Chapter 7

Using New Technologies to Engage and Support English Language Learners in Mathematics Classrooms

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EXECUTIVE SUMMARY

An emerging body of research is demonstrating the potential of new technologies such as iPad and phone apps, wikis, blogs, podcasts and web-based editing tools for significantly improving the academic language development of English language learners. The authors of this chapter present an expanded definition of academic language, explain why these new technologies are important, and discuss how they can be used to provide effective and innovative mathematics instruction to English language learners. Three classroom vignettes demonstrate specific ways in which a variety of technologies can be implemented across grade levels to meet the Common Core State Standards for Mathematical Practice and Content.

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INTRODUCTION

An emerging body of research is demonstrating the potential of new technologies such as iPad and phone apps, wikis, blogs, podcasts and web-based editing tools for significantly improving the academic language and disciplinary learning of English language learners (ELLs). In this chapter we present an expanded definition of academic language, explain why these new technologies are important, and discuss how they can be used to provide effective and innovative mathematics instruction to ELLs. We also present a set of frames that articulate high leverage practices for differentiating instruction to meet the needs of ELLs, as well as classroom vignettes that demonstrate specific ways in which a variety of technologies can be implemented to meet the challenges of the Common Core State Standards in Mathematics (CCSS-M).

THE CHALLENGES OF THE COMMON CORE STATE STANDARDS IN MATHEMATICS

Academic language and literacy play a critical role in the new CCSS. A set of papers commissioned by the Understanding Language Initiative at Stanford University stresses the challenges and language demands that the new standards place on ELLs and their teachers (Bunch, Kibler & Pimentel, 2012; Moschkovich, 2012; Quinn, Oklee, & Valdes, 2012; Van Lier & Walqui, 2012; Wong Filmore & Filmore, 2012). These scholars suggest that the CCSS have added an exciting and challenging layer to the schooling of ELLs. The exciting part is that many of the CCSS will require a focus on robust development of disciplinary thinking and communication skills, which better prepare all students for success in college. In math this means students will need to use and explain connections between representations, share and refine their reasoning, and develop meaning for symbols. The challenging part is that meeting these new standards requires higher levels of receptive and productive academic language.

For ELLs in particular, the development of academic language is one of the most important factors in their academic success and has been increasingly cited as a major contributor to gaps in achievement between ELLs and native speakers of English (Anstrom et al., 2010; Francis, Rivera, Lesauz, Kieffer, & Rivera, 2006).

Proficient use of - and control over - academic language in English is the key to content area learning in our schools. Given the nature of today's academic demands, lack of proficiency in academic language affects students' ability to comprehend and analyze texts, limits their ability to write and express themselves effectively, *and can hinder their acquisition of academic content in all academic areas (Abedi, 2007, p. 16).*

Academic language development is also associated with student achievement, as demonstrated by the correlation between measures of English language proficiency and content assessment scores (Cook, Boals, & Lundberg, 2011). For example, the results of a study looking at the relationship between language proficiency and mathematics achievement suggested that success in mathematics was influenced by English proficiency in both productive and receptive skills (Grant, Cook, Phakiti, & Lundberg, 2011). Therefore, explicit attention to all aspects of academic language instruction, coupled with extended opportunities for students to hear and use academic language, can help improve the quality of instruction for ELLs while helping all students meet the CCSS.

THE DIMENSIONS AND FEATURES OF ACADEMIC LANGUAGE

Since academic language is vital both for learning and for demonstrating one's learning in math classrooms, a deep understanding of the concept is an essential element of the knowledge base teachers need. Unfortunately, a major challenge in the field is that many teachers equate academic language with content vocabulary, which causes them to neglect other critical dimensions of academic language development such as: a discipline's complex grammatical structures and discourse patterns (Carr, Sexton, & Lagunoff, 2006; Zwiers, 2008); disciplinary habits, behaviors and cognitive features such as the ability to think critically (Merino & Scarcella, 2005); and how to use language within particular functions and settings (Carrier, 2005; Echevarria, Short, & Powers, 2006). A leading math researcher agrees: "The language of mathematics does not mean a list of vocabulary words with precise meanings but the communicative competence necessary and sufficient for competent participation in mathematical discourse practices. Although learning vocabulary may be necessary, it is not sufficient" (Moschkovich, 2012, p. 3).

