CHILDREN SOLVING WORD PROBLEMS IN AN IMPORTED LANGUAGE: AN INTERVENTION STUDY

DEBBIE BAUTISTA VERZOSA

Macquarie University

debbie.bautista@students.mq.edu.au

This paper reports on one aspect of a two-year design study aimed to assist second-grade Filipino children solve additive word problems in English, a language they primarily encounter only in school. With Filipino as the medium of instruction, an out-of-school pedagogical intervention providing linguistic and representational scaffolds was implemented with 17 children. Pre-intervention, children experienced linguistic difficulties and were limited to conceptualising and solving simple additive structures. Post-intervention interviews revealed improved understanding of more complex structures, but only when linguistic difficulties were minimised.

Filipino children from disadvantaged families are expected to learn mathematics and solve word problems in English, a language they primarily encounter only in school (Young, 2002). Thus, it is not surprising that many Filipino students who have completed two or three years of schooling are unable to solve even simple addition and subtraction word problems (Bautista, Mitchelmore, & Mulligan, 2009; Bernardo, 1999). While language problems often arise as a cause for poor performance in mathematics (Philippine Executive Report on the TIMSS, cited by Carteciano, 2005), what is not clear is whether lack of English language proficiency is the main reason for Filipino children's poor problem-solving performance. This study attempts to provide insight into these issues by addressing the following research questions:

1. Is the failure to solve problems due to linguistic difficulties and/or to an inadequate understanding of the semantic structure and associated mathematical relationships in the given problem?
2. Is it possible to improve young Filipino children's strategies for solving addition and subtraction word problems presented in English?

Although the study was conducted in the Philippines, it has applications to similar contexts where children learn mathematics in a language not widely spoken in the community. Such is the case in remote Indigenous communities in Australia, as well as in several developing nations in Asia and Africa.

Theoretical background

The classification of addition and subtraction word problems according to their semantic structure (see Table 1) has formed the basis of a long tradition of research on addition and subtraction word problems (Carpenter & Moser, 1984).

Table 1. Some types of addition or subtraction word problems.

Problem Type	Problem
Join	Alvin had 3 coins. Then Jun gave him 8 more coins. How many coins does Alvin have now?
Separate	Dora had 11 mangoes. Then Dora gave 6 mangoes to Kevin. How many mangoes does Dora have now?
Combine	Tess has 5 hats. Rodel has 8 hats. How many hats do they have altogether?
Missing Addend	Jolina had 7 pencils. Then Alma gave her some more pencils. Now Jolina has 12 pencils. How many pencils did Alma give her?
Part Unknown	Jimmy and Mia have 11 marbles altogether. Jimmy has 4 marbles. How many marbles does Mia have?
Compare	Rica has 12 books. Luis has 7 books. How many more books does Rica have than Luis?
Equalise	Rica has 12 books. Luis has 7 books. How many books does Luis need to have the same number of books as Rica?

Recent theories on word problem solving processes have drawn on the text comprehension theories of van Dijk and Kintsch (1983). When solving problems, the solver first integrates the textual information into an appropriate *situation model*, or a mental representation of the situation being described in the problem, which then forms the basis for a solution strategy (Mayer, 2003; Thevenot, 2010). Because the construction of a coherent situation model depends on adequate proficiency in the language of the text (Zwaan & Brown, 1996), children solving problems in a language not widely spoken outside school are clearly disadvantaged. Unless children's proficiency in their second language allows them to use their bilingualism as a cognitive tool (Clarkson, 2007), they struggle with linguistic structures that would not be as problematic for native speakers (Martiniello, 2008).

This is not to say that linguistic factors are the only barriers to problem comprehension and solution. Strong part-whole knowledge and a flexible understanding of number meanings are seen as essential for recognising the structure of additive problems (Poirier & Bednarz, 1991; Zhou & Lin, 2001). For example, children may fail to solve the Missing Addend problem in Table 1 if they can reason about a set only if they know its cardinal measure. In Vergnaud's (2009) terms, they lack essential *concepts-in-action*. Interestingly, the advantage of expertise in the problem domain (in this case, part-whole knowledge) on the construction of situation models is widely recognised in text comprehension research (Hirsch, 2003).

