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Key Vocabulary and Supporting Strategies for Early Number Concepts

Teacher-facilitated "math talk" in the early years significantly increases children's growth in understanding of mathematical concepts (Klibanoff, Levine, Huttenlocher, Vasilyeva and Hedges, 2006). Young children often lack the language to communicate their ideas regarding their understanding of early number concepts. Teacher modelling and use of mathematical language throughout the school day allows children to articulate their ideas and communicate their understanding. Fostering "math talk" in young children as they explain, question and discuss their strategies is paramount. Teacher guidance is essential in helping 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.

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MATHEMATICS ACHIEVEMENT

Achievement in mathematics is a key educational concern. Competence in mathematics is crucial in meeting workplace demands 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 (Department of Education Northern Ireland (DENI), 2011; Department of Education and Skills (DES), 2011). 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, Huttenlocher, Vasilyeva and Hedges, 2006). Such early differences are a matter of some concern since although considerable attention has been focused on mathematics achievement at primary and secondary levels, the foundations for learning mathematics are established much earlier (Clements and Sarama, 2007).

Levels of mathematics knowledge at school entry have been shown to predict later achievement (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov, Pagani, Feinstein, Engel, Brooks-Gunn, Sexton, Duckworth and Japel, 2007).

Mathematics success 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, Blevins-Knabe, Ota, Trowe and Lindauer (2011) state that neglecting mathematics in the early years might impede both mathematical development and literacy skills. In their research, 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 meet the growing needs of a scientifically and technologically sophisticated workforce (National Research Council (NRC), 2009).

The key theoretical perspectives and relevant research studies underlining the development of a resource of key vocabulary and teaching and learning strategies for teachers to support their planning and teaching in early number will be outlined with regard to achievement in mathematics. The socio-cultural perspective on learning, language and mathematics, number sense and the role of the teacher will also be addressed

A Socio-cultural Perspective on Learning

Both socio-culturalists and constructivists highlight the significance of individual activity in learning. While constructivists prioritise psychological processes, sociocultural approaches give priority to the context for learning (Vygotsky, 1978), placing importance on "the conditions for the possibilities for learning" (Cobb and Yackel, 1998, p. 184). Rogoff (1998) states that 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 interprets learning as the development of mind in a socio-cultural context. Children's active participation in an activity is regarded as an essential component of the process by which they gain mastery. Rogoff (1990) considers children as "apprentices in thinking, active in their efforts to learn from observing and participating with peers and more skilled members of their society" (p. 7). As children engage in culturally valued activities, they become more responsible participants. However, Rogoff (1995) postulates 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* (p. 700).

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

LANGUAGE AND MATHEMATICS

For most children, language is the principal form of communication. "The ability to communicate is at the very heart of early learning and development" (National Council for Curriculum and Assessment (NCCA), 2003, p. 29). Vygotsy (1978) proposes that 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 plays a primary role in understanding and mastering what is learned. Berk and Winsler (1995) argue that language, "the primary cultural tool ... is instrumental in restructuring the mind and in forming higher-order, self-regulated thought processes" (p. 5). Language also plays a critical 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, Kaplan, Locuniak and Ramineni, 2007) and express (Ginsburg, Lee and Boyd, 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) suggest that the process of developing facility with one cultural tool enables the child to gain better facility with another. Further, it appears that competence in language is a key factor in predicting proficiency in mathematics (Austin et al.).

Language is central to education because it is the major form of representation of cultural knowledge and the principal medium of teaching. Currently, the nature of the relationship between language and mathematical cognition is the subject of much discussion (Donlan, Cowan, Newton and Lloyd, 2007). While some argue that increasing the time spent on mathematics activities could decrease time available to spend on language activities, thus inhibiting children's development of language, Sarama, Lange, Clements and Woulfe (2012) contend 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 would seem to follow comparable pathways (Sarama et al.). Moreover, Duncan et al. (2007) propose that mathematics learning has the potential to make a unique contribution to children's developing literacy due to its emphasis on reasoning, problem solving and communication (Senk and Thompson, 2003; National Council of Teachers of Mathematics (NCTM), 2006).

