Scaffolding Tasks for the Professional Development of Mathematics Teachers of English Language Learners ChuThemeE

Haiwen Chu

Quality Teaching for English Learners, WestEd

This article outlines a design framework for classroom exemplars to be used in the professional development of mathematics teachers of English Language Learners. This framework shapes activities built around mathematical practices to scaffold student engagement in interactive tasks that foster their emerging autonomy. Empirical results from applying this framework to design teacher apprenticeship is reported. Data includes both professional development institutes and instructional coaching cycles. Results suggest trajectories for teachers' shifting understanding of conceptual, academic, and linguistic goals as they appropriate a pedagogy of promise that fully develops the potential of all ELLs.

English language learners, scaffolding, interaction, lesson design

Introduction: Challenging and Supporting English Language Learners

In the United States, English Language Learners (ELLs) are a rapidly growing population, increasing by 51% in the past decade. Policy at the federal level has positioned ELLs through a deficit lens as "Limited English Proficient". Mainstream pedagogical approaches have remained simplified and simplistic, emphasizing vocabulary terms taught atomistically. Within the high-stakes environment of standardized assessments, simplification and accommodation for ELLs might be necessary and appropriate (e.g., Sato, Rabinowitz, Gallagher, & Huang, 2009). The classroom environment, however, offers broader and more varied opportunities for students to learn important mathematics with use value beyond the classroom and to interact with teachers and their peers. Just as ELLs need support in meeting the challenges of conceptual understanding, procedural fluency, and language proficiency, their teachers also must navigate national shifts in academic needs, emphases, and practices. Rather than lowering the cognitive demands of tasks (Henningsen & Stein, 1997), mathematics teachers must find multiple approaches to provide ELLs with temporary support as they engage with mathematical ideas and with their classmates and they develop their autonomy.

As the Quality Teaching for English Learners (QTEL) intiative at WestEd, we engage teachers in professional development workshops and cycles of instructional coaching through a whole-school model. QTEL employs a pedagogical design framework across multiple disciplines. Our work entails the design of fully articulated lessons which use scaffolding tasks, activities that invite and structure peer support to develop students' independent abilities. Lessons form the basis of site-based workshops for teachers. Teachers then apprentice in cycles of disciplinary coaching. We nurture teachers' growing expertise in setting conceptual, academic, and linguistic goals and their effective planning and implementation of lessons that challenge and support ELLs.

This article is organized as follows. First, I define classroom-based, interactive scaffolding tasks. I then describe the interlocking sets of principles that guide the design and sequencing of these tasks into coherent lessons. Third, I report empirical findings from practitioner research conducted during the first of a three-year partnership at two secondary schools. I conclude with directions for further research and development based upon these design principles.

Defining classroom-based, interactive scaffolding tasks

Classroom-based, interactive scaffolding tasks are drawn from research on second language acquisition. Although these tasks are compatible with mathematical tasks (e.g., Henningsen & Stein, 1997), I focus on meeting the specific needs of ELLs for pedagogical scaffolding and the authentic use of language in interaction.

Ellis (2003) frames the analysis of tasks along five dimensions: 1) goals, 2) input, 3) conditions, 4) procedures, and 5) predicted outcomes as product and process. *Goals* define general purposes and target competencies. *Input* and *conditions* are linked: *input* is the information given including the modality (e.g., oral or written descriptions, or mathematical representations), while *conditions* are how information is either split or shared among students. When information is split there is an information gap (Gibbons, 2009). Students possess or are given pieces of information which they must put together through communicating with one another in order to complete the task. *Procedures* give students discourse moves and participation formats, such as working in pairs, taking explicit turns, or using specified language. *Predicted outcomes* include *products* such as materials students will write or draw and the linguistic or cognitive *processes* the task is intended to engender in students.

The QTEL approach emphasizes not just individual tasks but repeatable task-types with similar structures. Through regular participation, ELLs gain familiarity with the structure of a task-type, and therefore shift focus away from following instructions toward understanding new concepts (Walqui & van Lier, 2010). For example, the Compare and Contrast task-type has the *goal* of identifying similarities and differences between two mathematical objects or situations. As *inputs*, students are given a matrix as a graphic organizer. The two columns are headed by descriptive titles and the three to six rows are labelled with focus questions. The *conditions* are split or shared. One way to split information is to have one student report to another as an expert on a particular case. Alternatively, students could share information, going back and forth as they fill out cells of the matrix. *Procedurally*, students take turns filling out the matrix, orally stating what they are writing down. Once the matrix is complete, students take turns orally pointing out similarities and differences, using the appropriate formulaic expressions such as, “One difference between these two functions is...” Finally, students write a summary of key similarities and differences. The predicted *product* includes a completed matrix and summary statements of key similarities and differences. The predicted *process* includes noticing similarities and differences and expressing them orally as well as in written form.