Method

The intervention study reported here is part of a larger project aimed to improve word problem solving performance in the Philippine context. A design research methodology

(Lesh & Sriraman, 2010) was adopted, as it is particularly appropriate for identifying and responding to conditions for success (Dede, 2004). The study involved several iterations of assessments and interventions (Table 2).

Data reported in this paper refer to 17 children (11 girls, 6 boys; mean age: 7.8 years) from public schools in the Greater Manila area who voluntarily participated in a parish-based tutorial program from June to September 2009. They were taught in shifts of 4-8 students by the author and two volunteer tutors who were trained on the pedagogical approach.

Table 2. Design study process and timeline.

Oct-Nov 2008	Feb-Mar 2009	Apr-May 2009	Jun-Sep 2009	Oct 2010
Written test (*N* = 75) Interview (*N*=7)	Written test (*N* = 348) Interview (*N*=50)	Pilot intervention (*N* = 90)	Intervention (*N* = 17)	Community consultations (*N* = 23 teachers)

Consistent with features of a design study, pedagogy was informed by an integration of van Dijk and Kintsch's (1983) linguistic comprehension theory and Vergnaud's (2009) theory of mathematical learning, as well as by earlier stages of the study (Table 2). The following section briefly describes how the pedagogical approach was designed.

The decision to use Filipino as the medium of instruction during the intervention, to provide word lists of common English words, and to present text in simplified formats was based on several convergent findings. First, two written tests administered to two different samples of Grade 2 and Grade 3 students (Bautista, Mitchelmore et al., 2009; Bautista & Mulligan, 2010a) confirmed that Filipino students were more successful in solving word problems written in Filipino than equivalent problems written in English. Second, interviews with 57 children from 15 public schools (see Bautista, Mulligan, & Mitchelmore, 2009, for interviews with 7 of these children) showed that children could not use English even for social conversation, and a considerable number used Filipino rules to decode English text, making it very difficult to teach them in English.

Because it was hypothesised that word problem solving involves more than linguistic competence (Vergnaud, 2009), the intervention aimed to strengthen children's concepts-in-action by presenting each additive structure in Table 1 through a range of representations (Lesh, Post, & Behr, 1987). For example, a concrete representation for the Separate problem structure in Table 1 was to briefly display, then screen, 11 counters (Wright, Martland, & Stafford, 2000). Without allowing the child to see, 6 counters were then removed. The child was then asked in Filipino, "There were 11 counters, but then I took away 6 counters. How many counters are there now?" These various representations were particularly helpful given that the children in this study struggled with textual representations (Bautista & Mulligan, 2010b).

The primary data source was the individual scaffolded pre- and post-intervention interviews illustrated in Figure 1 (see Bautista & Mulligan, 2010b for details). In essence, the interview schedule involved presenting the first six word problems in Table 1 for the child to read and solve in English. However, if the child reached an impasse, successive linguistic and mathematical scaffolds were provided. The mathematical scaffold was either a concrete representation of the task or a transformation of the

Compare problem to a mathematically simpler Equalise task (see Table 1). All number triples were in the range 1-20, and based on Carpenter and Moser's (1984) procedure. Pre- and post-intervention tasks differed only in their surface elements (e.g., using mangoes instead of coins) and in the number triples used. The interviews were conducted in Filipino by the author.

