# Early Number Concepts: Key Vocabulary and Supporting Strategies

Ann Marie Casserly, Pamela Moffett and Bairbre Tiernan
*St Angela's College, Sligo; Stranmills University College, Belfast; St Angela's College, Sligo*

Teacher-facilitated "math talk" in the early years significantly increases children's growth in understanding of mathematical concepts (Klibanoff et al., 2006). Although young children may have a beginning understanding of early number concepts, they often lack the language to communicate their ideas. Teacher modelling and fostering of mathematical language throughout the day and across various subject areas, allows children to articulate their ideas and communicate their understanding. Encouraging "math talk" in young children as they explain, question and discuss their strategies is important. The teacher plays a significant role in guiding children to make connections, to recognise how their thinking relates to key mathematical number concepts and to make further conjectures and generalisations. This paper will outline the theoretical perspectives underpinning the development of a resource of key vocabulary and teaching and learning strategies for teachers to support their planning and teaching in early number.

**Keywords: number; language; early years**

## Achievement in mathematics

Achievement in mathematics is a key educational concern. Competence in mathematics is essential in meeting the demands of the workplace and in successful functioning in everyday life. However, recent research reports have indicated that many children in the North and South of Ireland are failing to reach the expected levels of achievement in mathematics (DENI, 2011; DES, 2011). Although considerable attention has been devoted to mathematics achievement at primary and secondary levels, the foundations for learning mathematics are established much earlier (Clements and Sarama, 2007).

By the time children enter preschool, they demonstrate wide individual differences in their mathematical knowledge, with children from high and middle socioeconomic status (SES) families showing higher levels of mathematics achievement (Klibanoff et al., 2006). Such early differences are a matter of some concern since levels of mathematics knowledge at the time children enter school have been shown to predict later achievement (Duncan et al., 2007). Success in mathematics in the early years is critical. If children can learn to think mathematically and to express their thoughts in mathematical terms during the preschool years, then they are better prepared to learn formal mathematics concepts upon school entry (Ginsburg, Lee and Boyd, 2008). Austin et al. (2011) argue that neglecting mathematics in the early years might hamper both mathematical development and literacy skills. Duncan et al. (2007) found that early mathematics knowledge is a more powerful predictor of later achievement than early language and reading skills. High levels of mathematical competency are also required to satisfy growing needs for a scientifically and technologically sophisticated workforce (NRC, 2009).

## A socio-cultural perspective on learning

Both socio-culturalists and constructivists recognise the importance of individual activity in learning. While constructivists prioritise psychological processes, socio-cultural approaches give priority to the context for learning, placing emphasis on "the conditions for the possibilities for learning" (Cobb and Yackel, 1998: 184). According to Rogoff (1998), learning arises from both individual activity and participation in social activity. Rogoff's (1995) view is that individual learning cannot be understood outside of an activity or of the people participating in it. She views learning as the development of mind in a socio-cultural context. Children's active participation in an activity is regarded as an important element of the process by which they gain mastery. Rogoff (1990: 7) conceives of children as "apprentices in thinking, active in their efforts to learn from observing and participating with peers and more skilled members of their society." As children engage in culturally valued activities, they become more responsible participants. However, Rogoff (1995) argues that children need to be guided in that participation and she defines 'guided participation' as

> The processes and systems of involvement between people as they communicate and co-ordinate efforts while participating in culturally valued activities. This includes not only face-to-face interaction … but also the side-by-side joint participation that is frequent in everyday life and the more distal arrangements of people's activities that do not require co-presence…. The 'guidance' referred to in guided participation refers to observation, as well as hands on involvement in an activity. (Rogoff 1995: 700)

From a socio-cultural stance, learning is seen to be a consequence of collaboration in social activity.

## Language and mathematics

"The ability to communicate is at the very heart of early learning and development" (NCCA, 2003: 29). For most children, language is the dominant form of communication. According to Vygotsy (1978), concepts are first introduced on an interpersonal level through social interaction and then develop, integrate and expand intrapersonally, as children work to understand and use the concept. On both levels – interpersonally and intrapersonally – language serves a primary role in understanding and mastering what is learned. Language, "the primary cultural tool … is instrumental in restructuring the mind and in forming higher-order, self-regulated thought processes" (Berk and Winsler, 1995: 5). Language also plays a crucial role in helping children to use other cultural tools, including the notational systems of writing and counting (John-Steiner and Mahn, 1996), and is necessary to understand (Jordan et al., 2007) and express (Ginsburg et al., 2008) other kinds of mathematical thinking. Although the notational system for numbers is governed by different rules than those for writing, Austin et al. (2011) argue that the process of developing facility with one cultural tool enables the child to gain better facility with another. Further, it appears that proficiency in language is a key factor in predicting proficiency in mathematics (Austin et al., 2011).