Children's language acquisition is associated with the overall amount of language input they receive (Weizman and Snow, 2001). Furthermore, the specific lexical terms assimilated 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) propose that the amount of teachers' mathematics-related talk is significantly related to the development 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 developing the language of conventional mathematics is only a part of acquiring understanding in mathematics, it is an important tool for promoting mathematical thinking.

Number Sense

Number sense and its importance in school mathematics has been highlighted by many national reports (Cockroft, 1982; NCTM, 2000; NRC, 2009) but there is no consensus on a precise definition of the term. Cockcroft (1982) established that a "feeling for number" is an important mathematical prerequisite for adult life and used the word 'numerate' to infer 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* (p. 11).

Recent policy has focused on numeracy and is highlighted in national strategies north and south of Ireland (DES, 2011; DENI, 2011). Numeracy is defined as "the ability to use mathematics to solve problems and meet the demands of day-to-day living" (DES, p. 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, p. 3).

Dunphy (2007) notes that the introduction and the use 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. Anghileri (2000) states that number sense, in curriculum documents worldwide, refers to "flexibility" and "inventiveness" in calculation and is a response to an "overemphasis on computational procedures devoid of thinking" (p. 2). Not only does it relate to the development of understanding but also to the "nurturing of a positive attitude and confidence" (Anghileri, 2000, p. 2). Consistent with a socio-cultural perspective on learning where children's number sense is perceived as developing in collaboration in activity with others, Dunphy (2007) states that number sense in very young children will look different from that of older children. Dunphy's (2006) framework considers key aspects of number sense as it relates to four year olds including: pleasure and interest in number; understandings of the purposes of number; ability to think quantitatively; and awareness/understanding of numerals.

The Role of the Teacher

According to Bobis (2004), there is a strong relationship between the mathematical knowledge teachers possess and the impact on what and how they teach. Many researchers argue that the role of teachers is paramount 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). Dunphy (2006) also emphasises 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* (pp. 72-73).

Yang, Reys and Reys (2009) infer that teachers' lack of confidence regarding number sense as well as their lack of knowledge on how to help children develop number sense may explain weak performance in number sense. They claim that teachers empowered with knowledge and appreciation for number sense will be more likely to focus on number sense when working with learners. Greeno (1991) recognises 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" (p. 197). Consistent with Rogoff (1990; 1995), this acknowledges that in order to develop children's number sense, young learners need the assistance of more experienced others and this is intrinsically bound up in everyday experiences. It is through guided participation in a range of meaningful mathematical experiences, that young children become more proficient in understanding and using number.

The next section provides an account of the methodology employed whereby following a meta-analysis of the literature teachers were piloted and asked to review the resource subsequently developed by the authors.

METHODOLOGY

The NRC (2009) advocates that number should be highlighted in the development of young children's early mathematics (Cockroft, 1982; NCTM, 2000). As a result, in this research project, it was decided to concentrate 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 used for the project, that is, 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 employed 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. Children's development of number, mathematical language and intervention techniques/strategies used to support the development of number and language were the areas of focus emphasised. Recent national and international research from an Irish, UK and international perspective were the principal focus of the documentary analysis. The researchers completed a meticulous literature search exploring the role of mathematical vocabulary and language in the acquisition of early number. Evidence-based research was also 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 and number sense. These sources supplied an extensive basis of documentary evidence and information. Emphasis was given to peer-reviewed sources. Four criteria, namely; authenticity, credibility, representativeness, and meaning (Denscombe, 2004) were used to evaluate and critique the research. The central and exclusive research method was the analysis of documentary evidence. Content analysis was considered the most suitable 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, Manion and Morrison, 2004). The studies were reviewed and critiqued and conclusions drawn concerning the nature of early number concepts and language.

This project gathered data from the analysis of secondary sources, namely document analyses. Therefore, 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 early years'- mainstream and special class teachers. 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 (Appendix 1). The review process was completed at three different stages of the project to reflect the three core areas highlighted above. At each stage of the review process, teachers were provided with a pack which contained an introductory letter explaining the project, a sample of number activities to pilot, and an evaluation form to complete. The latter included statements which teachers responded to, using a five-point Likert Scale. Qualitative feedback was also sought regarding the strengths of the resource; possible improvements that could be made in relation to presentation, layout and content; and any other recommendations on further activities. Feedback from teachers who piloted the resource activities was extremely positive. Most teachers indicated that the resource provided excellent material which would serve to support them in their planning for teaching early number. Teachers agreed that the resource was appropriate for children in Infant classes (Republic of Ireland) and the Foundation Stage (Northern Ireland). The involvement of teachers 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 outlined 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 emphasised. 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 includes 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 structured according to the following subheadings: mathematical focus, key vocabulary, resources required, activity and possible interactions, taking ideas further, and assessment opportunities (Appendix 2). A socio-cultural stance was adopted in relation to the development of the resource. Therefore, 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 were also included.