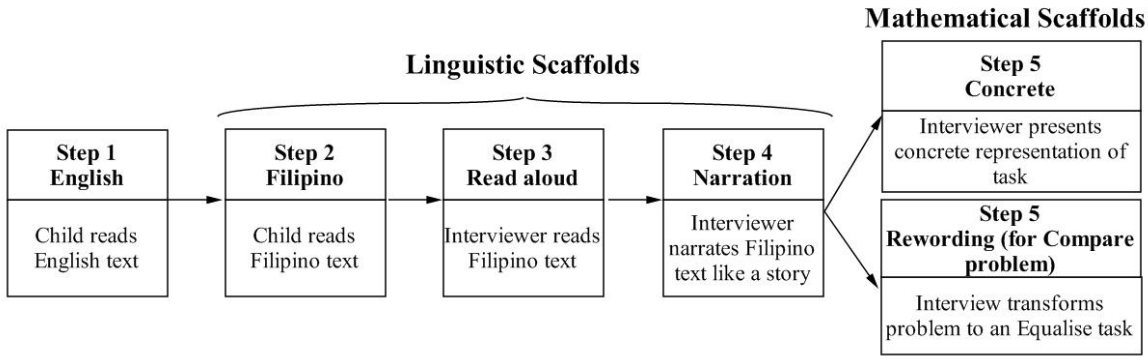

Figure 1. Structure and sequence of the interview protocol.

Results

The results are discussed in terms of the two research questions.

Linguistic and/or mathematics difficulty?

The scaffolding techniques in the pre-intervention interviews were used to investigate to what extent linguistic or mathematical factors impeded word problem solving. The Pre-intervention graph in Figure 2 shows the type of scaffold that facilitated correct solutions. Darker areas in the graph represent instances when linguistic scaffolds were necessary and sufficient for success. The extent of the dark regions shows that the children were dependent on linguistic scaffolds—very few of them could solve problems in English, without assistance. However, the linguistic scaffolds were primarily helpful for the Join, Separate and Combine problems. In contrast, the linguistic scaffolds facilitated correct solutions for less than a quarter of the children for the remaining problems, indicating underlying mathematical difficulties.

Linguistic difficulties were reflected in children's struggle to interpret the text. Thirteen children had difficulties in decoding text (7 in English, 6 in Filipino), and one could not read at all. Further, several children knew only a few basic English words. For example, 11 children did not understand the statement, "Alvin had 3 coins." Difficulties in retrieving textual information also occurred for Filipino problems. For example, 4 children could not identify the giver from the Filipino translation of the statement, "Then Alvin gave her 8 more mangoes."

Mathematical difficulties were observed in the Missing Addend, Part Unknown, and Compare problems. Some children were limited to conceptualising and reasoning about disjoint subsets with known quantities. For example, C7[1] constructed two disjoint sets, instead of one set having a subset for the Part Unknown problem, even when a corresponding concrete task had been provided, and even when smaller numbers were

[1] To preserve anonymity, codes were used in place of children's names. The coding conventions will be explained in a later section.

used (2 + □ = 6). Only 10 children correctly solved the Compare problem, pre-intervention, and 8 of these managed to solve only the corresponding Equalise task.