Language is fundamental to education because it is the major form of representation of cultural knowledge and the principal medium of teaching. The nature of the relationship between language and mathematical cognition is currently the subject of much debate (Donlan et al., 2007). While some argue that increasing the time spent on mathematics activities could decrease time available to spend on language activities, thus impeding children's development of language, Sarama et al.

(2012) argue that this is based on the assumption that mathematics activities have little or no positive effects on language. However, evidence from both educational and psychological research suggests that language and mathematics have co-mutual beneficial influences. Development in both domains appears to follow similar pathways (Sarama et al., 2012). Moreover, Duncan et al. (2007) suggest that mathematics learning has the potential to make a unique contribution to children's emerging literacy due to its emphasis on reasoning, problem solving and communication (NCTM, 2006; Senk and Thompson, 2003).

A number of studies show that children's language acquisition is related to the overall amount of language input they receive (Weizman and Snow, 2001). Furthermore, the specific lexical terms acquired appear to be sensitive to variations in the amount of input. It therefore seems reasonable to suggest that children's acquisition of mathematical language is also related to the amount of "math talk" they are exposed to. Klibanoff et al. (2006) contend that the amount of teachers' mathematics-related talk is significantly related to the growth of young children's mathematical knowledge. In other words, teacher input that helps children to learn the language of mathematics will have a positive impact on the development of their mathematics skills. Although acquiring the language of conventional mathematics is only a part of developing understanding in mathematics, it is an important tool for fostering mathematical thinking.

## Number sense

The importance of number sense in school mathematics has been highlighted by many national reports (Cockroft, 1982; NCTM, 2000; NRC, 2009). However, there is no consensus on a precise definition of the term. Over thirty years ago, Cockcroft (1982) established that a "feeling for number" is an important mathematical requirement of adult life and used the word 'numerate' to imply the possession of two attributes:

> an 'at-homeness' with numbers and an ability to cope with the practical mathematical demands of everyday life …. an ability to have some appreciation and understanding of information which is presented in mathematical terms,... (Cockcroft, 1982: 11).

More recently, 'numeracy' is highlighted in national strategies north and south of Ireland (DES, 2011; DENI, 2011) and is defined as "the ability to use mathematics to solve problems and meet the demands of day-to-day living" (DES, 2011: 8) or "the ability to apply appropriate mathematical skills and knowledge in familiar and unfamiliar contexts and in a range of settings throughout life, including the workplace" (DENI, 2011: 3).

The introduction of the term 'number sense' was aimed at embracing a range of real-life applications of number as well as balancing the traditional skills-based curricula with approaches which included other aspects of number (Dunphy, 2007). Number sense, in curriculum documents worldwide, refers to "flexibility" and "inventiveness" in calculation and is a reaction to an "overemphasis on computational procedures devoid of thinking" (Anghileri, 2000: 2). Not only does it relate to the development of understanding but also to the "nurturing of a positive attitude and confidence" (Anghileri, 2000: 2). Consistent with a socio-cultural perspective on learning where children's number sense is viewed as developing in collaboration in activity with others, Dunphy (2007) considers that number sense in very young children will look different from that of older children. Her framework reflecting key aspects of number sense as it relates to four year olds includes: pleasure and interest

in number; understandings of the purposes of number; ability to think quantitatively; and awareness/understanding of numerals (Dunphy, 2006).

### *The role of the teacher*

The mathematical knowledge teachers possess has a profound impact on what and how they teach (Bobis, 2004). Teachers play a key role in helping children develop number sense through creating a learning environment that encourages children to freely explore numbers, operations, and their relationships in meaningful contexts (McIntosh, 2004; Siegler and Booth, 2005). Similarly, Dunphy (2006) highlights the importance of mathematical language in the provision of a quality early years' mathematics curriculum and acknowledges the pivotal role of the teacher:

> Responding to children's curiosity and interest about numbers, encouraging children to use number and number language as a means of organising and communicating their experiences, modelling of skills related to quantification, and drawing children's attention to the use of numerals in different contexts are also essential pedagogical tasks for the early years teacher' (Dunphy, 2006: 72-73).