These five analytic dimensions more fully specify the task-types described by Swan (2007), which emphasize *goals* and *predicted processes*. These task-types include: classifying mathematical objects, interpreting multiple representations, evaluating mathematical statements, creating problems, and analyzing reasoning and solutions. A “classifying mathematical objects” task provides students with multiple mathematical objects to sort, either by excluding an “odd one out” or by placing cards containing the objects into a table with given headings for rows and columns. A “multiple representations” task has students match cards containing tables, graphs, and equations. These tasks specify *inputs*.

Focusing attention on the *conditions* and *procedure* ensures that English language learners receive peer support through structured interaction. For example, we use a task-type called "Sort and Label". We stipulate the condition that knowledge of what is written on different cards, while ultimately shared publically, is rationed out sequentially. Information is gradually revealed to the whole group as students take turns drawing one card at a time from a stack, reading out loud or describing what is on that card. Students use targeted formulaic expressions to offer and justify tentative groupings. This procedure distributes participation more evenly. Patterns emerge as cards are placed on the table in an order that is not predetermined. Without this condition, both students and teachers will shuffle around cards wordlessly, with only a few stating reasons after the fact. Further, this task-type can be more cognitively demanding than "classifying mathematical objects" because the categories are not given in advance, and must instead by devised, discussed, and agreed upon by students working as groups.

These five analytic dimensions provide explicit invitations for ELLs to engage with mathematical concepts and procedures as they participate fully in classroom interactions. For the remainder of this article, I use "task" as shorthand for these classroom-based scaffolding tasks that require, specify, and support peer interaction.

Design principles for tasks, lessons, and units

The design of tasks is guided by a framework on three different levels. First, five Principles for Quality Teaching of English Learners address general pedagogical features of the classroom environment. Backwards design emphasizes that all planning must begin by articulating conceptual, academic, and linguistic goals. Finally, an architecture of three moments assists teachers in deconstructing broad goals into connected intermediate objectives that flow together smoothly. This framework thus provides nested layers, including *outcomes* with the Principles, a *process* with backwards design, and an *architecture* with three moments.

Principles of Quality Teaching for English Learners

Five Principles guide the design of instructional experiences for students: 1) academic rigor; 2) high expectations, high support; 3) quality interactions; 4) language focus; 5) quality curriculum (Walqui & van Lier, 2010). In work designed to last three years, each year focuses on different Principles. During the first year, our whole-school coaching model highlighted three Principles: academic rigor, quality interactions, and language focus.

Academic rigor considers the extent to which students acquire deep disciplinary knowledge, use higher order thinking skills, and develop central and generative concepts and skills. This aspect maps well to the construct of the cognitive demand of a mathematical task (Henningsen and Stein, 1997). Within workshops, teachers have engaged in sorting tasks by cognitive demand and then constructing variations that amplify the level of academic rigor.

Quality interactions include both interactions between the teacher and students as well as those between students as peers. These interactions must be sustained and reciprocal so that the teacher is not the sole authority who asks questions and then evaluates students' responses. Rather, students should respond to each other directly, elaborating on their own ideas, qualifying or extending them, and sharing responsibility for negotiating validity. As they co-construct new understandings, students generalize, evaluate, and connect their ideas to each other, reflecting and revising each others' ideas. These quality interactions take place not only in whole-class discussions when students or groups share work, but are infused into students' participation in tasks working in small groups or pairs. This Principle is embedded in the specification of the inputs, conditions, and procedures associated with tasks.

Further, teachers must sustain a *language focus* by providing students with opportunities to use disciplinary language authentically. Therefore, teachers need to have pedagogical content knowledge of language to provide students with clear and purposeful explanations of the metalinguistic knowledge that will assist them in completing a task, such as false cognates or mathematical language functions. Further, language can be viewed as performance, including disciplinary subgenres and language functions such as proving, providing counterexamples, and generalizing. Building on an approach of message redundancy, teachers should not simplify the language associated with a task, but rather amplify through extralinguistic and paralinguistic cues. Finally, in terms of correctness, teachers should judiciously select feedback focusing not on perfect usage or grammar, but on language production that meets the goals of the task (cf Moschkovich, 2012).

