a talk about erosion* [L:pro].
> *Den*[L:sig] *I ~~done~~ do tolk what happen with the yard, if get a gentle rain* BAR9 (WID - Day 9)

While a third stated:

> *First*[L:sig] *I sat up a modl* [L:pro]. RD(WID-Day 9)

Yet another EML wrote:

> *First[L:sig], I make serap stream-table[L:aca] what is the more[L:aca] of the dr Molly's yard and nexts[L:sig] the point of vew of my eye then[L:sig] pured three-wedges for make the strea-table[L:aca] go a little up and than[L:sig] make wind to see what happen with the saind [L:pro].* BAR(WID-Day 6)

In the WIL entries, *cause/effect* and *learned that* were coded most frequently. Unlike the procedural *signal words* used in WID, cause/effect *signal words* (e.g., if, can cause) were more prevalent in the WIL. Students often framed their initial response to this prompt with the expression 'I learned that…'. Further in-depth analysis revealed that when students used 'that,' the text presented more complex writings that linked at least two other argumentation features (i.e., *cause/effect*, *comparison*, *explanation*, *observation*, and *synthesis*) in their response. For example, in the following entry the student linked an explanation and a synthesis:

> *I learned that* [L:tha] *theres 3 things that can cause erosion and they are water, icea and wind all of them am cause erosion the wather by geting inside rocks then when it turns into ice it expans and cracks the rock the*

water hits the rocks then the rocks dissolve little_by_little wind can cause [L:cau] *sand_duns by blowing it a sand_dum is a big hill made of sand* [L:exp] [L:syn]. MUJ (WIL - Day 8)

In contrast, when students used "about" most entries only incorporated one text feature, mainly *synthesis*.

after we learned mor about [L:abo] *the eresia how many types of erosion have What is the cause* [L:syn]. FHB (WIL - Day 8)

However, occasionally they used *cause/effect* as a condition to reiterate an *observation*:

I learned about [L:abo] *erosion because when* [L:cau] *at first trial the gentle rain made a small hole* [L:obs]. LJ (WIL - Day 8)

In both, WID and WIL entries, students extensively incorporated academic terms that had been introduced by the instructors as part of the inquiry process. Some of these were specialized academic words (e.g., alluvial fan). The students also incorporated common, non-technical terms contextualized for scientific investigations (e.g., trial) and polysemous words (e.g., record, table) as seen in the journal of these two students:

After that we filled up a container with 500_ml of water ~~to represeant the cloud filled with water~~ than we set the container with a hole to represent the gentle_rain[L:aca]. *And poured the water to the container to see what happened. finally we record*[L:aca] *the reselts in a table*[L:aca]. SAD (WID - Day 8).

I learned that in first_trial[L:aca] *sum rain got in street and I also learned in trial_2*[L:aca] *alout of water got in street, I observed the water made a big gully and a big alluvial_Streame*[L:aca]. VIR (WIL - Day 11)

Mathematical Expressions

In the WID section, while describing the procedures for setting-up of the model and the parameters used to test the variables, students' entries paralleled the instructions for the science experiments. *Topology* was frequently found in the WID with the corresponding code of *measurement*.

*Thin measured the straw to fou*r[M:num] 4[M:num] *cetimeter*[M:mea][M:top]. DC (WID – Day 6)

Because We lower the higth[M:typ] *to 10_cm*[M:num][M:top][M:mea] *instead of 20_cm*[M:num][M:top][M:mea]. DC (WID – Day 6)

Even though *topology* was frequently noted, *typology* was the most common mathematical code used in WID. This included writing that implied mathematical descriptions.

second, we started measuring the width[M:typ] *of the stream to find the middle*[M:typ]. GA (WID-Day 6)

Next ~~we~~ I had to measure everything[M:typ] *so we knowed how and from were to start.* VR (WID – Day 11)

The *numerical* code was used on numbers and words that expressed value. Therefore, these examples could be linked directly with *measurement*. Interestingly, *numerical* was also assigned when students were communicating quantities or sequences. Below is an example that shows how *numerical* was not linked with *measurement*.