Yang et al. (2009) suggest that teachers' lack of number sense as well as their lack of knowledge on how to help children develop number sense may account for weak performance in number sense. They argue that teachers empowered with knowledge and appreciation for number sense will be more likely to attend to number sense when working with learners. Greeno (1991) explicitly acknowledges the role of adults in relation to the development of number sense and recognises that "someone who already lives in the environment is an important resource for a newcomer" (Greeno, 1991: 197). Consistent with Rogoff (1990; 1995), this acknowledges that the development of children's number sense needs to be guided by more experienced others and is intrinsically bound up in everyday experiences. Through guided participation in a range of meaningful mathematical experiences, young children become more skilled in understanding and using number.

The theoretical perspectives underpinning the development of a resource of key vocabulary and teaching and learning strategies for teachers to support their planning and teaching in early number have been outlined with regard to achievement in mathematics, the socio-cultural perspective on learning, language and mathematics, number sense and the role of the teacher.

## Methodology

The NRC (2009) recommends that number should be emphasised in the development of young children's early mathematics. In light of this, it was decided to focus on the development of young children's early number concepts with a particular emphasis on the key associated vocabulary. The proposed research questions included: (1) What is the core vocabulary children require to understand, communicate and apply early number concepts? and (2) What approaches/strategies could assist teachers in their planning and teaching of the language of early number? Cooper's (2007) model of research synthesis was adapted for the project, namely: step 1, formulating the problem; step 2, searching the literature; step 3, gathering information from literature sources; step 4, evaluating, analysing and integrating the studies; step 5, interpreting the evidence, and step 6, developing the resource.

The research methodology utilised in the project was documentary analysis. During this review, books, papers, research reports and policy documents using

library and internet sources were consulted and reviewed. The areas of focus emphasised children's development of number, mathematical language and intervention techniques/strategies used to support the development of number and language. The principal focus of the research was on recent national and international research from an Irish, UK and international perspective. The researchers completed a rigorous literature search examining the role of mathematical vocabulary and language in the acquisition of early number. In addition, evidence-based research was reviewed to identify strategies supporting the teaching and learning of early number concepts.

Major Education and Social Science Databases (for example, Australian Education Index; British Education Index; Education Research Abstract; PsychINFO; International Bibliography of the Social Sciences; and the Mathematics Didactics Database) were searched using search terms such as mathematical language, language development, development of mathematical language, analysis of number, early number concept, number sense, and so on. These sources provided an extensive basis of documentary evidence and information. Emphasis was given to peer-reviewed sources. Documents were evaluated and critiqued on four criteria, namely; authenticity, credibility, representativeness, and meaning (Denscombe, 2004). The analysis of documentary evidence was the central and exclusive research method. Content analysis was considered the most appropriate approach in analysing the documents. It was important that appropriate categories and units of analysis, both of which reflect the nature of the documents being analysed and the purpose of the research were identified (Cohen et al., 2004). The studies were reviewed and compared and conclusions drawn concerning the nature of early number concepts and language.

As already stated, this project gathered data from the analysis of secondary sources, namely document analyses. In this sense, no defined research sample was involved in the project. As this research project centred on the development of a resource, there was need for independent review by teachers. The resource was piloted and reviewed by teachers of infant classes (Republic of Ireland) and the foundation stage (Northern Ireland). This process involved teachers familiarising themselves with the resource, implementing the activities and strategies in their classrooms with a focus on facilitating "math talk", and subsequently critiquing the resource by completing an evaluation form. The review process was completed at three different stages of the project to reflect the three core areas highlighted above. The involvement of key stakeholders facilitated the socio-cultural perspective.

