

GROWING STUDENT LANGUAGE IN MATH CLASS

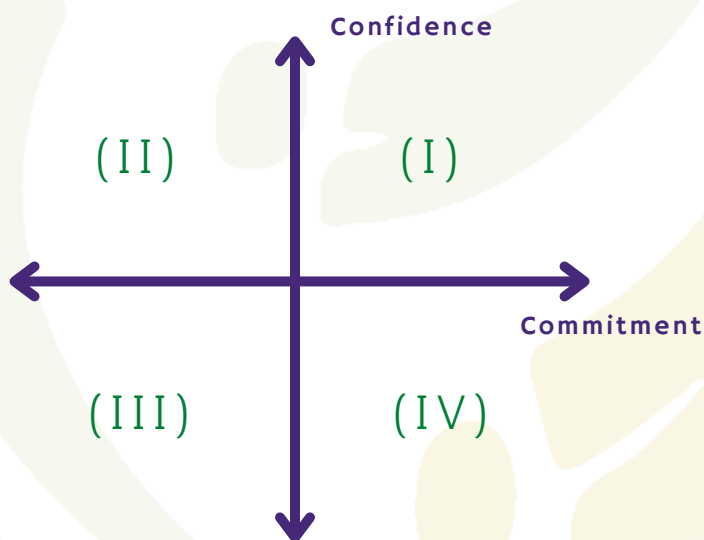
A HYPOTHESIS



Vinci Daro, PhD
ELP Director of STEM Learning
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OBSERVATIONS

I have been observing math teachers respond to expert guidance on how to support English language and academic language development since 2009. Over this time period, several patterns have become clear among teachers' responses. Many have been slowly stretching open spaces within their lessons, assignments, and assessments for students to communicate their reasoning, or have created classroom norms and grading systems meant to incentivize students to explain and justify answers, while others have resisted investing class time in language development. These patterns reflect variation along two major dimensions: sense of responsibility or commitment to supporting language development, and sense of self-efficacy or confidence in doing so. The coordinate plane below represents four general response patterns: (I) confident and committed ("I ask my students to explain all of their work, all of the time"); (II) confident but uncommitted ("I know how to use strategies to develop language, but they don't work for my students"); (III) not confident and uncommitted ("Teaching language is not my job as a math teacher"); (IV) committed but not confident ("I know I need to support language development, but I don't know how").



Based on these observed patterns, I invite math teachers, as well as fellow coaches, leaders, and curriculum and assessment developers, to better optimize our efforts by moving toward the center of these axes from wherever we stand. For the math educators most likely to be reading this resource, this may mean taking a few steps back along the commitment continuum: while it is our job to anticipate, plan for, design for, attend to, interpret, work with, and build on student language, it is not our responsibility to determine, insist upon, and judge what counts as correct or sufficient language use at every moment. Likewise, it may mean taking a few steps down the confidence scale: supporting student language development requires a skill set every math educator should be actively using, but adult strategies and tools must be taken as provisional and revisable in order to stay responsive to the brilliance and creativity of young people's ever-evolving means of expression. (The minute you think you have it all figured out, you are definitely missing something! (Dean 2021))

In what follows, I describe three processes that naturally occur but can be built more intentionally into mathematics instruction, curriculum, and assessment practice to grow student language. I hypothesize that doing so will help math educators stay more centered in our sense of responsibility and in our sense of efficacy, so that our work can be better optimized for students themselves.

THREE PROCESSES

The three processes that I hypothesize can be optimized for growing student language in math class are:

REVISION

INTERPRETATION OF PEER WRITING

INTERACTION

The hypothesis to be tested is that these processes, when optimized by math teachers for their students *and* for the content they are teaching at a given point in time, will generate the conditions for student language to grow as an integrated part of content learning. I propose that focusing on these three things will help teachers be more intentional about when, how, and how often to structure space for students to produce and explicitly attend to language.

ASSUMPTIONS

My hypothesis is based on the following assumptions about what language is for, and why language development is indeed within the scope of responsibility for math educators.