Finally, *when we blow the first_time*[M:num] *the sand want to the end of the stream_table and is made a hole the 2*[M:num] *try was a smaler*[M:typ] *hole at the third*[M:num] *try my other partner made the first*[M:num] *hole deeper*[M:typ]. GA (WID – Day 6)

For WIL, the most common code was *typology*. The code for *numerical* was found frequently, but it was a small fraction of those noted in the WID section. The numbers used in this case were not to show measurement, but rather as a signifier for number of trials or variables.

I learned about erosion because when at first_trial[M:num] *the gentle_rain* [M:typ][M:mea] *made a small*[M:typ] *hole.* LJ (WIL – Day 8)

I learned that theres 3[M:num] *things that can cause erosion and they are water, icea and wind all*[M:typ] *of them am cause erosion...* MJ (WIL – Day 8)

We learned about the hard_rain[M:typ][M:mea] *is, the Dr M's yard the rain are more_mstrong*[M:typ][M:mea] *because the note are more_big*[M:typ][M:mea] ~~*strong be*~~ *and learnes about the variables.* FHB (WIL – Day 11)

Manual Technical Operations

In the WID section, students often began by describing the *set-up* of the investigation. Many continued with more detail about the process.

First, we started building[MT:set] *Ms. Dolly's yard.* DC (WID – Day 6)

The second most used code was *transporting* (e.g., using equipment such as beakers or straw to move a liquid, solid, or gas) as students moved sand, air, or water as part of the investigation. This was followed closely by *measurement* (e.g., ruler) and *transfe*r (e.g., energy related), both of which were only used in WID. There were only two incidents of the code *tool* (e.g., safety items).

When describing the rain investigation, EMLs used more of the transporting code as they measured the correct amount of water and then moved it from the original beaker to the 'cloud' (i.e., a plastic cup with one or more holds for various degrees of rainfall).

Thin measured[MT:mea] *the straw to 4 centimeter.* DC (WID – Day 6)

After that we start blowing[MT:port] *for 5 seconds with a straw.* SAD (WID – Day 6)

I blowed[MT:port] *on it, and also I holde*[MT:set] *the straw and the ruler.* ROA (WID – Day 6)

Manual-technical codes were found less often in the WIL as students did not appear to realize that they had developed a new skill such as measuring mass with a triple-beam balance or measuring volume with a graduated cylinder. Rather, they indicated that they learned some new content about erosion because they transported and used wind or water in the model. This was often signaled by stating that 'when' an action was taken, something happened.

I learned that you can have a different effect whenever you blow[MT:port] *it from different angles.* EJ (WIL – Day 6)

For example, when we blow[MT:port] *the sand with the straw it make a hole in the sand that changed the size of the hill and form.* MUJ (WIL – Day 6)

Setting

In the WID section, setting often referred directly to the situation being examined in the classroom. The code *specific* from the setting category was often found when describing 'doing' within the context of Dr. M's yard. As students described the procedures, they focused directly on the investigation as it was conducted in class.

Finally we draw a illustration and write what was happening with the sand [S:spe]. GAE (WID – Day 11)

When the student broadly discussed the setting by going beyond the actual in-class investigation, the code *general* was used. This code was exclusively assigned in the WIL. In the following example, the student concluded the WIL entry by making a generalization as to the use of models in the process of conducting investigations. This is the only instance of a student stating the usefulness and the dynamic nature of the model:

The final_thing I learnd is that we can conduct other investigations with the same model [S:gen]. SAD (WIL – Day 6)

and can take the sand or what you have in your yard to the street [S:gen]. GAE (WIL – Day 6)

Discussion

Situated Meaning

The students wrote a WID/WIL entry after they tested the effect of a natural event (i.e., wind, gentle rain, hard rain) on a dynamic model of Dr. M's yard. Thus, learning was situated not only within the 16-day summer school program, but also within the need to learn about the effects of each variable on the erosion using the model of the yard. With each trial, EMLs needed to communicate what they did (re-establish the model and test for each variable) and what they learned (content and skills) as they engaged in authentic practical situations (Klassen, 2006). These social interactions within the authentic investigation provided students with a context in which to learn language, mathematics, and science. Thus, in the context of situated learning and sociocultural language learning, students used language for making meaning rather than demonstrating grammatical proficiency.