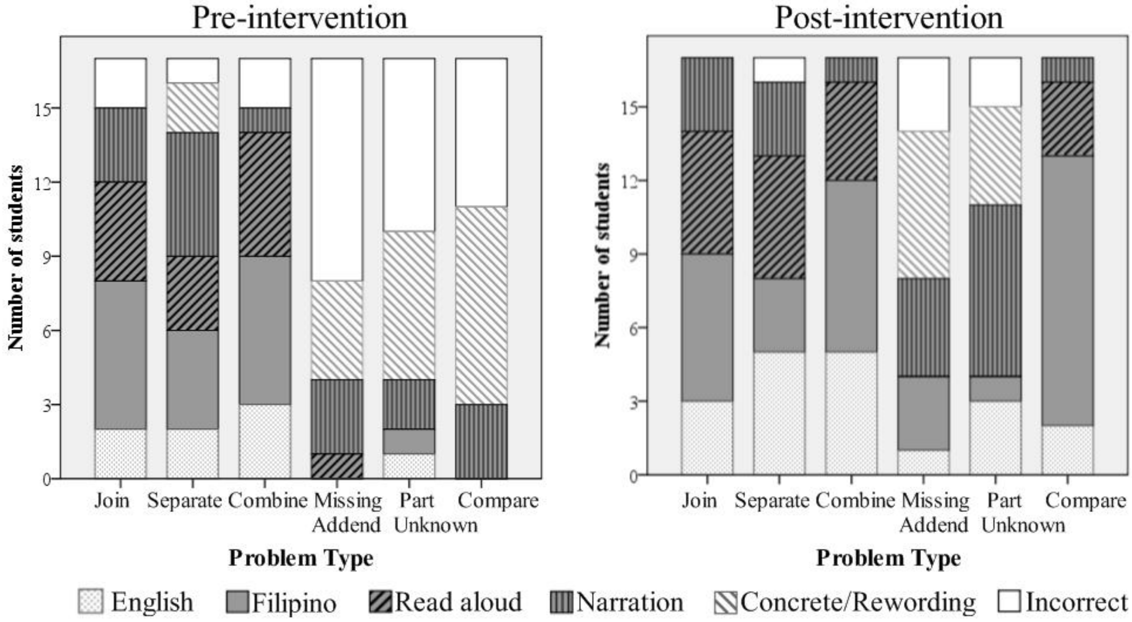

Figure 2. Text processing strategies before and after the intervention.

Intervention outcomes

The Post-intervention graph in Figure 2 presents the step in the interview, post-intervention, at which a correct solution was achieved. While performance on the Missing Addend, Part Unknown, and Compare problems improved post-intervention, the children's unfamiliarity with the language continued to prevent them from solving word problems presented in English. When A2 was asked if there was any word he did not understand, he looked at the text and said, "*Lahat 'yan* [All of them]." The words directly taught during the intervention were largely just memorised. When C5 was asked what "more" meant, she said, "*Nakalimutan ko* [I forgot]."

Children were also found to construct a situation model based on isolated words from the text. For example, C2's understanding of "Alvin had 3 coins" was reduced to one word: "*Pera* [money]". Having been exposed to various additive structures during the intervention, however, some children tried to determine which of these structures matched the problem text. For instance, after B2 read the English Missing Addend problem, she asked whether it was an "*Ilan yung lagpas* [How many more]" task.

Individual student profiles

To further investigate the outcomes of the intervention, an analysis of each child's progress was made. An analysis of the interviews revealed that children could be classified into distinct categories according to their (1) level of mathematical strategies, and (2) level of text processing strategies. Table 3 describes children's increasing levels of mathematical strategies, from counting strategies to more advanced relational strategies (e.g., calculating 9 + 6 as 9 + 1 + 5). Similarly, Table 4 shows levels of text processing strategies, which are based on the interview structure in Figure 1.

Table 3. Most sophisticated strategy observed at each level.

Level	Addition Strategies	Subtraction Strategies
1	Erroneous Strategy/Count All	Erroneous Strategy/Separate
2	Count All	Separate
3	Count On	Count Up
4	Mental	Mental
5	Bridge-through-ten/Compensation	Bridge-through-ten

Table 4. Level of text processing strategies.

Level	Description
1	Needed to have the text elaborated or concretely presented to them for most problems
2	Could use Filipino text to solve word problems, albeit limited to Join, Separate, and Combine problems
3	Could use Filipino text to solve at least one of the Missing Addend, Part Unknown, and Compare problems
4	Could use English text to solve at least three problems

The matrices in Figure 3 display the levels for each child pre- and post-intervention along two dimensions: mathematical and text processing levels. The pre-intervention matrix was divided into four regions (A, B, C, and D), representing various combinations of high and low levels on each dimension. Children were then assigned codes based on the region where their results were located in the matrix. For example, children in the upper right region were all prefixed B. This system was developed in order to more easily compare pre- and post-intervention results. The numbers in parentheses represent the number of problems each child solved correctly.