The title of the resource is 'Number Talk'. The resource was designed purposefully to be a practical support for early years' teachers, in mainstream and special settings, 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

"Improvements in early childhood mathematics education can provide young children with the foundational educational resources that are critical for school success" (NRC, 2009, p 331). If children are to develop number sense, then teachers must first be empowered with knowledge and appreciation for number sense (Yang et al., 2009).Therefore, 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. The resource acknowledges the crucial 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.

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APPENDIX 1: SAMPLE EVALUATION FORM

Developing Early Vocabulary in Number Relationships

Please indicate the year group you used the resource with.
Year group: _____

Based on your experience of using the resource, please indicate the extent to which you agree with the following statements by ticking the appropriate box. Please tick <u>one</u> box only.

SD – Strongly Disagree, **D** – Disagree, **U** – Undecided, **A** – Agree, **SA** – Strongly Agree

	SD	D	U	A	SA
1. I understand the purpose of the resource					
2. The introductory section is interesting to read					
3. The resource is clear and easy to follow					
4. The resource is user friendly					
5. The resource provides a useful bank of activities to support my teaching					
6. The activities are clearly outlined					
7. The resource highlights the key vocabulary of number relationships					
8. As a result of using the resource, I have a greater awareness of how to promote the key vocabulary of number relationships					
9. The resource helped me to facilitate children's discussion of number relationships					
10. Children enjoyed the activities					

	SD	D	U	A	SA
11. As a result of using the resource, children in my classroom are better able to engage with the vocabulary of number relationships					
12. As a result of using the resource, I have observed children in my classroom spontaneously using the vocabulary addressed in this resource					

We would appreciate any additional comments/suggestions in the section below.

Overall, what do you consider to be the strengths of this resource?

Can you recommend any further activities in relation to number relationships?

Can you suggest any improvements to this resource? For example, you may wish to recommend improvements in relation to content, layout, presentation, etc.

Any other comments

Appendix 2: Sample Activity

one,
two,
three ...

count

how many?

altogether

each

enough

more

a lot

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Teddy's Tea Party

Mathematics focus

- One-one correspondence
- Count to find out how many

Resources

Teddy bears
Small table and chairs
Sets of party items such as plates, cups, saucers, knives and forks

Activity and possible interactions

Set up the role-play area with equipment available for children to organise their own teddies' tea party.

Observe children as they play. Listen to what they say, taking note of any mathematical language they use.

Model appropriate language to describe children's actions.

"I see that you are giving each bear a cup – one for the big bear, one for the little bear, ..."

Encourage children to talk about what they are doing.
Use prompts and questions, such as:

"You have put each bear on a chair. What are you going to do next?"
"How many bears have come along to your tea party?"
"Do you have enough plates? How can you find out?"

Challenge children's thinking by posing problems such as:

"Can this little bear join the tea party? What will you need to do?"
"How many cups do you have?"
"How many more do you need?"

Taking ideas further

Set up the role-play area for a picnic or BBQ. Make a video of children engaged in the role-play scenario. Children could use play dough to make food items for the role-play.

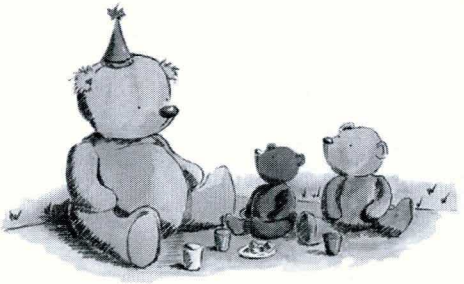
Encourage children to help set the table at snack time.

Relate the activity to stories such as Goldilocks and the three bears. Encourage children to retell or act out the story.

Assessment opportunities

Do the children:

- Match one item to each bear
- Use appropriate counting vocabulary to explain their actions



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