For the EMLs participating in this unit on erosion, the multimodal language is a way to communicate a particular socially situated scientific investigation. The situated meanings constructed (and later communicated) by the students are rooted in the embodied experiences of creating the model and manipulating one variable with each investigation (manual-technical operations). Thus, the language and science knowledge, as predicted by the intersection of situated and sociocultural theories, developed in response to particular practice and topic.

Multimodal Communication for Doing and Learning

The WID/WIL entries showed that EMLs used the appropriate multimodal communication resources needed to express the physical act of 'doing' and the cognitive act of 'learning'. In responding to the WID/WIL tasks, written entries presented general features of summative and reflective text respectively. Accordingly, students integrated mathematical expressions as both typology and topology. They described their use of manual-technical operations through their writings by recounting their actions.

The WID triggers a summative writing task. In general, summative writing is considered a basic task since it is grounded on memory and recall (Lamb et al., 2019). Writing summaries involves complex cognitive processes like choosing salient concepts, removing details, and connecting ideas (Gelati et al., 2014). However, and especially for EMLs, summative writing that details scientific activities presents many challenges (Tang & Rappa, 2021). Therefore, the students in this study used the prompt to focus their attention on practice. Not only did they have to recount procedures but also use academic discourse that was appropriate.

As suggested by Scheppegrell (2004), the summative WID entries reflected features of *procedure* and *procedural recount* genres typically used to summarize the series of steps they took in setting up their investigations. Prevalent in the WID entries was the use of signal words (e.g., first, next, finally) to organize a sequence of instructions to be followed when assembling tools and materials needed for a procedure. In contract, the WIL is regarded as a reflective writing task since reflection entails reorganization of the knowledge one already has in order to achieve an outcome (Moon, 2006; Rodgers, 2002). An advantage of introducing the reflection task with the "what I learned" prompt, is that instructors avoid confusing students about what is expected from them. The students sometimes identified the content (*learned about*) with little elaboration as to specific conceptual understandings or making connections between events. However, more students were able to use this prompt to write complex responses that included causal relationships, comparisons, explanations, and synthesis.

As emerging users of English, EMLs were not only learning new words, but also learning the function of these words. Each word was, therefore, important in expressing new technical terms. The students' writing also reflected their developing understanding of the expository language used in the science classroom to construct meaning. This helped address Tang and Rappa's (2021) concern that teachers often do not help students understand "the hidden conventions in science that govern the language used to produce and communicate scientific knowledge (p. 1312).

Noticeable across the writings are the typical grammatical and vocabulary errors (e.g., subject/verb agreement, spelling, lack of article) made in the process of learning English. These mistakes, accepted by the instructors/researchers, allowed for *linguistic flexibility*. When the reader of the journal moves past these mistakes the students' intended meaning emerges. The entries indicate that students were appropriating the discourse practices needed to authentically communicate in the science classroom. Moreover, this linguistic flexibility aligns with the teaching goal of helping students become comfortable in talking and writing about their experiences within the learning environment (Brown et al., 2017; Krashen, 1988).

Although we anticipated the incorporation of visuals representations, no student used drawings to complete the WID/WIL tasks. This may be explained by the nature of the WID-WIL task and the records of the investigations found prior to the WID-WIL entry within the journal. The students had detailed drawings of the model for each variable manipulated. These drawings represented different perspectives (e.g., bird's eye view and worm's eye view) of the event before and after variable manipulation and included measurements. Other journal entries also contained a number of tables used to record results after each trial. The extended use of visual representations might be one reason why students chose not to integrate this modality in their responses. Another possible explanation is the format of the WID/WIL, a T-chart dividing the journal page into two slim columns, discouraged them from including visual representations.

Lemke (2002) argued that the modality of natural language is not precise enough to represent the nuances of measurement and other mathematical phenomena. Thus, humans find it necessary to extend natural language from typological (qualitative meaning) to include topological (quantitative meaning). In their WID, the EMLs used numbers to express meanings more precisely regarding how to set-up the investigation. They recognized the need to use the modality of mathematical representation to communicate the number of trials, the length and height of the yard, placement of the straw for wind, and amount of water for gentle and hard rain.

