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Unlocking the Language of Mathematics to Ensure Our English Learners Acquire Algebra

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Each year, tens of thousands of California students fail courses in algebra

In spite of the attention and resources invested in curricula, instruction, and assessment, overall algebra acquisition continues to be painfully slow and inadequate, especially for our state's English learners. Without a strong command of both common everyday language and specialized mathematical language (in English) California's English learners cannot fully engage the mathematics content of the lesson or assessment item. Although professional development for mathematics instruction in California includes some specific strategies to address English learners' needs, the state's current models scarcely address the range of linguistic issues hindering English learners' performance.

Mathematics has the greatest impact on English learners than any other content area

As a key "gatekeeper" to entrance into higher education, mathematics has had a greater impact on general advancement for English learners than any other content area except for English itself. No other mathematics content filters out English learners faster than algebra. Algebra allows students to move from concrete to abstract thinking. Though there are many variables (such as poor teaching, socioeconomic status, parents' education, students' self-esteem, etc.) that may influence English learners' learning, the common link among difficulties endured by these students is language. The typical mathematics instructor speaks only English, and is inexperienced and inadequately prepared to teach mathematics content to students who are learning English and assess their mathematical understanding.

Pre-service courses and in-service professional development need retooling

California's pre-service courses and in-service professional development need retooling to address the mathematics learning needs of the state's largest and fastest growing population of mathematically starved students—English learners—and the state can play a vital role by demanding:

- Mathematics curricula, instruction, and assessment that anticipate the language needs of English learners for learning rigorous mathematics content and for communicating their mathematical understandings to others
- Resources, incentives, technical support, and information that facilitate English learners' mathematics acquisition
- Equitable distribution of mathematics learning resources, including highly qualified mathematics teachers with specific training in meeting English learners' language needs.

Background

- **Enrollment data — English learner population growing**
  During the 2002–03 school year, 1.6 million English learners were enrolled in California public schools, making up 25.6% of all California K-12 public school students. Over 84.3% of California English learners, or 1.35 million, are Spanish-speaking. More than 310,000 (of the 1,600,000) English learners attended middle school (grades 6-8) (CDE, 2003). Students first come into regular contact with algebraic content and language in middle school.

- **Assessment data—English learners scoring low on tests**
  In California, only 32% of 6th grade English learners and 20% of 8th grade English learners scored at or above the 50th national percentile ranking (NPR) on the 2001-02 Stanford 9 Mathematics Exam (CDE, 2003). These data point to chilling future consequences. On the 2002-03 California High School Exit Exam – Mathematics (CAHSEE-M) field test (administered to students in grades 10-12), less than 50% of the Redesignated Fluent English Proficient students (former English Learners) passed. Worse still, less than 23% of English Learners passed (CDE, 2003). These low scores are particularly relevant because more than 36% of all the CAHSEE-M items are derived from the Algebra strand within California's mathematics standards (CDE, 2003).

- **Interpreting the assessment data—English learners face a triple challenge**
  Though mathematics concepts are universal, mathematical language is not. Though certain mathematical notation is recognized worldwide (($f($x$)$, $\Delta y/\Delta x$, π, etc.), the overwhelming majority of vocabulary (*coefficient*, *function*, *factor*, etc.) as well as many of the language and discourse structures in mathematical English are unique to English. Further, the more advanced the mathematics content is, the more language-dependent it becomes. For English learners, the ongoing *triple challenge* of simultaneously acquiring 1) "everyday" English, 2) mathematical English, and 3) new mathematics content, can be quite daunting.

Yet, mathematics teachers who consciously integrate all three components into their daily instruction can directly help English learners acquire mathematical understanding and communicate that understanding to another person. However, being sensitive to identifying and remedying possible linguistic difficulties, even in a familiar problem-solving context, is not easy.

For example, take a common type of problem:

> *At a bake sale, María had 50 cookies to sell. María sold 7 cookies per hour.*
> *After 6 hours of selling, how many cookies were left?*

While most instructors would ensure that their students understood that *7 cookies per hour* is a constant rate of change (a key middle school mathematical concept), they would not anticipate that English learners might confuse the intended meaning of *left* ("to remain") with other common meanings and forms, such as direction ("turn left") or motion (she "left the room"). Further, asking English learners solely to memorize that *left* in one specific instance means *remain* is woefully inadequate and potentially injurious, because the question could be rewritten in several forms: *How many cookies were left over? How many cookies did she not sell? How many cookies were left unsold? How many cookies went unsold?*

Results from this study

Using results from a 2001-02 study of 221 students from two low-performing California middle schools, researchers found that many specific linguistic difficulties hindering English learners' performance in algebra can be categorized into two groups: obstacles to understanding the algebra task, and obstacles to communicating the correct response.