Because language is a primary means for thinking and learning, student language is rich fuel for content instruction: without student ideas, expressed in student language, the machinery of teaching does not move well. Content learning and language learning happen together,

Disciplinary language of mathematics includes rich non-verbal resources and actions, such as gesture, diagrams, graphs, sketches, and symbols. Math class can therefore be an especially language-rich context for learning.

Language diversity is a fact of contemporary life, inside and outside of school; this means diversity in languages spoken and diversity in dialect, style, and register. Multilingual students who are learning English as an additional language and monolingual English speakers who are learning mathematics as a disciplinary language have different needs, but are not different kinds of people: their uses of language are directed toward the same purposes.

Language is a means of building shared meaning and achieving mutual understanding. Keeping this purpose of language - reaching agreement about meaning - as a focus for learning does not come naturally to all mathematics educators. Playing with language is another important use of language.

Audience matters. Language is used to communicate to others, and who the 'others' are matters. Giving students experience communicating to a variety of audiences develops language more fully than positioning the teacher as the primary audience.

On the pages that follow are descriptions and examples of the three processes that I hypothesize will support math educators to optimize learning for student language development.



THE IMPORTANCE OF REVISION

FOR LANGUAGE & MATHEMATICS CONTENT LEARNING

Revision, in one form or another, is a normal process in school, and in life: in many ways, learning is revising. Students, however, don't always want to – or know how to – revise their language, especially in math class.

Students are often more receptive to language inputs when they know they will need to produce language themselves. Revision of written language is an especially reflective kind of language production: when students are asked to revise their written work, they are really being asked to reflect on what might make their writing more clear, more complete, and/or more convincing. When students are expected to revise their *mathematical* writing, they can also be prompted to reflect on what might make their writing more accurate or more precise.

This meta-cognitive and meta-linguistic awareness is critical for the development of disciplinary writing (e.g., mathematical explanations and justifications), and it is also critical to the more basic effort of building mutual understanding of what something is, means, or implies.

When students are expected to revise their written work, they are also likely to seek and use feedback to help them identify what needs to be

improved, why improvements are needed, and how to make the improvements. Feedback is a key process for optimizing revision in that it provides a response from an audience (e.g., a classmate, the teacher, or someone else) about whether or not an explanation or justification makes sense *to that audience*.

Another key tool for optimizing revision is providing students with direct access to materials with precise uses of relevant disciplinary language, in the form of written definitions and examples, e.g., an 'instructional resource guide' for each unit of study or project, to be used in the way that technical documents are referenced by STEM professionals. (Walker 2020) Having access to technical writing provides students with rich linguistic ingredients to work with as they refine both their internal understandings and each iteration of their output.

Finally, when students are engaged in the work of revision, they are activating and expanding the body of linguistic resources they are willing to 'try on' as they reach for ways to incorporate new words, phrases, and grammatical structures into their own oral and written output.

Revision can be optimized when students are:

- invited to clarify or revise their own ideas orally for the purpose of shared understanding
- asked to critique/improve the work of another student, real or fictitious
- expected to improve their own written explanations and justifications for a specific audience, based on feedback
- provided tools for self-assessment and peer-assessment

Routines that directly support students to revise:



Stronger & Clearer Each Time



Collect & Display



Critique, Correct, Clarify



THE IMPORTANCE OF INTERPRETATION OF PEER WRITING FOR LANGUAGE & MATHEMATICS CONTENT LEARNING

While 'making student thinking visible' is widely accepted as good instructional practice among mathematics educators, making student *writing* visible is not always emphasized as an aspect of this practice.

When students have access to peer writing (for young people, this includes pictures), they notice, and can reflect on, uses of language beyond their own current set of linguistic resources and practices. By reading and interpreting peer writing, students experience the value of expressing ideas in a variety of different ways, including different ways of playing with language to communicate meaning to different audiences.

Moreover, peer writing is often rich with connections to learning in other content areas, to experiences outside of school, and to personal interests. All of these connections support engagement and cultivate a sense of belonging, particularly for students who do not have ample

opportunities to see themselves' reflected in teaching staff or in curricular materials.