Not surprising was the more general mathematical language used for WIL entries. Students shifted from using *topology*, a feature that can be considered as part of "cookbook" laboratories, to using *typology* almost exclusively. Students were asked to observe and give descriptive accounts rather than to measure the exact changes in the model after each trial. Therefore, students included general descriptors (e.g., "made a small hole") instead of providing precise information to communicate what they learned. Consequently, students did not view mathematics as a central part of supporting scientific findings (NGSS Lead States, 2013). Rather, the students used numerical values to communicate the procedural aspects of the investigation.

While the modality of manual-technical operations could only be measured through the students' reflections on their awareness of this modality, they integrated this understanding in the WID, but failed to reflect on the process of learning these manual-technical operations in WIL. While new equipment (e.g., triple-beam balance and digital scales) and new skills such as setting up a model or manipulating the independent variable were introduced to the students during the investigation, they did not write in the WIL about their engagement with these new tools. The discourse of science learning occurs in both factual knowledge and skill-related practices. Skill learning is certainly a part of the science curriculum but, in this case, the students did not acknowledge the learning of science practices. A possible explanation may be that these students are used to "normal science education" (Klassen, 2006, p. 2) in the form of cookbook laboratories and acquiring 'factual' knowledge.

Setting/Context

In order to test a variable, the students had to re-construct the model of the yard with each investigation. Rather than giving details of this procedure, they simply stated that they 'set up' for the investigation. As with providing visuals, describing the model set-up may have seemed redundant and not relevant as seen in the general statements, "*I measured everything so we know how and were to start"* and *"I make serap stream-table what is the more of the dr. Molly's yard."* In addition, students were more apt to write typological explanations to describe their procedural recounts. Students extended their description by including more precise mathematical expressions. Therefore, a relationship can be observed between manual-technical and mathematics. The students provided a specific measurement (e.g., 4 cm) when explaining the manual-technical operations of the experiment.

The context helped dictate the student responses with regard to the setting. The initial task of designing the model of Dr. M's yard to be tested set the practical, social, and affective context (Klassen, 2006). Each investigation continued stressing these contexts as they were framed using Dr. M's yard as the research site. However, in the WIL, the prevalence of references specific to the model of Dr. M's yard and the rare use of readings and personal knowledge to generalize what they had learned from the class results, indicates that EMLs struggled connecting the classroom investigation to a general idea.

Conclusions and Implications

Sociocultural theory provided researchers with the expectation that students would construct knowledge using social cues and science norms within the class. During the summer program, many nuanced norms of scientific inquiry were utilized with each investigation. The reiteration of these norms was an important pedagogical practice in helping students become comfortable conducting investigations. Situated learning theory, emphasizing the role of context, helped explain the students' focus on Dr. M's yard as they were given a real-world problem and were asked to create a dynamic model to test the effect of three different variables allowing them to experience "an infusion of scientific culture" (Meyer & Crawford, 2015, p. 631). Scaffolding helped the EMLs not only develop multimodal language, but also develop a way to communicate their growing understanding of scientific investigations and erosion. The linguistic flexibility found in the journals and supported by the researchers allowed the students to express their science knowledge.

The following implications for instructional practice and teacher education are based on what was found and was absent in the student texts. First, the students did not transfer their understanding of erosion as seen in the model to a more general context. This lack of generalization calls for teachers to help students move beyond the immediate context of the classroom activity. Considering the importance of deliberate and intentional planning around the NGSS practices, teachers need to scaffold students into the application of the concepts learned into new contexts.

Second, when teaching science, teachers may assume that practices and skills are learned, but sometimes neglect to identify the skill as a learning outcome. The lack of students communicating that they learned a skill or how to use equipment highlights that these students either did not see skills and practices as 'learning' or did not feel the need to discuss them. Areas that educators should explicitly emphasize are: (a) scientific models and modeling; (b) scientific practices and skills as learning objectives; (c) relationships between mathematics and science; and (d) mathematical thinking used to support the communication of scientific findings.

Third, the findings indicate that to scaffold the use of discursive resources needed for summative and reflective journal entries, the WID/WIL writing prompt is an effective tool. The T-chart explicitly separates the actions of scientific practice from the learning, thus addressing the limitations of the classical lab report. However, to make the WID task more demanding, educators should scaffold instruction so that students provide enough information that varied audiences can understand and follow their experiences (Lamb et al., 2019). As presented in previous research (Wilmes & Siry, 2020), context-rich activities that truly engage students help them improve their language and science concepts. Students should also be encouraged to start their WIL prompt responses by writing the phrase "I learned that". This phrase—different from using "I learned about"—serves to focus students on generating more complex responses.