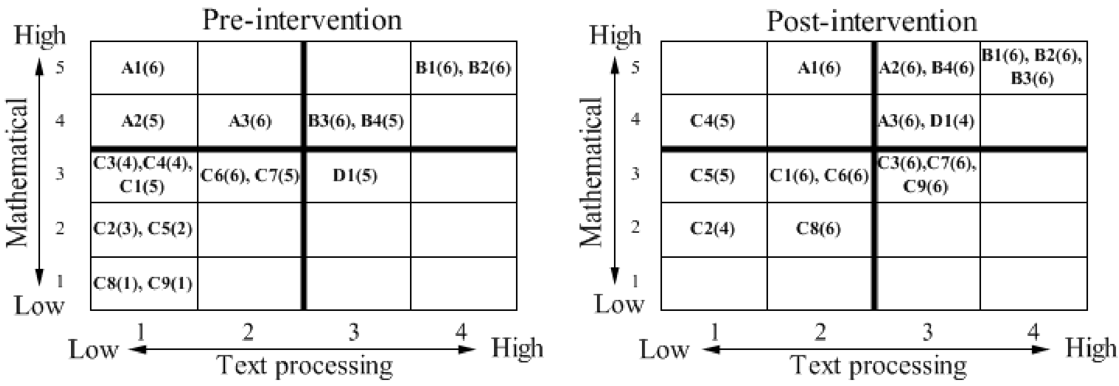

Figure 3. Student profiles before and after the intervention.

Prior to instruction, children's mathematical levels were associated with the number of word problems they solved correctly. Children at higher mathematical levels tended to solve more problems than those at lower mathematical levels. However, post-intervention, it became possible for children with low mathematical levels to solve five or six problems. Remarkably, all children who could solve problems in English (Level 4 in text processing) could also utilise sophisticated mathematical strategies (Level 5 in mathematics), both pre- and post-intervention.

A comparison of the matrices demonstrates how each child progressed during the intervention. However, the matrices also reveal conditions for success. For instance, the only children who reached Level 5 in mathematics were those prefixed A and B. Thus, these were children who already utilised a range of strategies before the intervention. The rest of the children continued to count by ones. Similarly, post-intervention, only three children could solve word problems in English (Level 4 in text processing), and they were all prefixed B. These were the children who, prior to the intervention, could solve some of the more difficult problems without the need for read-aloud or narration supports. In contrast, seven children continued to rely on substantial help from the interviewer. These seven included two children who, in spite of having low text processing levels, had high mathematical levels—A1 who was a non-reader and C4 who read one syllable at a time, often with errors.

Discussion

Although this part of the larger study involved a small sample, which does not permit generalisation, the results provide a rich description of how language proficiency and reading skill interact with word problem solving performance. There were apparent linguistic difficulties observed, as when children could not understand simple English statements, or when reading difficulties prevented them from retrieving information explicitly stated in the text. Indeed, these challenges were more pronounced than those commonly reported in the literature, which tends to relate to difficulties with academic, rather than conversational, language (Fillmore, 2007), and to comprehension difficulties associated with ambiguous text (Cummins, 1991).

This is not to say that linguistic difficulties were the only obstacles to solving word problems. Mathematical difficulties were uncovered, but only when linguistic difficulties were minimised through the provision of linguistic scaffolds. Consistent with findings from monolingual children (Carpenter & Moser, 1984), the data indicate difficulties in conceptualising certain semantic structures. Some children found it difficult to conceptualise relations involving comparisons and sets with unknown quantities. Thus, they failed to solve the Missing Addend, Part Unknown, and Compare problems even when linguistic scaffolds were available.