Backwards design

Consistent with the Understanding by Design framework (Wiggins & McTighe, 2005), the design of scaffolding tasks begins with identifying goals at the level of the lesson or unit. To meet the needs of English language learners, it is essential to clearly identify not only disciplinary or conceptual goals, but also academic and linguistic goals (Walqui & van Lier, 2010).

Conceptual goals emerge from the discipline of mathematics, and are often associated with the conceptual understanding and procedural fluency that underpin teaching mathematics for understanding (e.g., Kilpatrick, Swafford, & Findell, 2001). Academic goals are generative and span multiple school disciplines. These usually require higher order thinking: generalizing, synthesizing, and comparing and contrasting. These academic goals are aligned with both the National Council of Teachers of Mathematics Process Standards as well as the Standards for Mathematical Practice from the Common Core State Standards in Mathematics. For instance, to "model with mathematics" students need to engage in generating, applying, testing, and revising mathematical representations as they relate to real-world scenarios.

Linguistic goals can be considered on two levels. At a broad level, each unit, lesson, and task has specific language functions or genres as its objectives. For example, comparison and contrast is a language function that applies not only to mathematics but any academic discipline. Providing counterexamples is a language function that is more specific to mathematics. This approach to language views proof, for instance, as a specific genre with its own rules, conventions, and structures about which students need explicit instruction. Further, the genre of proof itself has subgenres: a proof by contradiction reads differently than a constructive proof or an existence proof. These differences can be understood in terms of language functions.

On a narrower level, specific swatches of language are necessary to accomplish various language functions. These formulaic expressions are used not as individual words but flexible grammatical structures. For example, "*9* is *odd*, but not *prime*" is an instance of a formulaic expression useful for giving counterexamples. The expression is like a mathematical formula in that different objects or predicates can be substituted into the positions marked in italics. ELLs in particular need explicit instruction about the formulaic expressions appropriate to mathematical language functions. It would be difficult to devise counterexamples and to communicate them to the classroom community without these linguistic structures.

While it is possible to articulate and define these different goals separately in developing teachers' expertise, in well-designed instruction the goals converge and support each other. Academic goals are the generalizations and transfer of disciplinary goals, and language is a medium for both. Focusing on goals and increasing their challenge is essential in expanding teacher expertise. Setting these goals and objectives for units and lessons is a means of specifying the more general Principles of academic rigor, quality interactions, and language focus.

Lesson architecture in three moments

A typical "traditional" lesson sequence is explanation, example, exercise (Swan, 2007). The teacher gives a general explanation, demonstrates a worked example, and then students engage in repetitive practice of the target procedure. Curricula based upon NCTM Standards such as the Connected Mathematics Project focus on a single, central problem set in a real-world context and follow a "three phase" model: Launch, Explore, Summarize (Lappan et al., 2009). In the Launch phase, students are introduced to the problem and certain key contextual features or mathematical relationships can be explained. Students work in small groups to solve the problem using their own methods in the Explore phase. In the Summarize phase, the teacher orchestrates a whole-class discussion in which different solution methods are publically shared, compared, and contrasted.

By contrast, an architecture in three moments provides a more flexible structure: 1) preparing learners, 2) interacting with the concept, and 3) extending understanding (Walqui & van Lier, 2010). When directed toward a mathematical problem set in a real-world context, Preparing, Interacting, and Extending are compatible with Launch-Explore-Summarize. The more flexible architecture of three moments, however, offers three additional benefits: broader notions of prior knowledge and explicit attention to transitions from everyday to academic language, more flexibility in terms of building students' procedural fluency with embedded opportunities for reflection and interaction, and a clearly delineated, more varied set of options for extending understanding.

The Preparing Learners moment has three possible functions in the lesson. First, it articulates a focus on key understandings for the lesson. Second, the tasks bring to the surface students' prior experiences and knowledge with the objective of narrowing these contributions toward the lesson objective. Finally, the teacher can introduce essential understandings as reflected by key vocabulary terms, presented in context. For example, students can engage in a Think-Pair-Share. The prompt is kept as general as possible to appeal to students' personal experiences rather than their mathematical opinions. For example, students might be asked to tell a story about how they had to balance something, in preparation for a lesson about the arithmetic mean as a balancing point. Students have a few minutes to think individually, before they take turns with a partner sharing responses. The teacher then leads a whole-class discussion, calling individuals to share what *their partners* said. The teacher then summarizes these experiences and connects them explicitly to the mathematical topic of the lesson. In contrast with the Launch phase's focus on a single mathematical problem set in a real-world context, other tasks, such as ones that involve sorting mathematical objects or representations, function well in the Preparing moment.

