Research Précis

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EARLY NUMERACY:

Number and Language

Though there is much about the concept of number that is distinctly domain-specific, language plays an important role in both the early development and the lifelong application of those concepts. Difficult to isolate locally in terms of effect on number learning at the preschool and early elementary level, language requirements nonetheless permeate the expectations of kindergarten and early elementary mathematics standards and assessment/screening instruments. Furthermore, the very notion that seems to fly in the face of importance of language—the much-touted "universality" of numbers—has allowed unique evidence of the profound effects of language on young children' s developing mathematical understandings.

Essential role of language in mathematics: Preparation for future instruction, impact on validity of diagnosis and assessment, vehicle for natural processing of ideas in building early understanding

> Reading mathematics is somewhat like reading *The Iliad* in its original Greek…

It has been 15 years since the U.S. National Council of Teachers of Mathematics asserted in the *Curriculum and Evaluation Standards for School Mathematics* that "mathematics and literacy are intertwined" (National Council of Teachers of Mathematics [NCTM], 1989). Actually, mathematics *is* a language, and reading a mathematics text is somewhat like reading Homer's *The Iliad* in its original (Greek) language. Though solid research evidence remains scant, the importance of the language of mathematics—oral and print (e.g., reading and writing)—is reaffirmed through research literature review. Martinez (2001) clarifies reasons for assigning value to learning the language of mathematics by explaining that we teach and communicate through language, we use students' oral and written communication to assess mathematics understandings and to diagnose strengths and weaknesses, and students process their ideas through language as they build understanding. Insofar as our reliance on language in teaching and communicating mathematics, the relevance of the Homer analogy cannot be overstated. Though we hopefully do not use language nearly as complex with young school-age children, they nevertheless must be able to read and comprehend the language of mathematics for their mathematical understanding to progress beyond the early elementary years. Writing *The Iliad* could be even more challenging. Yet, writing mathematically (and with a command of symbols, at least in the school-age years) is essential for students' progress (Rubenstein & Thompson, 2002). The Communication process standard in the latest U.S. national document *Principles* *and Standards for School Mathematics* (NCTM, 2000) underscores this emphasis on communication fluency. A key point in that document is that mastery of mathematics vocabulary is essential if a student's ability to speak, read, and write mathematics is to enhance rather than diminish his progress in developing further domain-specific understanding. Literature further supports a confluence of perceptions: vocabulary is essential for communication and extending mathematical understanding (Raiker, 2002), provides a means for building confidence (Monroe & Orme, 2002), and students are handicapped without it (Miller, 1993). While the importance of vocabulary—especially oral—in the development of early reading comprehension is documented (read about vocabulary and oral reading comprehension), domain-specific meanings in any field pose an added challenge to educators. Though not exceptional in this regard, this is an important consideration in mathematics, where teaching (and teaching with) unfamiliar words is a given (Schell, 1982), and where mathematical words transferred outside of the classroom assume a much more ambiguous nature that is detached from the actual mathematical *context* in which they typically appear (Raiker, 2002). Munroe & Orme (2002) reassert the importance of context, and claim that mathematics instruction encourages the teacher and student communication that provides the context for learning the language of mathematics. Vacca and Vacca's (1996) conclusion that most vocabulary words must be "taught directly and taught well" is partially true, as is the idea that even in preschool students are certainly capable of dealing with this instruction—by the age of four many preschool children recognize numerals and are even showing interest in writing them (Althouse, 1994). It's a good thing, because young children are expected to read and write numerals up to ten by the end of kindergarten (Brigance, 1997), and this among other language expectations is measured either implicitly or explicitly through our reliance on vocabulary and language in our diagnosis and assessment instruments (see sidebar).

Language influences number concept diagnosis and assessment…

… on many tests that are used to diagnose or identify young children's existing and potential mathematical strengths. For example, the Peabody Individual Achievement Test - Revised (PIAT-R; Markwardt, 1989) tests understanding of words and terms beyond memorization by requiring the child to match correct numerals to number of objects in a group, and point to pictures that correctly indicate terms (e.g., bigger, taller, equal, etc.). The Einstein Evaluation of School-Related Skills - Kindergarten Level (Gottesman & Cerullo, 1996) and the Wide Range Achievement Test - 3 (WRAT3; Wilkinson, 1993) both address terms as well as the abilities to read, comprehend, and follow directions through word problems. Children must also be able to count—usually using fingers—to do well on the above tests. This language-based skill of counting is also assessed in the Brigance Comprehensive Inventory of Basic Skills - Revised (CIBS-R; Brigance, 1999), the Wechsler Preschool and Primary Scale of Intelligence, 3rd ed. (WPPSI-III; Wechsler, 2002), and the Stanford-Binet Intelligence Scales, 5th Edition - Quantitative subtest (Roid, 2003).