Variety in how students communicate about mathematical ideas is useful, and insistence on 'correct' mathematical language can constrain this variety. When peers' words and phrases are available during mathematical sense-making, students have a wider range of resources to refine both their own ideas and their own communication.

When students have access to peer language beyond moments of oral discussion and interaction, students benefit from processing others' words and phrases at their own pace. Reading other students' posts to a discussion board, for example, or looking at classmates' math journals or slides, or using a public graphic organizer to capture students' words and phrases, are all ways of making peer language accessible as a stabilized resource.

Interpretation of peer writing can be optimized when students are:

- provided time to read other students' written responses to questions
- expected to provide feedback on the work of another student
- asked to analyze, annotate, or explain peer work that includes writing
- invited to ask questions about peer writing in order to clarify meaning
- interpreting peer work displayed on posters or projected on the board
- circulating to look at each others' notebooks shared from their desks

Routines that support students to interpret peer writing:



Stronger & Clearer Each Time



Collect & Display



Critique, Correct, Clarify



Co-Craft Questions



Three Reads



Compare & Connect



THE IMPORTANCE OF INTERACTION

FOR LANGUAGE & MATHEMATICS CONTENT LEARNING

When students interact they are using language to build meaning together in real time. If we assume that the purpose of language is to be understood and to understand one another, interaction is the action of using language to reach common understanding with others.

The value of “academic conversations” is well-accepted among educators, including many mathematics educators, however the value of students using everyday language, Non-Standard English, and non-English during conversations in math class is less broadly appreciated. Instructional approaches that value ‘academic language’ over the variety of students’ social language during peer conversations unintentionally miss important opportunities for learning.

The ‘language of ideas’ – the language students use as they make sense of concepts and problems – is different from the ‘language of display’ – the language used when communicating to an external audience – and both are essential for academic learning. (Bunch & Martin 2020) The language of ideas includes whatever words, phrases,

grammatical structures, communicative styles, expressive tools, and language hybrids that are activated during students’ own sense-making processes. Moreover, sense-making across multiple ‘registers’ (Barwell 2018) is a highly productive and dynamic form of learning that can be supported by both structured and less-structured interaction.

By optimizing class time for a healthy balance of interaction – both structured and less-structured – students have opportunities to engage in the work of translating and developing their own understandings of mathematical ideas into the variety of linguistic forms at play in the room, including relevant disciplinary words, phrases, and representations. This work of active translation happens naturally and informally in language diverse contexts, and can also be intentionally supported by structured routines for interaction.

Key considerations for optimizing student interaction are the quality and design of tasks students are asked to work on together: are the problems discussion-worthy, and are their solutions explanation-worthy?

Interaction can be optimized when students are:

- working on a problem that can be solved in a variety of ways
- motivated (or incentivized) to understand each others' ideas
- able to easily begin – but not easily finish – solving a problem
- respected, willing to share provisional thinking, and feeling like they belong in the conversation

Routines that directly support students to interact productively:



Stronger & Clearer Each Time



Compare & Connect



Information Gap



Discussion Supports

A HYPOTHESIS TO TEST

Optimizing for language learning means being intentional about when, how, and how often students are asked to produce – and explicitly attend to – language. My hypothesis is that the naturally occurring processes of revision, interpreting peer writing, and interaction are to a student's language development like sunlight, water, and soil are to a plant's leaves: they grow best when there is an optimal range of duration and intensity of sunlight, an optimal dose and frequency of water, and a healthy balance of underground interactivity in the soil. While clearly essential to growth, too much sun can damage a plant's leaves, too much water can drown their roots or even wash them away, and too much of one nutrient versus another threatens the balance of interactions in the soil. Optimizing for growth requires sensing how much of each is needed.

Temperature is another key factor for the well-being of plants, and in this analogy temperature might be the feeling of a classroom: the range and rhythm of cool (serious) and warm (joyful) will vary by teacher, by school, by student community, and also by time of year and time of day.