Based on reviews of literature, classroom observation analyses, and a Delphi Panel study, the authors define academic language as the set of vocabulary, syntax, and discourse strategies used to describe complex concepts, abstract ideas, and cognitive processes (Zwiers, O'Hara, & Pritchard, 2014). Figure 1 shows how the three dimensions of vocabulary, syntax, and discourse can be broken down even further into features that can be observed in lessons and student work.

Figure 1. Features of academic language

Dimensions	AL Features	AL Skills
Vocabulary	- Content terms and collocations - Figurative expressions and multiple meaning terms - Affixes, roots, and transformations - General academic terms (*aspects, consider, as long as, perhaps, evaluate*)	- Figure out the meaning of new words and terms in a particular message – connect to underlying concepts and for comprehension of text - Use new words to build ideas or create products - Choose and use the best words and phrases to get the message across
Syntax	- Sentence structure & length - Transitions/Connectives - Complex verb tenses and passive voice - Pronouns and references	- Craft sentences to be clear and correct - Use of a variety of sentence types to clarify a message, condense information, and combine ideas, phrases, and clauses.
Discourse	- Organization and text structure - Voice and register - Density - Clarity and Coherence	- Combine features to communicate, clarify, & negotiate meaning - Create a logical flow and connection between ideas - Match language with purpose of message (Clear, complete, focused, logical, & appropriate to the discipline)

ESSENTIAL PRACTICE FRAMES

The CCSS, more than previous sets of standards, emphasize skills that require advanced uses of academic language. An analysis of the Standards reveals a core set of skills that are common across grade levels and disciplines. These "common core across the Common Core" skills include: making conjectures, presenting explanations, constructing arguments with sound reasoning and logical evidence, questioning assumptions, understanding multiple perspectives, making sense of complex texts, and negotiating meaning in academic discussions with others across subject areas. By conducting extant review of research and analyzing the kinds of teaching moves that foster such skills and their language, the authors identified high leverage, essential teaching practices.

This research revealed not just a list of practices, but ways in which the essential instructional practices support one another. The authors therefore organized the practices into three "frames," each consisting of a high-impact essential practice at the top supported by three cross-cutting practices and a foundational practice that are common across the three frames. (See Figure 2.) The three essential practices identified as having the highest impact were: Using Complex Text, Fortifying Complex Output, and Fostering Academic Interactions. The three cross-cutting essential practices were: Clarifying Complex Language, Modeling Complex Language, and Guiding Learning of Complex Language. These are all supported by the foundational essential practice, Designing Activities and Lessons.

Figure 2. Essential practice frames

High-Impact Practices	**Foster Academic Interactions** • (INT) Provide and support extended and rich opportunities for student-to-student interactions • (COM) Build disciplinary communication skills		
High-Impact Practices	**Fortify Academic Output** • (ORL) Provide and support extended and rich opportunities for oral AL output • (PCT) Provide and support extended and rich opportunities to use AL to produce written texts		
High-Impact Practices	**Use Complex Texts to Build AL** • (TXT) Analyze the text's organization, syntax, and word choice to develop disciplinary thinking, language, and literacy • (RCT) Provide and support extended and rich opportunities for students to read complex texts		
Cross-Cutting Practices	**Clarify Academic language** • (INP) Use communication strategies to make AL input understandable • (CHK) Check for AL comprehension	**Model Complex Language** • (MOD) Model target AL • (DEC) Deconstruct target AL	**Guide Language Learning** • (PRO) Prompt for and provide target AL • (FBK) Provide specific feedback on AL use
Foundational Practices	**Design Language & Literacy Activities** • (OBJ) Set language objective(s) that support content objectives • (AUT) Structure tasks to require authentic and meaningful communication using target AL. • (MAT) Use AL support materials		

Many teaching checklists contain discreet practices that do not relate to one another in significant ways. Unlike lists, the frames show the interconnectedness and interdependence of the practices. The frames help educators see how the essential practices support one another, and they help teachers focus on the essential practices with the highest impact at the top of each frame. Within each practice are more observable and detailed "strands," each of which has descriptions of three levels of expertise.