Fourth, the lack of visual representation found in the data is worth noting and indicates that more explicit instruction should be included. Teachers should remind students that it is acceptable to include visual representations if these might serve to better communicate meaning within the WID/WIL. While these suggestions do not guarantee rich responses, we believe they can lead students to engage in substantive writing without including extensive instructions. We also stress that when using the WID/WIL writing prompt teachers attend to the students' intended meaning, rather than focusing on grammatical mistakes.

Limitations

The most important limitation of this study lies in the fact that three authors were teachers in the summer program. However, we mitigated potential bias and increased credibility by using an insider/outsider team approach for the analysis. In addition, the students were only engaged in the instructions for 16 days. Although this amounts to 80 hours, it does not allow for the extended time needed to become fully proficient in the multimodal discursive resources.

As a closing remark, we considered pertinent to mention that in the fall of 2017, after Hurricane Harvey hit the coast of Texas and a year after the summer program ended, Dr. M received a phone call from one of the teachers on behalf of her students. They were worried about her yard in the wake of Harvey. This anecdote substantiates Klassen's (2006) idea of affective context. It illustrates how students' strong emotional involvement in the summer program propelled them to raise their concerns about the vulnerability of Dr. M's yard long after they had participated in the summer experience.

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Callie Price (callieprice@outlook.com) is a Science Education Doctoral Student at Texas Christian University. She is also a Senior Instructor and Lab Coordinator at Tarleton State University. Her research interests are centered within disability studies, equitable-science, and universal design for learning.

Daniella Biffi (daniella.biffi@gmail.com) is an interdisciplinary conservation biologist & science education researcher.

Molly H. Weinburgh (m.weinburgh@tcu.edu) is the Andrew Chair of Mathematics & Science Education and Director of the Andrews Institute of Mathematics & Science Education at Texas Christian University. Her honors include the *Chancellor's Distinguished Achievement as a Creative Teachers and Scholar, Piper Professorship,* Fellow of the *American Association for the Advancement of Science,* and *2020 Award for Liftetime Outstanding Service to ASTE*. Her scholarship focuses on academic language acquisition and conceptual understanding in science by emerging multilingual students. She is the co-author of *Supporting Emergent Multilingual Students using the 5R Instructional Model: The Hybrid Language of Inquiry-based Science* (NSTA Press) and co-author on a chapter outlining the 5R Instructional Model in the *Handbook of Educational Theories* (IAP, 2013). She is also co-editor of *Science Teacher Preparation in Content-Based Second Language Acquisition* and *Becoming and Being: Women's Experience in Leadership in K-16 Science Education Communities.*

Kathy Horak Smith (ksmith@tarleton.edu) is the Department Head and Professor of Mathematics at Tarleton State University. She has taught in the private and public-school sectors, as well as the university level for over 35 years. She currently teaches Mathematics Education to pre-service and in-service teachers. Her scholarship focuses on academic language acquisition and conceptual understanding in mathematics and the integration of mathematics in science by emerging multilingual students. She is the co-author of *Supporting Emergent Multilingual Students using the 5R Instructional Model: The Hybrid Language of Inquiry-based Science* (NSTA Press).

Cecilia Silva (c.silva@tcu.edu) is a professor emerita at Texas Christian University. Her research focuses on bilingual education and is interested in the integration of content to promote literacy and conceptual development.

Monica Amyett (m.amyett@tcu.edu) served as a science and engineering teacher at the secondary level for over 15 years. She is currently an Instructional Specialist and leads secondary teachers in professional learning. Monica's research interests include investigations of instructional practice and the nature of student problem solving in the secondary science and engineering classroom.

Antonia Domino (a.domino@tcu.edu) is a practicing veterinarian and science education Ph.D. student at Texas Christian University. She has always enjoyed wearing her "teaching hat" in various capacities as a veterinarian, but it was during her experience of teaching and working with students during her residency that she decided to pursue more formal training in the field of education. Her research interests include veterinary professional identity development and clinical skills for teaching and learning.

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