Students have remarkable capacity to adapt to their conditions, within limits. While adults are always adapting to conditions as well, adults can do more to actively adjust the conditions for learning. By focusing on whether – and on how, and how often – revision, interpreting peer writing, and interaction are built into the conditions for learning, I contend that teachers will be better equipped to optimize their adjustments for student language development.

If you, or someone you know, decides to test any part of this hypothesis, please be in touch about what happens; I would love to hear from you, learn from your experience, and revise these ideas as needed.

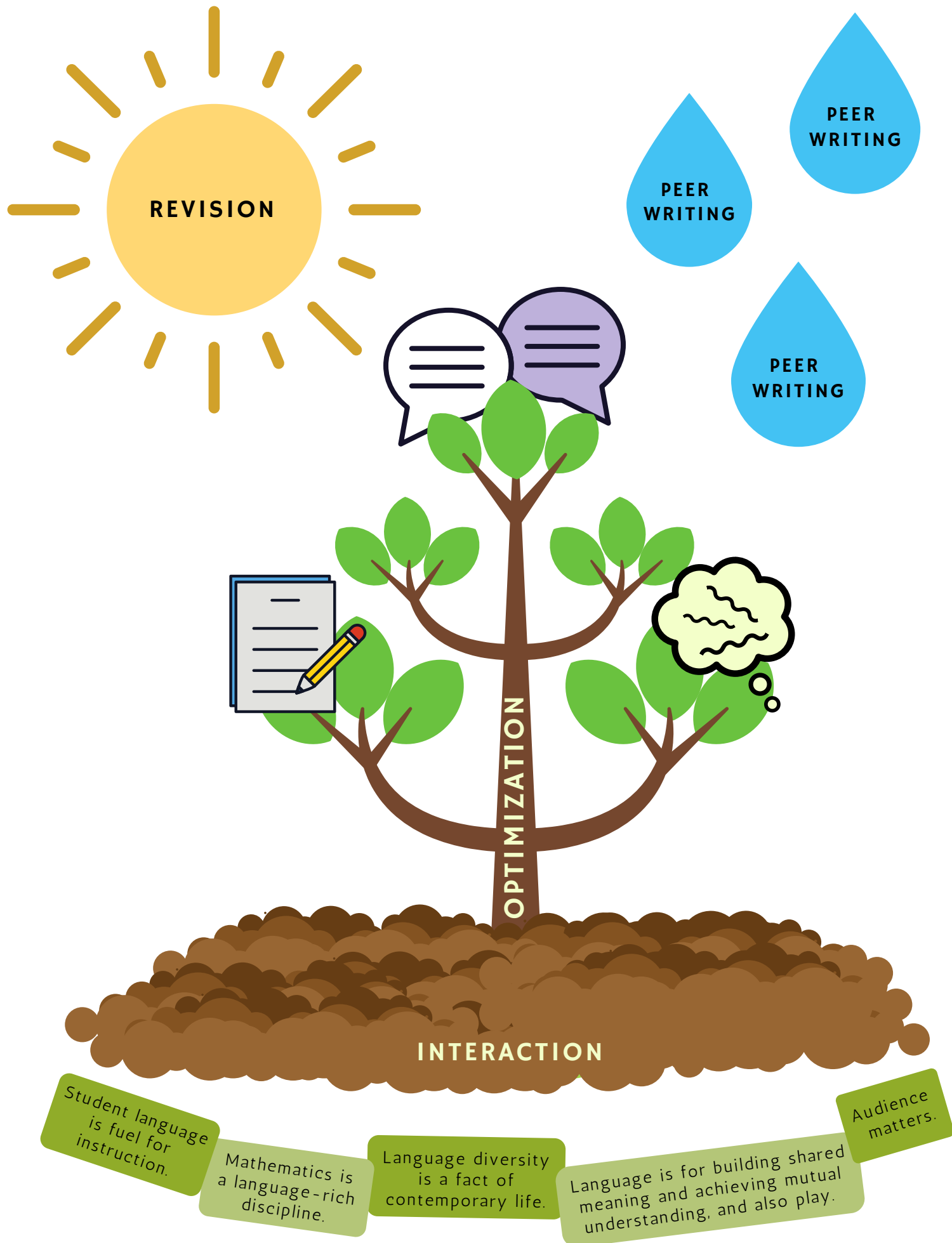
BACKGROUND & ACKNOWLEDGEMENTS

As Director of Mathematics Learning at Understanding Language/Stanford Center for Assessment, Learning, and Equity, I helped identify, describe, and adapt eight Math Language Routines in collaboration with the writers of the Illustrative Mathematics Curriculum. While I am a math content specialist, not a linguist or a language acquisition specialist, I am also trained as a cultural anthropologist, and have deep interest in interactions across sociocultural differences that take place in school settings.