The first of the three high-impact practices is Using Complex Texts, which focuses on developing students' overall abilities to practice with and process the language of complex texts (August, Artzi, & Mazrum, 2010; Wong Fillmore & Fillmore, 2012). The teacher engages students in analysis of how a text's organization, syntax, and word choice combine to create meaning, and fosters analytical discussions of authors' use of language to convey certain meanings for given purposes. This practice develops students' overall math language while also strengthening their disciplinary thinking skills, comprehension habits, and content knowledge of specific texts (Urquhart & Weir, 1998).

The second high-impact practice is Fortifying Complex Output, which focuses on structuring, strengthening, and supporting the quantity and quality of students' production of original, extended academic messages which require complex language (Cazden, 2001; Mercer, 2000). The teacher provides and scaffolds multiple opportunities for students to communicate mathematical ideas in activities such as oral presentations and answering teacher questions. Output also includes producing complex texts such as math guides and problem solutions. The teacher provides opportunities and supports students in using academic language (vocabulary, syntax, discourse) to produce texts that communicate clear, meaningful, and original academic messages (Harklau, 2002).

Perhaps the most challenging high-impact practice is Fostering Complex Interactions, which focuses on structuring and strengthening student-to-student interactions that use academic language. Interaction consists of students responding to one another, building and challenging ideas, and negotiating meaning around mathematical ideas and concepts. The teacher provides and scaffolds multiple opportunities for students to interact with original, academic messages that require academic language (Cazden, 2001; Mercer & Littleton, 2007).

THE PROMISE OF NEW TECHNOLOGIES FOR ACADEMIC LANGUAGE DEVELOPMENT AND MATHEMATICAL PRACTICE

As an emerging body of research has begun to examine the importance of academic language development for disciplinary learning of ELLs, other researchers have been investigating the potential of new technologies for significantly improving academic language learning in math and other subjects (O'Hara, & Pritchard, 2006, 2008, 2009, 2013a, 2013b; Pritchard, & O'Hara, 2011; Chapelle, 2001; Dalton, 2010; Joubert, 2013; Lopez, 2010; Rance-Rooney, 2008; Razfar & Yang, 2010; Salaberry, 2001; Suhr, Hernandez, Grimes, & Warschauer, 2010). New uses of technologies such as iPad and phone apps, blogs, wikis, podcasts, social networking, video, and web-based editing tools like Google Docs are increasing in popularity. These technological resources provide environments that potentially foster deep reading and collaborative writing (Cooper, 2012), provide opportunities for interactive practices and the development of authentic language tasks (Elola & Oszok, 2010; Oszok & Elola, 2010; Rance-Rooney, 2010), and in many cases, emphasize the social aspect of the reading and writing processes which often motivates learners to participate in ways and at levels not typically seen in the past (Brown & Adler, 2008). As such, these technologies can aid the enactment of the research-based essential practice frames.

In addition, resources such as Visual Thesaurus, Word Clouds, Online Encyclopedia, Interactive White Boards and hyperlinked multimedia products create environments that support linking graphics, sound, and video elements to text elements. The most recent advances in technology also afford ELLs the opportunity to annotate video and text (Silverman & Hines, 2009). These environments can be tailored to meet the needs of ELLs by incorporating an appropriate amount of text for the language level of the students and by adding video, images, narration and animation. Thus, these new digital learning environments provide students with multiple opportunities for language production, interactive learning experiences, task engagement, and academic vocabulary development.

A number of studies investigated uses of new technology that positively impact student achievement and the development of academic language for ELLs in the content areas (O'Hara, & Pritchard, 2008, 2013a; Hobbs & Frost, 2003; Skinner, 2007; Zhao, 2003). Many of these studies, conducted directly with students and also through teacher professional development, have shown a positive impact of participation in technology-enhanced units of instruction on upper elementary and middle school ELLs' academic language development and content understanding.