As students are Interacting with the Concept, they engage in three processes: deconstructing, reassembling, and connecting different aspects of the central concept of the lesson. Although compatible with the “Explore” phase of investigating a central mathematical problem, this moment can address procedural fluency. For example, students work in groups of four to carry out an Algorithm in Four Steps. In this task-type, students play the roles of different steps of a procedure, such as finding the slope of the line between two points. After completing a case or problem, students rotate roles so that each gets a chance to play each of the four steps. In contrast with the typical “exercise” part of a lesson, students are collaboratively engaged in interaction structured to heighten awareness of the interdependence of steps.

Another suitable Interacting task-type is a Jigsaw Project. Students convene in expert groups to learn about a particular case or solve a problem, becoming experts and answering common focus questions that cut across the different cases. These focus questions cannot just be factual and isolated, and should cohere to require students to negotiate, discuss, and select in expert groups. Students then return to base groups to report their findings. Base groups use a graphic organizer similar to a Compare and Contrast matrix. The focus questions allow the base group to see connections, such as different proofs of the Pythagorean theorem or different real-world instances of unit rate.

Finally, as the lesson moves toward Extending Understanding, students are invited to work in three ways: to apply the concept to novel real-world applications, to connect to other concepts or algorithms previously studied, or to re-present their understanding in new genres and formats. This moment also includes having students create their own problems and solve those created by their peers (cf Swan, 2007). Reflecting on one’s own process of thinking and the relative usefulness of different representations is also appropriate in this moment. The Collaborative Poster task-type has students work in groups of four to create a poster, with the condition that each student uses a different color marker. A good prompt requires students to make a choice as a group, such as only choosing one type of representation from among tables, equations, or graphs, in order to compare two different linear functions.

Tracing teacher engagement and growth trajectories

After the first of three years of whole-school coaching and professional development across the disciplines at two secondary schools, three phases in growth among mathematics teachers have begun to emerge. First, are *shifts* in teachers’ professed beliefs, priorities, and approaches. Next, teachers *adopt* tasks wholesale during coaching. Third, teachers have begun to *adapt* tasks in planning units and lessons.

When first working with the design framework and tasks, teachers respond most frequently and extensively to three features. First, teachers express appreciation for how tasks specify clearly outlined roles for students and how the interaction is structured. They contrast this approach with the “bare” problems provided in textbooks or other curriculum resources, or generic roles for collaborative work (e.g. recorder, materials manager, etc). Second, teachers respond positively to notions of language which look beyond vocabulary toward language functions and linguistic goals in lesson planning. Many teachers say that they had not been given other tools beyond generic state-based language proficiency standards, or that they have previously focused only on definitions-centered vocabulary. Finally, within the context of planning, teachers focus on the Extending moment and developing flexibility in selecting from the multiple tasks appropriate to that moment. This focus on Extending is particularly important given the lack of closure that is often characteristic of many mathematics lessons in the United States.

Within coaching cycles, initially teachers often place undue focus on task-types as the end goal rather than as a means for achieving outcomes such as quality interactions. This emphasis is perhaps a consequence of previous district-wide mandates which evaluate teachers based upon implementation of specified strategies. Modeling specific tasks in coherent instructional sequences by the coach facilitates both teachers building belief in their students and their technical knowledge for implementing specific tasks and transitions between tasks. A key insight that many teacher reach through practice is that language development is not spontaneous but occurs within the context of planned scaffolding.

Simultaneously, teachers see how the language modeled for students facilitates their conceptual development, and they begin to select and model appropriate formulaic expressions and genres for their students. Teachers begin develop their capacity to enact the Principle of language focus as they become aware of how many mathematical tasks need to be further unpacked for ELLs. A common example is around the prompt to "summarize". Students typically produce a narrative recount of the procedure, or a laundry list of responses to specific questions, rather than a coherent summary oriented toward goals and methods that generalize. Once they have unpacked the complex processes and structures involved in summarizing, teachers can apply the process to other common but complicated commands, such as "explain" and "justify".