Concerning the attempt to help children solve word problems in English, the findings demonstrate that while it is possible to help children conceptualise a wider range of additive situations and advance their mathematical strategies, children's pervasive reliance on linguistic scaffolds suggests difficulties in mapping the text to mathematical knowledge. To compensate, some children constructed situation models based on a few words and the situations they encountered during the intervention. Although the data could not directly establish that children's weak linguistic skills encouraged such coping strategies, it remains clear that their linguistic difficulties inadvertently presented them with no other option.

The finding that all children who had advanced text processing strategies in English also utilised advanced mathematical strategies suggests possible connections between mathematical strategies and the ability to solve word problems in an imported language. Further research is needed to investigate this conjecture.

Implications

This study has a number of educational implications. First, it critically questions the use of an imported language for mathematics instruction. However, as there are pragmatic difficulties in changing the language policy in Philippine classrooms (Bernardo, 2008), other avenues for coping with language issues need to be explored. Recommendations include code-switching, the development of materials in the local language, and equipping teachers with tools for teaching in the imported language.

Second, as reading difficulties definitely limited children's text-processing strategies, reading comprehension strategies should be integrated into the mathematics classroom (Fogelberg et al., 2008), and reading instruction should be provided to non-readers.

Third, teachers should provide children with opportunities to develop their conceptions of relational structures by creating lessons that incorporate various representations. A range of representations is particularly helpful as children who struggle with one representation may be able to handle other forms of representation.

Fourth, children's continued reliance on unitary counting suggests that they may benefit from an intervention specifically focussed on developing relational strategies (Gersten et al., 2009). Left unattended, these unitary counting strategies may impede performance on multidigit addition and subtraction (Ellemor-Collins, Wright, & Lewis, 2007).

Finally, written tests should be supplemented with individual interviews or informal conversations because language issues may conceal underlying mathematical difficulties. However, considering the onerous time demands these may place on teachers with large classes, a whole-class assessment followed by individual interviews for a target group of low-attaining students may be feasible (White, 2008).

References

Bautista, D., Mitchelmore, M., & Mulligan, J. T. (2009). Factors influencing Filipino children's solutions to addition and subtraction word problems. *Educational Psychology, 29*, 729–745.

Bautista, D., & Mulligan, J. T. (2010a). Solutions of addition and subtraction word problems by Filipino public school children. *Intersection, 11,* 39–60.

Bautista, D., & Mulligan, J. T. (2010b). Why do disadvantaged Filipino children find word problems in English difficult? In L. Sparrow, B. Kissane & C. Hurst (Eds.). *Mathematics: Essential research, essential practice* (Proceedings of the 33rd Annual Conference of the Mathematics Education Research Group of Australasia, pp. 69–76). Fremantle, Western Australia: MERGA.

Bautista, D., Mulligan, J. T., & Mitchelmore, M. (2009). Young Filipino students making sense of arithmetic word problems in English. *Journal of Science and Mathematics Education in Southeast Asia, 32*, 131–160.

Bernardo, A. B. I. (1999). Overcoming obstacles to understanding and solving word problems in mathematics. *Educational Psychology, 19*, 149–163.

Bernardo, A. B. I. (2008). English in Philippine education: Solution or problem? In M. L. S. Bautista & K. Bolton (Eds.), *Philippine English: Linguistic and literary perspectives* (pp. 29-48). Hong Kong: Hong Kong University Press.

Carpenter, T. P., & Moser, J. M. (1984). The acquisition of addition and subtraction concepts in grades one through three. *Journal for Research in Mathematics Education, 15*, 179–202.

Carteciano, J. A. (2005). *NRCP/DOST addresses dire state of S&T education in the regions*. Retrieved December 23, 2008, from http://nrcp.dost.gov.ph/index.php?option=com_content&task=view&id=31&Itemid=106

Clarkson, P. C. (2007). Australian Vietnamese students learning mathematics: High ability bilinguals and their use of their languages. *Educational Studies in Mathematics, 64*, 191–215.

Cummins, D. D. (1991). Children's interpretations of arithmetic word problems. *Cognition and Instruction, 8*, 261–289.