The three most common language obstacles to understanding an algebra task were:

- **Unknown or misunderstood vocabulary** - e.g., *Figure number (n), pattern*, *extension*
- **Incomplete understanding of syntax** – e.g., not recognizing in the query *Each time the figure number increases by one, the number of blue squares changes by* <u>*how many*</u>*?* the comma is the sole indicator of the "given-then" construction of the entire interrogative
- **Unanticipated contradictory visual cues** – e.g., when asked to draw the next iteration of a linear pattern, the student focuses on the size and shape of a given visual aid instead of the pattern itself.

For example, English learners often misinterpret what a task is asking and set about trying to solve the wrong problem. Or, the student might misunderstand a key word needed to understand the math concept required to solve the problem. When a student had neither an accurate understanding of the task nor a complete understanding of a mathematical concept (not an unusual event when students are in the process of learning), the student generally trusted her language competency over her mathematical competency, especially if the mathematical understanding appeared weak to begin with. Finally, moving from non-mathematical language to mathematical language for task instructions increased the difficulty in understanding the task's directions.

As a result, language and mathematics obstacles compounded one another, and many students in the study thought they understood a task, when they did not. This "false-knowing" phenomenon is truly alarming, as these students represent the English learners who are attempting to build new mathematical knowledge on top of developing, but faulty English language foundations. If students are unaware of their own linguistic misunderstandings, they will not be motivated to ask the appropriate questions or to seek outside help to correct them.

Researchers also found that sometimes, students came up with a correct answer to a task, but for the wrong reason. A teacher would likely overestimate those students' mathematical understanding. Conversely, those students who understood and solved the problem, but incorrectly communicated their answers would likely have their mathematical understanding underestimated. Overall, these linguistic patterns of difficulty impeded students' access to the mathematics of the tasks.

Driven by state and national standards-based instruction and accountability movements, all students are expected to learn the rigorous mathematics content of a 1-year or 2-year algebra course. To meet this goal, state policy has focused almost entirely on defining content, approving curricula, promoting specific classroom pedagogies, and assessing student results. Glaringly absent from both policymaking and practice has been attention to the language needed by teacher and student for them to interact mathematically.

What can the state do: Policy and practice recommendations

1. Retool pre-service courses and in-service professional development

To enact sorely-needed systemic change, teachers need to value and actively participate in ongoing, on-site, professional development centered around four main components: 1) language acquisition, 2) rigorous mathematical content, 3) the interactions between language acquisition and mathematical learning, and 4) equity – from the moment they walk into their first pre-service class until the day they retire, understanding why meeting English learners' needs is just as important as meeting non-English learners' needs, and continually learning, honing, and upgrading their skills.

2. Redefine the role of the mathematics teacher

Such new and improved professional development will necessitate redefining the role of the mathematics teacher. Every mathematics teacher must now view herself as a language teacher too. In addition to having extensive mathematical training and understanding, she must be cognizant of the language she uses in her instruction and assessments and anticipate the language needs of her students. She must be able to teach students to become independent monitors of their own language and mathematics needs. And, mathematics teachers should draw on linguistic strengths the English learners already bring to the classroom, which largely go untapped.

3. Revamp curricula and assessments

To support the instructor's new role, California should only approve mathematics curricula and assessments that anticipate and then avoid unintended comprehension problems. Current curricula and assessments unnecessarily employ unfamiliar contexts (page one of widely-used algebra textbook introduces *variable* through an elaborate scuba-diving scenario) and obtuse language that obscures meaning. As a result, students spend more energy misunderstanding and less time learning mathematics.

Language must become a mathematics focus

It is no surprise a large number of California middle school English learners have become averse to learning mathematics and believe that they are incapable of understanding math. Using manipulatives and facilitating cooperative group learning are the two common classroom strategies promoted to make mathematics instruction more comprehensible, but even here, too little attention is paid to the language needed to make these strategies viable.

By ensuring increased awareness of English learners' language needs in algebra classroom and supporting the development of programs that meet English learners' needs in all mathematics classrooms, State policymakers can help narrow the achievement gap between English learners and non-English learners.

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