Through multiple projects over the past 11 years, I have had much good fortune to work with various communities of scholars and practitioners assembled by Kenji Hakuta. Many things grow when you tend to them, and one of the insights I have taken from conversations with Kenji is that language is one those things: if the conditions are right, it will grow.

The hypothesis presented here stems directly from conversations with my professional mentor, Ann Shannon, and also builds on the work of Judit Moschovich, Harold Asturias, and Jana Dean. In addition, these ideas have been shaped through working alongside Tamyra Walker, Jim Malamut, Jack Dieckmann, Jeff Zwiers, and Phil Daro. Finally, I have been recently inspired by several math teachers who are doing more to grow student language in their classrooms than they might even realize: Richard Moreno, Vianey Rodriguez, Wendy Vanegas, Yesenia Sedano, and Amanda Pirog.







Stronger & Clearer Each Time

Students write a first draft response to a prompt, then engage in successive pair-shares to have multiple opportunities to refine and clarify their response through conversation. After at least two rounds of paired conversation, students revise their original response by incorporating feedback and additional ideas from their partners. In conversation, students press each other for clarity and details.

- Provides a structured and interactive opportunity for students to revise and refine both their ideas and their verbal and written output.
- Also provides a purpose for student interaction and fortifies student output.



Critique, Correct, Clarify

Students are provided with an incorrect, incomplete, or unclear "first draft" written argument or explanation, and students' job is to improve the writing by correcting any errors, clarifying meaning, and adding explanation, justification, or details. Begins with a brief critique of the first draft, in which the teacher elicits 2-3 ideas from students to identify what could be improved; students then individually write second drafts, and finally, the teacher scribes as 2-3 students read their second drafts aloud. The final step of public scribing creates an opportunity to invite all students to work together to generate a final draft that makes sense to the whole class.

- Provides an efficient and iterative process for students to analyze and develop a piece of mathematical writing that is not their own.
- Prompts student reflection, fortifies output, and builds students' meta-linguistic awareness.



Collect & Display

The teacher captures students' oral words and phrases into a visual reference in order to stabilize the fleeting language that students use during partner, small-group, or whole-class discussions. The teacher listens for, and scribes, student output using written words, diagrams, and pictures; this collected output can be organized, revoiced, or explicitly connected to other language in a display for all students to use over the course of a lesson or unit.

- Mirrors student language back to the whole class to enable students' own output to be used as a reference in developing mathematical language over time.
- Provides feedback for students in a way that increases accessibility while simultaneously supporting meta-awareness of language.



Information Gap

Students are positioned as holders of information that is needed by other students to accomplish a goal, such as solving a problem or winning a game. Students bridge a gap in information and accomplish something that they could not have done alone. For example, in pairs, one student is given a problem to be solved, and the other student is given the information needed to solve the problem. The student who has the problem asks for specific information, and explains how that information will help in solving the problem; the student who has the information provides the specific information requested. Once enough information has been shared, the students can solve the problem. Another example is a game format where one student has a value, ratio, geometric figure, or function in mind, and other students ask questions strategically to identify the mystery object.

- Gives students a clear purpose for communicating.
- Supports meta-awareness of language, and provides motivation to be precise in both asking questions and giving answers.



Co-Craft Questions

Students are presented with a picture, video, diagram, data display, or description of a situation, and their job is to generate one or more mathematical questions that could be asked about the situation. Students then share and compare their questions, as the teacher calls attention to questions that align with the content goals of the lesson. Finally, the “official” question or problem is revealed for students to work on.