Another important facet of these new technologies is the opportunity for students to engage in intellectually challenging tasks, and develop and interact with complex, multimodal texts containing linguistic scaffolds. These texts, containing socially and culturally shaped resources for meaning making (Bezemer & Kress, 2008; Northcote, 2011), afford teachers the ability to place students in an interactive, contextualized learning environment in which they interact with traditional or electronic texts, choose particular pathways to follow, and incorporate images and graphics. New technologies can provide opportunities for ELLs to design digital, multimodal products and access information in interactive digital learning environments, which encourages meaningful applications of new knowledge and new complex language. When designed properly these tasks allow students to engage with challenging math content while simultaneously developing their academic language and disciplinary literacy (O'Hara, & Pritchard, 2008, 2009).

Instruction designed to utilize new technologies can facilitate fortifying complex academic language abilities as students interact with multimodal texts and produce their own multimodal texts to deepen their understanding of complex language and math concepts (Hull & Moje, 2012; White, Booker, Ching, & Martin, 2012). These tools can also promote the use of cognitive and metacognitive learning strategies as students decide how to represent information and communicate messages, and decide what associations to make between the text they are reading or producing and the multimedia components they are utilizing. Not only can various language development needs be addressed simultaneously by promoting the use of visually engaging and language rich technologies, the ability to use these environments encompasses many of the challenging 21st century technology skills students need (Hull & Moje, 2012; White & Martin, 2014).

- Provide a variety of opportunities to communicate about mathematical ideas using listening, speaking, reading and writing;
- Help ELLs develop the communicative competence necessary for competent participation in mathematical discourse practices;

- Encourage ELLs to actively use mathematical language to communicate about and negotiate meaning for mathematical situations;
- Encourage ELLs to take risks, construct meaning and make connections to their prior knowledge;
- Teach ELLs to be independent and strategic learners (O'Hara & Pritchard, 2008, 2009, 2013a, 2013b; Pritchard & O'Hara, 2011; Hobbs & Frost, 2003; Moschkovich, 2012; Skinner, 2007; Zhao, 2003).

The findings from these studies underscore the value in utilizing the interactive and multimodal aspects of these technologies in a manner that will simultaneously enhance academic language development and mathematical understanding. The following vignettes provide examples of how teachers have integrated a range of technological resources into their math classrooms to create these types of learning experiences.

LEARNING ACTIVITIES WITH NEW TECHNOLOGIES

More and more math teachers are finding that new technologies engage the visual, auditory, and sensory learning modalities of their students in conjunction with stimulating interactive activities. As a result, academic language development needs at the vocabulary, syntax and discourse levels can be addressed by promoting the use of visually engaging and language rich technologies. All of the following activities utilize technologies that can build a multimodal background, foster academic language and literacy development, and greater understanding of math content among ELLs.

Classroom Vignette 1: Fortifying Academic Output with a Multimodal Math Guide

Building communication skills can be especially challenging in math classes where texts and teachers often simplify or avoid using large amounts of explanatory language for describing conceptual understandings. Much of the focus is on solving problems as quickly as possible. In this activity students create a webpage that helps other students understand (not just get the correct answer to) an important aspect or concept of math, and in the process explore how sentences are constructed to convey meaning.

Math texts switch between both natural language and mathematical language and symbols, requiring students to make similar shifts in the grammars of both. Thus, Mr. Santini's activity supports students' academic language development by requiring students to incorporate syntactical structures in complex, multimodal texts that incorporate linguistic scaffolds. This enables students to understand how writers and speakers make their texts cohesive, and it helps them develop the linguistic resources they will need to convey their own thinking.

ELLs can also benefit greatly from the collaborative production of complex, multimodal texts that emphasize the social aspects of learning over extended periods of time. In addition, as students utilize images, video, animation, sound, and language to develop their guides, they can make connections between the use of sounds and images and the appropriate use of descriptive language and syntax to convey meaning (Cooper, 2012; Hobbs & Frost, 2003; Morrell, 2002; Skinner, 2007). As the language proficiency levels of students increase, teachers can require them to incorporate more text into their multimodal guides.