Visit links above for information on these tests. For additional information on a variety of other test instruments, go to:

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Yet, Thompson and Rubenstein's (2000) concept of "enculturation" with the language of mathematics bears further thought, especially with regard to learning at the preschool level. Comparisons of student gains in mathematics understanding resulting from directive (formal) instruction and nondirective (informal) learning, though not specifically language-related, showed little supportable difference (Whitehurst, 2001), and in response, Elkind (2001) stated bluntly that the whole notion of comparison is overdone and that both (formal and informal learning) are important. Conversely, related to vocabulary but not specifically mathematics, it is noteworthy that highly regarded language and reading specialists (Beals & Tabor, 1996; Dickinson & Smith, 1994; Snow, 1991) find strong correlations between the young preschool child's vocabulary learning and the opportunity afforded by informal interaction (e.g., mealtime conversation), around the home as well as at school or daycare. Finally, though the expertise of the advocates for strong language-number correlation is unquestionable, and cannot be discounted, these viewpoints still largely remain just that—viewpoints; it is very difficult to isolate language variables within a highly pluralistic society; what children do not share a wide array of language commonalities (in counting, vocabulary, spatial references, etc.), and what linguistic characteristics can actually be isolated among test and control groups with a high degree of validity?

International comparisons: Preschool number concept understandings across language types

Though the principles of counting are constant, as with the underlying concepts of number, we know that the counting words and numeral symbols vary with the number system and language within which the preschool child forms their early conceptions of number. Although the variables cannot be completely isolated, we also know that children from word-rich environments do better on the above assessments than children from environments where mathematical vocabulary is more sterile or even incorrect. As well, we see a corpus of findings that seems to indicate that children's understanding of number is impacted by differences between linguistic aspects of numeration systems in different countries, particularly as they relate to the structure of the number words (their similarity or dissimilarity to the numerals they represent) and the speed with which they can be spoken. This is especially evident in studies related to children's understandings of concepts included in NCTM's Number and Operations standard, most notably in objectives tied to calculation, where children's use of counting, memory, verbal reasoning, and base-10 structure awareness are critical to their success.

> "38" is "three ten eight" in an Asian language…

Number words in some languages are structured more in keeping with their written form and the numeration system used. For instance, in Asian languages 12 is spoken as "ten two" and 38 as "three ten eight," clearly not the case in most European systems, including English. Findings, most notably in studies comparing Asian- and English-speaking children, indicate that children reared in environments where language systems more closely represent numerical structure develop stronger understanding of place value and base structure, as well as mathematical computations that build from these understandings (Fuson & Kwon, 1991, 1992). When numbers are linguistically organized as structures of tens and ones, place value seems to becomes part of young children's implicit learning, facilitating understanding of base-10 structure of two- and three-digit written numbers before being introduced to tens and ones in school and earlier than their French-, Swedish- and English-speaking counterparts, both of whose conceptions are more likely to be based on single units, and who are less likely to understand individual digits in written numerals (Fuson, Zecker, Lo Cicero, & Ron, 1995; Miura, 1987; Miura, Okamoto, Kim, Chang, Steere, & Fayol, 1994). Similarly, when performing simple written addition calculations, Korean children in second and third grades were more likely than American children to correctly identify "carry marks" above the tens column as a value of ten, another indication of understanding place value (Fuson & Kwon, 1992). Interestingly, even with higher structural language-number congruency than in English, Asian-language number words can be spoken more rapidly. National differences in number memory span across languages (Stigler, Lee, & Stevenson, 1986) may possibly be attributed this phenomenon. Considering also that Asian-speaking children learning to count have less to memorize structurally—the first nine in sequence (largest to smallest) rather than 19, and words for powers of ten (e.g., ten, hundred, etc.) rather than both powers of ten and decade numerals (e.g., twenty, thirty, etc.)—it may make common sense that Chinese children have a numerical span that exceeds that of English-speaking children by 2.6 digits (Geary, Bow-Thomas, Fan, & Siegler, 1993), make fewer errors speaking number words through 19 than do children in the U.S. (Miller & Stigler, 1987), and Korean children demonstrate mastery of counting earlier than their U.S. counterparts (Song & Ginsburg, 1987). When working with addition calculations in which counting is typically employed, even with addends (numeral values involved) less than 5, Chinese kindergarten children solved three times as many addition problems than U.S. children, and were also more likely to use verbal counting in their solutions (Geary et al., 1993).

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