## Outcomes

The principal outcome of the project was the production of a teaching and learning resource for teachers in the area of early number concepts with an emphasis on developing associated language. As a result of the documentary analysis detailed above, it was decided to organise the resource into three core areas: Number and counting; Number relationships; and Number operations. The number core considers the different uses of number and draws attention to the use of number symbols. The five key principles that underlie counting (Gelman and Gallistel, 1978) are also highlighted. The number relationships core addresses comparing, ordering and structuring numbers (with particular emphasis on the use of spatial and finger patterns), and partitioning and combining numbers. Finally, the number operations core focuses mainly on early addition and subtraction. With a view to empowering

teachers (Yang et al., 2009), each section begins with an overview explaining the underpinning mathematical concepts and principles; a table setting out the key vocabulary and examples of learning experiences associated with these important mathematical ideas; and a sample of activities for use in the classroom. Each activity is presented according to the following subheadings: mathematical focus, key vocabulary, resources required, activity and possible interactions, taking ideas further, and assessment opportunities. A socio-cultural stance was adopted in relation to the development of the resource which also includes introductory guidance material on the provision of a number rich environment, ideas for developing number across the setting, and suggestions for promoting home-school links.

The title of the resource is 'Number Talk'. The resource was designed specifically to be a practical support for early years' teachers in developing early number concepts and the associated language. The resource may be useful to teachers in planning their teaching of early number, and, thereby, to children in aiding their understanding and use of language with regard to early number concepts both in school and in their day-to-day lives. It is important to acknowledge that this resource builds on materials already developed for teachers.

## Conclusion

The aim of this research project was to develop a resource of key vocabulary and teaching and learning strategies to support teachers in their planning and teaching in early number. "Improvements in early childhood mathematics education can provide young children with the foundational educational resources that are critical for school success" (NRC, 2009: 331). Yang et al. (2009) believe that if children are to develop number sense, then teachers must first be empowered with knowledge and appreciation for number sense. The resource acknowledges the critical role that teachers play in developing young children's number sense through the environment created, the language and behaviour modelled, and the involvement of children as they communicate with them in worthwhile number activities.

## Acknowledgements

The support of SCoTENS (Standing Conference of Teacher Education North and South) is acknowledged as the sole funder of the project involving St. Angela's College, Sligo, Ireland and Stranmillis University College, Belfast, Northern Ireland.

## References

Anghileri, J. (2000) *Teaching number sense.* London: Continuum.

Austin, A.M.B., Blevins-Knabe, B., Ota, C., Trowe, T. & Lindauer, S.L.K. (2011) Mediators of preschoolers' early mathematics concepts. *Early Child Development and Care,* 181(9), 1181-1198.

Berk, L.E. & Winsler, A. (1995) *Scaffolding Children's Learning: Vygotsky and Early Childhood Education.* Washington, DC: National Association for the Education of Young Children.

Bobis, J. (2004) Number sense and the professional development of teachers. In McIntosh, A. & Sparrow, L. (Eds.) *Beyond written computation* (pp. 160-170). Perth, Western Australia: Mathematics, Science and Technology Education Centre, Edith Cowan University.

Clements, D.H. & Sarama, J. (2007) Early childhood mathematics learning. In Lester, J.F.K. (Ed.) *Second handbook of research on mathematics teaching and learning* (pp. 461-555). New York: Information Age.

Cobb, P. & Yackel, E. (1998) A constructivist perspective on the culture of the mathematics classroom. In Seeger, F., Voigt, V. & Waschescio, U. (Eds.) *The culture of the mathematics classroom* (pp. 159-189). Cambridge: Cambridge University Press.

Cockcroft, W.H. (1982) *Mathematics counts: Report of the committee of inquiry into the teaching of mathematics in schools under the chairmanship of Dr W. H. Cockcroft.* London: Her Majesty's Stationery Office.

Cohen, L., Manion, L. & Morrison, K. (2004) *Research methods in education* (5th edn.). London: RoutledgeFalmer.

Cooper, H. (2007) *Evaluating and interpreting research syntheses in adult learning and literacy.* Boston: National College Transition Network, New England Literacy Resource Centre/World Education.

Denscombe, M. (2004) *The good research guide for small-scale social research projects.* (2nd edn.). Berkshire: Open University Press.

Department of Education and Skills (DES) (2011) *Literacy and numeracy for learning and life: The national strategy to improve literacy and numeracy among children and young people 2011-2020.* Dublin: DES.

Department of Education, Northern Ireland (DENI) (2010) *Initial teacher education: approval of programmes.* (DE Circular 2010/03).

Department of Education, Northern Ireland (DENI) (2011) *Count read: Success – A strategy to improve outcomes in literacy and numeracy*. Belfast: DENI.