Using Multimodal Guides to Explore How Sentences Are Constructed to Convey Meaning

The topic of study for Mr. Santini's ninth grade algebra class is quadratic equations. Mr. Santini would like for his students to be able to understand and explain the process for using quadratic equations, and apply quadratic equations to solve real world problems. In addition to understanding and using the necessary math vocabulary, Mr. Santini wants his students to use the appropriate oral language functions to explain the process for solving quadratic equations. Thus, the academic language demands include using connected sentences, logical paragraph order, and terms such as more than, less than, quadratic, equal to. The focal math standards are:

CCSS.Math.Content.HSA-REI.A.1: Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them.

CCSS.Math.Practice.MP5: Use appropriate tools strategically.

Having spent two periods studying quadratic equations and exploring the important target vocabulary, Mr. Santini has his students create an interactive guide to solving quadratic equations. For the main page of the guide, students create podcasts explaining what a quadratic equation is and why learning to solve these equations is important. Students first produce a script of what they will record in the podcasts and in them highlight the key syntactic structures and vocabulary words that they use.

Then on the same page they solve four more quadratic equations, creating short podcasts that provide a detailed account of the process involved. Next, students create additional pages for the interactive guide that explains each of the target mathematical vocabulary, notations, and syntactic structures used in solving these problems. On these pages they include text, graphics, graphs and tables as appropriate. Students then create hyperlinks from all the appropriate words and phrases on the main page of the guide to these additional pages.

Classroom Vignette 2: Using Complex Text on an iPad App

Using complex texts is a practice not usually associated with kindergarten students. However, understanding the elements of story structure, and organization and sequence of texts in different content areas, is a critical aspect of this practice, and the process of helping students develop this understanding can begin in kindergarten. Furthermore, it can be done in conjunction with mathematical content and processes. For example, this activity can help students connect mathematical language and symbols to things that occur in everyday life. In addition, it helps deepen their understanding of the sequence of problem solving.

This activity provides young students with contextualized, authentic opportunities to create and interact with texts around mathematical concepts. With the support of an adult, students use math content to create connections among text, images, sound and animation. The activity also highlights the important of linking oral and written language, and facilitates the collaborative production of complex texts that emphasize the social aspects of this process.

Using iPads to Extend Knowledge of Story Structure and Math Content

Miss Hernandez's kindergarten class is engaged in a unit on addition and subtraction. The objective for this highlighted lesson from the math unit is for students to demonstrate their ability to add within 10. The focal mathematical standards are:

CCSS.Math.Content.K.OA.A.1: Represent addition and subtraction with objects, fingers, mental images, drawings, sounds, acting out situations, verbal explanations, expressions, or equations.
CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them.
CCSS.Math.Practice.MP4: Model with mathematics.

The class has previously learned to use an iPad app called Toontastic that enables children as young as five to choose settings and characters for a story, animate scenes, and develop an understanding of story structure and sequence of events. During an earlier language arts lesson, students used Toontastic to develop a retelling of Goldilocks and the Three Bears. In this lesson students will use Toontastic to create an addition or subtraction story arc.

Before opening Toontastic, students pick out the manipulative (e.g., plastic spiders) and corresponding story mats that they want to use for telling their math story. Next, students choose an equation the story will be about using numbers that do not add up to more than 10, e.g., $6 + 4 = 10$. Working with the teacher's aid or a parent volunteer, students move the manipulatives on the story mats while simultaneously dictating their stories to the adult who writes the child's words on the lines next to the picture boxes on the story arc. (See Figure 3) Finally, the children illustrate the three scenes on the story arc sheet so they will have a clear idea of what to draw when using Toontastic.

Figure 3. Math paired conversation protocol

Paraphrase and clarify problem for one another (pairs)
(What is asked; what is given; what happens; what the units are; possible plans for solving it)
TALK

Estimate the answer
(Each partner generate and justify own estimate; then compare them)
TALK

METHOD A *(name it)*		**METHOD B** *(name it)*	
Visuals, Drawings, Charts, and/or Symbols	Justify *(using sentences)* ***TALK***	Visuals, Drawings, Charts, and/or Symbols	Justify *(using sentences)* ***TALK***
Calculations/Solution	Justify *(using sentences)* ***TALK***	Calculations/Solution	Justify *(using sentences)* ***TALK***
Check answer and compare to estimated ones ***TALK***		Check answer and compare to estimated ones ***TALK***	