Teachers' initial misfires reflect their emerging understanding of the rationale for procedures in task-types as connected to more general goals. Often, teachers create opening prompts that are too narrow, or after students share responses do not efficiently focus students' contributions toward the key ideas that connect directly with the mathematical topic. Successful openings require both pedagogical content knowledge and implementation skills. For example, in a lesson on solving equations by *undoing*, one teacher gave an example response to a Think-Pair-Share prompt a story of making a mistake with a baking recipe. Because this modelled example would require redoing rather than undoing, many examples students subsequently provided did not move toward the idea of inverse operations, and the intended question of the order in which operations would need to be undone. By engaging in reflection during coaching, teachers produce prompts that start more broadly and focus more narrowly. Through coaching, teachers have the chance to revise their lessons the same day. They thus can examine and reflect upon how changes in the clarity of directions or the inputs or conditions of the task affect student outcomes.

The refinement of teachers' choices can be traced in the quality of the focus questions that they generate for Jigsaw Projects and Compare and Contrast Matrices. Generic graphic organizers for comparing and contrasting two cases may be organized like a Venn diagram and do not have focus questions. Similarly, teachers often initially misunderstand the rationale for focus questions, omitting these questions, asking questions that are too general or do not apply to individual cases (e.g., "How are they the same?"), or barraging students with recall questions that do draw focus toward key ideas. Over time, teachers have developed questions that are both better phrased individually as well as coherent and well-sequenced as a whole.

Indeed, with more experience with this design framework, teachers begin to engage in a form of "task problematization" (Sierpinska, 2004). Not only are there possible variations on the mathematical question but the other aspects of the design of the task, including inputs, conditions, and procedures. Teachers begin to reflect on the flexibility in choosing similar but subtly different task-types as appropriate to different moments in the lesson and trade-offs between slightly different goals. In particular, teachers gravitate toward the tasks that involve algorithms, whether in the format of a group task as an Algorithm in Four Steps or in Comparing and Contrasting two different algorithms, such as for computing the median. Reflective coaching discussions with teachers about algorithms probe the dual demand for procedural fluency and conceptual understanding. For many teachers, the explicit modeling provided by scaffolding tasks in which students interact as they carry out different steps of procedures is an accessible entry point to providing ELLs with multiple algorithms which they will eventually be able to select from strategically. In this manner, the scaffolding embedded in well-designed tasks allows teachers to increase the academic rigor, or cognitive demand, of classroom activity.

Conclusion: Future directions for design and research

These emerging trajectories for teacher growth suggest three areas for further research and efforts in task design, starting from the level of individual teachers and extending, through coaching relationships, to the level of groups of math teachers working at the same school. 1) How do individual teachers engage with different aspects of the design framework and make connections across different components? 2) How does this design framework function as a coaching tool to foster teachers' development? 3) To what extent can this design framework serve as a common language as teachers collaborate with one another? While the design framework has so far served primarily as a means to design lessons for the purpose of professional development, handover would suggest that teacher-created lessons could also be eventually used for this purpose. Further in depth observational studies of student-to-student interactions would also be appropriate on the way to evaluating the extent to which shifts in teachers' practices around task design and implementation affect student outcomes.

References

Ellis, R. (2003). *Task-based language learning and teaching.* Oxford: Oxford University Press.

Gibbons, P. (2009). *English learners, academic literacy, and thinking: Learning in the challenge zone.* Portsmouth, NH: Heinemann.

Henningsen, M., & Stein, M. K. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning. *Journal for Research in Mathematics Education*, 28, 524-549.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Research Council.

Moschkovich, J. (2012). *Mathematics, the Common Core, and language: Recommendations for mathematics instruction for ELs aligned with the Common Core*. Stanford, CA: Understanding Language.

Sato, E., Rabinowitz, S., Gallagher, C. & Huang, C.-W. (2010). *Accommodations for English language learner students: the effect of linguistic modification of math test item sets.* Washington, DC: Institute of Education Sciences.

Sierpinska, A. (2004). Research in mathematics education through a keyhole: Task problematization. *For the Learning of Mathematics,* 24(2), 7-15.

Swan, M. (2007). The impact of task-based professional development on teachers' practices and beliefs: A design research study. *Journal of Mathematics Teacher Education,* 10, 217-237.

Walqui, A., & van Lier, L. (2010). *Scaffolding the academic success of adolescent English language learners.* San Francisco, CA: WestEd.

Wiggins, G., & McTighe, J. (2005). *Understanding by design.* Alexandria, VA: Association for Supervision and Curriculum Development.