- Invites students inside of the context for a mathematical problem without feeling immediate pressure to produce answers, and creates space for students to produce the language of mathematical questions themselves.
- Sparks curiosity about a new mathematical idea or representation, and elicits everyday student language to brainstorm about the quantitative relationships that might be investigated. Develops meta-awareness of the language used in mathematical questions and problems.



Compare & Connect

The teacher facilitates a discussion about two or more pieces of student work that include distinct mathematical representations or approaches to a problem, calling attention to the correspondences among quantities, relationships, and features of the representations. Teachers should demonstrate thinking out loud (e.g., exploring why one might do or say it this way, questioning an idea, wondering how an idea compares or connects to other ideas or language), and students should be prompted to reflect and respond.

- Fosters students' meta-awareness as they identify, compare, and contrast different mathematical approaches, representations, and language. This routine supports meta-cognitive and meta-linguistic awareness, and also supports mathematical conversation.



Three Reads

A word problem is read three times, with a different question posed with each read: (1) What is this situation about?; (2) What can be counted or measured in this situation?; (3) How might we approach this problem, or what is the first thing we could do to get started?

- Gives students a chance to use everyday language to help each other make sense of the context—and the language—of a word problem before jumping down a solution path.
- Helps ensure that students know what they are being asked to do, and to create an opportunity for students to reflect on the general structure of quantitative situations and on the ways mathematical questions are presented.
- Supports reading comprehension of problems and meta-awareness of mathematical language, and supports negotiating information in a text with peers through mathematical conversation.



Discussion Supports

The teacher uses multi-modal strategies for helping students comprehend and generate language and ideas, such as sentence frames, word walls, images and videos, revoicing, choral response, gesture, and graphic organizers. The strategies can be combined and used together with any of the other routines.

- Fosters rich and inclusive discussions about mathematical ideas, representations, contexts, and strategies.
- Helps to make classroom communication accessible, to increase meta-awareness of language, and to demonstrate strategies students can use to enhance their own communication and construction of ideas.

Finish the Conversation (forthcoming)

RESOURCES TO EXPLORE

- Resources offered by the [English Learner Success Forum](#)
- Resources offered by [Understanding Language](#), now part of Stanford's Center to Support Excellence in Teaching
- Resources offered by [WIDA](#), including [professional learning workshops](#).

REFERENCES

- Barwell, R. (2018). From language as a resource to sources of meaning in multilingual mathematics classrooms. *Journal of Mathematical Behavior*, 50, 155–168
- Barwell, R., Moschkovich, J. N., & Phakeng, M. (2017). Language diversity and mathematics: Second language, bilingual, and multilingual learners. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 583–606). National Council of Teachers of Mathematics.
- Bunch, G., & Martin, D. (2020). From “academic language” to the “language of ideas”: a disciplinary perspective on using language in K–12 settings. *Language and Education, Special Issue*.
- Bunch, G. (2013). Pedagogical Language Knowledge: Preparing Mainstream Teachers for English Learners in the New Standards Era. *Review of Educational Research*, 37(1), 298–341. American Educational Research Association.
- Chapin, S., O'Connor, M., & Anderson, N. (2009). *Classroom discussions: Using math talk to help students learn* (2nd ed.). Math Solutions.
- Chval, K. B., Pinnow, R. J., & Thomas, A. (2014). Learning how to focus on language while teaching mathematics to English language learners: A case study of Courtney. *Mathematics Education Research Journal*, 27(1), 103–127.
- de Araujo, Z., Roberts, S. A., Willey, C., & Zahner, W. (2018). English learners in K–12 mathematics education: A review of the literature. *Review of Educational Research*, 88(6), 879–919.
- Dean, J. (2021) Speechless in math class: What we do matters. In J. Miller, H. Bigley & S. Remillard (Eds.), *Teachers on Fulbright: Reflections on Global Pedagogy and Practice*. Independently Published.
- Erath, K., Ingram, J., Moschkovich, J. N., & Prediger, S. (2021). Designing and enacting instruction that enhances language for mathematics learning – A review of the state of development and research. *ZDM Mathematics Education*, 53(2),
- Erath, K., Prediger, S., Quasthoff, U., & Heller, V. (2018). Discourse competence as important part of academic language proficiency in mathematics classrooms: The case of explaining to learn and learning to explain. *Educational Studies in Mathematics*, 99(2), 161–179.
- Gutiérrez, R. (2002). Beyond essentialism: The complexity of language in teaching mathematics to Latina/o students. *American Educational Research Journal*, 39, 1047–1088.
- Gutiérrez, R. (2018). Political conocimiento for teaching mathematics: Why teachers need it and how to develop it. In S. E. Kastberg, A. M. Tyminski, A. E. Lischka, & W. B. Sanchez (Eds.), *Building support for scholarly practices in mathematics methods*. Information Age Publishing, Inc.