Dede, C. (2004). If design-based research is the answer, what is the question? *Journal of the Learning Sciences, 13*, 105-114.

Ellemor-Collins, D., Wright, R. J., & Lewis, G. (2007). Documenting the knowledge of low-attaining third- and fourth-graders: Robyn's and Bel's sequential structure and multidigit addition and subtraction. In J. Watson & K. Beswick (Eds.), *Proceedings of the 30th annual conference of the Mathematics Education Research Group of Australasia, Hobart* (Vol. 1, pp. 265–274). Adelaide: MERGA.

Fillmore, L. W. (2007). English learners and mathematics learning: Language issues to consider. In A. H. Schoenfeld (Ed.), *Assessing mathematical proficiency* (pp. 333–344). Cambridge, UK: Cambridge University Press.

Fogelberg, E., Skalinder, C., Satz, P., Hiller, B., Bernstein, L., & Vitantonio, S. (2008). *Integrating literacy and math: Strategies for K-6 teachers*. New York: Guilford Press.

Gersten, R., Beckmann, S., Clarke, B., Foegen, A., Marsh, L., Star, J. R., & Witzel, B. (2009). *Assisting students struggling with mathematics: Response to Intervention (RtI) for elementary and middle schools* Available from http://ies.ed.gov/ncee/wwc/publications/practiceguides

Hirsch, E. D., Jr. (2003). Reading comprehension requires knowledge—of words and the world. *American Educator, 27*(1), 10–13, 16–22, 28–29, 48.

Lesh, R., Post, T., & Behr, M. J. (1987). Representations and translations among representations in mathematics learning and problem solving. In C. Janvier (Ed.), *Problems of representation in the teaching and learning of mathematics* (pp. 33–40). Hillsdale, NJ: Lawrence Erlbaum.

Lesh, R., & Sriraman, B. (2010). Re-conceptualizing mathematics education as a design science. In L. D. English (Ed.), *Theories in mathematics education: Seeking new frontiers* (pp. 123–146). Heidelberg, Germany: Springer.

Martiniello, M. (2008). Language and the performance of English-language learners in math word problems. *Harvard Educational Review, 78*, 333–368.

Mayer, R. E. (2003). Mathematical problem solving. In J. M. Royer (Ed.), *Mathematical cognition* (pp. 69-92) Greenwich, CT: Information Age Publishing.

Poirier, L., & Bednarz, N. (1991). Mental models and problem solving: An illustration with complex arithmetical problems. In R. G. Underhill (Ed.), *Proceedings of the 13th annual meeting of the North American chapter of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 133–139). Blacksburg, VA: PME.

Thevenot, C. (2010). Arithmetic word problem solving: Evidence for the construction of a mental model. *Acta Psychologica, 133*, 90–95.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. New York: Academic Press.

Vergnaud, G. (2009). The theory of conceptual fields. *Human Development, 52*, 83–94.

White, A. L. (2008). Counting on 2007: A program for middle years students who have experienced difficulty with mathematics. In M. Goos, R. Brown & K. Makar (Eds.), *Navigating currents and charting directions* (Proceedings of the 31st annual conference of the Mathematics Education Research Group of Australasia, Vol. 2, pp. 573-579). Brisbane: MERGA.

Wright, R. J., Martland, J., & Stafford, A. K. (2000). *Early numeracy: Assessment for teaching and intervention*. London: Paul Chapman Publishing.

Young, C. (2002). First language first: Literacy education for the future in a multilingual Philippine society. *International Journal of Bilingual Education and Bilingualism, 5*, 221–232.

Zhou, Z., & Lin, J. (2001). Developing mathematical thinking in Chinese kindergarten children: The case of addition and subtraction. *International Journal of Educational Policy, Research and Practice*, *2*, 141–155.

Zwaan, R. A., & Brown, C. M. (1996). The influence of language proficiency and comprehension skill on situation-model construction. *Discourse Processes, 21*, 289–327.