Discuss (argue) which method you would recommend for problems like this. Why?
TALK

Discuss connections between the two methods
TALK

Generate a final summary for how to solve problems like this; use this problem as an example.
TALK

Co-create a similar problem, write it on the back, and solve it (then share the problem with others)
TALK & WRITE

Miss Hernandez then gives each student an iPad and tells them to open Toontastic. Working with their adult partner, the children do the following:

1. Retell what is written on the story arc sheet;
2. Illustrate what is drawn on the story arc sheet;
3. Manipulate the students' Toontastic drawings in sequence with the narration of their stories;
4. Manipulate an arrow so that it points to each number and symbol in the equation during the climax scene;
5. Select appropriate music to accompany the stories.

Classroom Vignette 3: Fostering Academic Interactions with Online Presentation and Feedback Applications

In this activity, two students engage in CCSS Mathematical Practices as they negotiate meaning to solve a complex math problem. The Math Paired Conversation Protocol (see Figure 3) helps students to structure their interactions. Notice that in the first two boxes, students need to talk after reading through and thinking about the problem. They also need to justify their responses throughout the process. As you see in the protocol, an important feature is working through at least two different ways to go about solving the problem. One method might be visual such as using a drawing or graph, while another might be using symbols or algebraic expressions. Sharing these methods online with other students provides additional opportunities to give and receive feedback.

Using Online Feedback Applications

Ms. Pitta is teaching her fifth grade students to analyze patterns and relationships related to operations and algebraic expressions. The focal math standards are:

CCSS.Math.Content.5.OA.B.3: Generate two numerical patterns using two given rules.
CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them.
CCSS.Math.Practice.MP3: Construct viable arguments and critique the reasoning of others.

Ms. Pitta provides a problem about two different salary options an employer offers to a new employee. Working in pairs, students are asked to use to the Math Paired Conversational Protocol to determine which option the employee should accept and develop a rationale for their choice. (See Figure 3.)

After clarifying the problem and estimating the answer, students take another look at the problem to think about it individually. Each shares a possible method for solving it and they agree on a first method (Method A) to try. They then develop a justification for the method that they practice verbalizing to one another. They can use a frame such as *One reason we chose this method was because it….* Students then solve the problem with the Method A and compare their answer to their estimates.

Next, students discuss ideas for Method B, practice justifying it with one another, and solve it. They compare the two answers and the estimates, and discuss any inconsistencies and possible reasons for them. Students come to an agreement on which method is better (e.g., clearer, more efficient, easier) and conclude by developing a justification for the method they chose.

The final step in the activity is for each pair of students to share their work online using Voicethread. After all completed protocols have been shared online, the students engage in online annotations and discussion of the other group's work. In Voicethread they can add both oral and written annotations. These products could be shared with others in Ms. Pitta's class or in a different fifth grade classroom. This additional step allows for further consideration of multiple problem solving methods and encourages students to push themselves to use academic language in their oral and written exchanges and final product.

CONCLUSION

In summary, all three vignettes illustrate ways in which teachers can utilize technology to:

- Provide students with multiple opportunities for language production, interactive learning experiences, and task engagement;
- Create environments in which students encounter realistic problem situations and choose pathways and strategies for problem solution;
- Change the role of students from passive recipients of information to active, strategic learners choosing instructional resources and methods of learning;
- Enable students to figure out the meaning of new words in a particular message, use a variety of sentence types to clarify a message, and combine organizational and text features to communicate, clarify and negotiate meaning.

The overall goal should be the integration of academic language, technology and the communication of math understandings. Utilizing these approaches, teachers can provide effective and innovative math instruction that facilitates the academic language development of all their students, particularly ELLs.

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KEY TERMS AND DEFINITIONS

Academic Language: Vocabulary words, phrases, and other language functions associated with academic fields and/or specific content areas such as mathematics.

Essential Practice Frames: Groups of practices that include a research-based high-impact essential practice and three high-leverage instructional practices.

Multimodal Guides: Resources that have multiple modes and types of activities to support students' mathematical learning and use of academic language.

Online Feedback Applications: Internet-based applications that give learners immediate feedback on their performance.