Donlan, C., Cowan, R., Newton, E.J. & Lloyd, D. (2007) The role of language in mathematical development: Evidence from children with specific language impairments. *Cognition,* 103, 23-33.

Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L.S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K. & Japel, C. (2007) School readiness and later achievement. *Developmental Psychology,* 43(6), 1428-1446.

Dunphy, E. (2006) The development of young children's number sense through participation in sociocultural activity: Profiles of two children. *European Early Childhood Education Research Journal,* 14, 57-76.

Dunphy, E. (2007) The primary mathematics curriculum: enhancing its potential for developing young children's number sense in the early years at school. *Irish Educational Studies,* 26(1), 5-25.

Gelman, R. & Gallistel, C. (1978) *The child's understanding of number.* Cambridge, MA: Harvard University Press.

Ginsburg, H.P., Lee, J.S. & Boyd, J.S. (2008) Mathematics education for young children: What it is and how to promote it. *Social policy report*, 22(1), 3-22.

Greeno, J. (1991) Number sense as situated knowing in a conceptual domain. *Journal for Research in Mathematics Education,* 22(3), 170-218.

John-Steiner, V. & Mahn, H. (1996) Sociocultural approaches to learning and development: A Vygotskian framework. *Educational Psychologist,* 31, 191–206.

Jordan, N.C., Kaplan, D., Locuniak, M.N. & Ramineni, C. (2007) Predicting first-grade math achievement from developmental number sense trajectories. *Child Development,* 22, 36-46.

Klibanoff, R.S., Levine, S.C., Huttenlocher, J., Vasilyeva, M. & Hedges, L.V. (2006) Preschool children's mathematical knowledge: The effect of teacher 'math talk'. *Developmental Psychology,* 42(1), 59–69.

McIntosh, A. (2004) Where we are today? In McIntosh, A. & Sparrow, L. (Eds.) *Beyond written computation* (pp. 3-14). Perth, Western Australia: Mathematics, Science and Technology Education Centre, Edith Cowan University.

National Council for Curriculum and Assessment (NCCA) (2003) *Towards a framework for early learning: a consultative document.* Dublin: NCCA.

National Council of Teachers of Mathematics (NCTM) (2000) *Principles and standards for school mathematics.* Reston, VA: NCTM.

National Council of Teachers of Mathematics (NCTM) (2006) *Curriculum focal points for prekindergarten through grade 8 mathematics: A quest for coherence.* Reston, VA: NCTM.

National Research Council (NRC) (2009) *Mathematics learning in early childhood: Paths toward excellence and equity.* Centre for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Rogoff, B. (1990) *Apprenticeship in thinking: cognitive development in social context*. New York: Oxford University Press.

Rogoff, B. (1995) Observing sociocultural activity on three planes: participatory appropriation, guided participation and apprenticeship. In Wertsch, J., Del Rio, P. & Alvarez, A. (Eds.) *Sociocultural studies of mind*, (pp. 139-164). New York: Cambridge University Press.

Rogoff, B. (1998) Cognition as a collaborative process. In Damon, W., Kuhn, D. & Siegler, R. (Eds.) *Handbook of child psychology. Vol. 2: Cognition, perception and language* (pp. 679-744). New York: Wiley.

Sarama, J., Lange, A.A., Clements, D.H. & Wolfe, C.B. (2012) The impacts of an early mathematics curriculum on oral language and literacy. *Early Childhood Research Quarterly,* 27, 489-502.

Senk, S.L. & Thompson, D.R. (2003) *Standards-based school mathematics curricula. What are they? What do students learn?* Mahwah, NJ: Erlbaum.

Siegler, R.S. & Booth, J.L. (2005) Development of numerical estimation: A review. In Campbell, J.I.D. (Ed.) *Handbook of mathematical cognition* (pp. 197-212). New York: Psychology Press.

Weizman, Z.O. & Snow, C.E. (2001) Lexical input as related to children's vocabulary acquisition: Effects of sophisticated exposure and support for meaning. *Developmental Psychology,* 37, 265-279.

Yang, D.C., Reys, R.E. & Reys, B.J. (2009) Number sense strategies used by pre-service teachers in Taiwan. *International Journal of Science and Mathematics Education,* 7(2): 383-403.