REFERENCES, CONTINUED

- Kersaint, G. (2019). Orchestrating Mathematical Discourse to Enhance Student Learning: Creating successful classroom environments where every student participates in rigorous discussions. Curriculum Associates.
- Koichu, B., Parasha, R. & Tabach, M. (2021). Who-Is-Right tasks as a means for supporting collective looking-back practices. *ZDM Mathematics Education* 53, 831–846.
- Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, 27, 29–64.
- Liljedahl, P. (2016). Building thinking classrooms: Conditions for problem-solving. In Felmer, P., Pehkonen, E., & Kilpatrick, J. (Eds.) *Posting and Solving Mathematical Problems*. 361–386.
- Martínez, Ramón. (2018). Beyond the English Learner Label: Recognizing the Richness of Bi/Multilingual Students' Linguistic Repertoires. *The Reading Teacher*, 17, 515–522
- Moschkovich, J. N. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning*, 4, 189–212.
- Moschkovich, J. N. (2007). Examining mathematical discourse practices. *For the Learning of Mathematics*, 27, 24–30.
- Moschkovich, J. (2013). Principles and guidelines for equitable mathematics teaching practices and materials for English language learners. *Journal of Urban Mathematics Education*, 6(1), 45–57.
- Moschkovich, J. N., & Zahner, W. (2018). Using the academic literacy in mathematics framework to uncover multiple aspects of activity during peer mathematical discussions. *ZDM Mathematics Education*, 50(6), 999–1011.
- O'Connor, C., Michaels, S., & Chapin, S. (2015). "Scaling down" to explore the role of talk in learning: From district intervention to controlled classroom study. In L. B. Resnick, C. S. C. Asterhan, & S. N. Clarke (Eds.), *Socializing intelligence through academic talk and dialogue*. American Educational Research Association.
- Sfard, A., & Kieran, C. (2001). Cognition as communication: Rethinking learning-by-talking through multi-faceted analysis of students' mathematical interactions. *Mind, Culture, and Activity*, 8(1), 42–76.
- Walker, T. (2020). The Importance of Technical Writing Documents: Building Rationale for Literacy in STEM. Slide Deck for Envision Schools.
- Wylie, C., Bauer, M., Bailey, A., & Heritage, M. (2018). Formative assessment of mathematics and language: Applying companion learning progressions to reveal greater insights to teachers. In A. Bailey, C. A. Maher, & L. C. Wilkinson (Eds.), *Language, literacy, and learning in the STEM disciplines: How language counts for English Learners*. Routledge.
- Zahner, W., Pelaez, K., & Calleros, E. (2020). Designing mathematics learning environments for multilingual students: Results of a redesign effort in introductory algebra. In A. I. Sacristán, J. C. Cortés (Eds). *Proceedings of the 42nd Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Mazatlán, MX: PMENA.
- Zwiers, J., Dieckmann, J., Rutherford-Quach, S., Daro, V., Skarin, R., Weiss, S., & Malamut, J. (2017). Principles for the design of mathematics curricula: Promoting language and content development. Stanford University UL/SCALE. https://ell.stanford.edu/sites/default/files/u6232/ULSCALE_ToA_Principles_MLRs_-_Final_v2.0_030217.pdf

