

Developing a Framework for the Selection of Picture Books to Promote Early Mathematical Development

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The purpose of this paper is to describe the development of a framework to facilitate the selection and evaluation of picture books that may be useful in promoting and developing mathematical concepts in young children. Three types of mathematical picture books were initially recognised with intercoder reliability of 0.92. Seven categories were identified in the framework: Mathematical content; Curriculum content, policies, and principles; Integration of mathematics content; Mathematical meaning; Mathematical problem solving and reasoning; Affordance for mathematics learning; and Pedagogical implementation.

There is a wide range of children's literature, such as picture books and trade books that may directly or indirectly promote mathematics learning. Shatzer (2008) emphasised the importance of choosing literature that both constructs mathematical meaning and makes connections to students' lives. Research suggests that shared book experiences assist in mathematical concept development in the early years (Anderson, Anderson, & Shapiro, 2005; Casey, Kersh, & Mercer Young, 2004; van den Heuvel-Panhuizen & van den Boogaard, 2008). Curriculum bodies (Australian Curriculum, Assessment and Reporting Authority, 2010; National Council of Teachers of Mathematics, 2000) and professional journals such as *Teaching Children Mathematics* and *Australian Primary Mathematics Classroom* encourage the integration of literacy and numeracy to teach mathematical concepts by promoting the use of children's literature. In practice, there has been some implementation of children's literature in mathematics learning through teacher resource books (Griffiths & Clyne, 1988; McDonald, 2009) and through the production of individual and series-based mathematics story books (Neuschwander, 1997). However, there are few guidelines or frameworks that can inform teacher choice or be used to evaluate books for their suitability.

Picture Books for Mathematics Learning

A picture book is defined as a book suitable for very young children, containing multiple visual images. It is often a simple narrative or descriptive text that is intended to be read aloud and shared between an adult and child or group of children (Muir, 1982). For the purpose of this research, "mathematical" picture books are defined as picture books with mathematical content present in both the text and images. The text may be either descriptive or narrative, with the mathematical content:

- (i) perceived to be occurring; these books are written to entertain and the mathematical concepts are unintentional and incidental (e.g., *Alexander's Outing*, Allen, 1992).
- (ii) explicitly referenced; these include counting books and "trade" books (those written in picture book format to specifically teach or develop one or more mathematical concepts), for example, *Minnie's Diner: A multiplying menu* (Dodds, 2004) or series such as *Sir Cumference* (Neuschwander, 1997).
- (iii) embedded; picture books that have been written to entertain as in (i) but include purposefully embedded mathematical ideas, for example, the work of Anno (1997).

Using Picture Books to Develop Mathematical Concepts

Picture books and other forms of children's literature have been used primarily to support an integrated approach to early learning curriculum. Bosma and De Vries Guth (1995, p. 7) asserted that literature is the "thread that weaves" the integrated curriculum together. This integrated approach is considered to make lessons more relevant, as it employs the elements of "engagement" and "connectedness" such as promoted by the Quality Teaching Framework (NSW Department of Education & Training, 2003) and helps children "better understand mathematical ideas and their application to real-world situations" (Whitin, 1992, p. 28). The use of picture books also supports student learning in familiar settings. If students can see mathematics as part of their everyday lives, they will be encouraged to value mathematics more than they would otherwise and build confidence in their own mathematical abilities (Whitin, 1992). Meaningful contexts provided by picture books also afford opportunities for problem solving and mathematical reasoning (Schiro, 1997; Whitin, 1992).

Background Literature

Picture books, not specifically written to teach mathematics, which often include mathematical ideas, images and linguistic terms, have been shown to promote mathematical play, discussion, disposition to mathematics (Young-Loveridge, 2004; van den Heuvel-Panhuizen & van den Boogaard, 2008) and improved mathematical achievement (Jennings, Jennings, Richey & Dixon-Krauss, 1992). Van den Heuvel-Panhuizen and van den Boogaard (2008) found that half the student utterances in their study related to mathematics and of these, most related to number, space and size (Anderson et al., 2005; van den Heuvel-Panhuizen & van den Boogaard, 2008). Anderson et al. (2005) believed that just reading a picture book is not sufficient, but that mathematical talk must be meaningful. However, van den Heuvel-Panhuizen and van den Boogaard (2008) concluded that five year old children do engage mathematically with such texts, even without adult intervention. These studies support the importance of the visual images in picture books, indicating that most of the discourse centred on the illustrations. Casey et al. (2004) showed that students who encountered geometry through specifically written storytelling sagas made greater improvement in mathematical skills than those who studied the geometry without the saga, while Halpern (1996) found adding annotations to a book did not affect the enjoyment but added to student understanding.

A number of studies, including Thomas, Mulligan, and Goldin (2002), emphasised the important role of visual representations and imagery in the development of mathematical concepts in young children. Research in early literacy has also emphasised the importance of visual images and illustrations in representing meaning in the text (Kress & van Leeuwen, 1996; Lewis, 2001). The interrelationship between text and visual images in picture books is critical to understanding how children form concepts, including mathematical concepts. This raises the question of how children interact with developing mathematical language and concepts. Do the visual images provided in picture books encourage the mathematical ideas and representations needed in the development of mathematical concepts and match those constructed by the young readers?

Method

Aims and Research Questions

An exploratory descriptive study has been designed to evaluate the role of picture books in facilitating mathematical development among children in the early years of formal schooling. The questions to be explored are:

- What potential do picture books (of different types) have for facilitating the development of mathematical concepts in young children?
- Do some picture books facilitate discussion of mathematical concepts more than others?

The aims of the research include the development of a framework for identifying and evaluating mathematical content in picture books and analysing students' verbal responses during shared book experiences, in order to assess how books can facilitate the development of mathematical concepts.

A pilot study of child-teacher and child-child talk during shared book experiences will inform the main study. The two parts of the main study will investigate the use of:

- picture books with perceived mathematical content, and
- purpose-written picture books with mathematical content.

These naturalistic studies will involve 54 students, six teachers, and six schools. Small groups of Year 1 children (approximately six years old) and their teacher will be engaged in shared reading of identified picture books with different types of mathematical content. There will be an emphasis on the areas of measurement, patterns and algebra, and problem solving to ascertain whether number and space concepts also predominate in this study.

Frameworks and Instruments for Selection and Evaluation of Picture Books

Some frameworks have been developed for this purpose but they predominantly appear to relate to the usefulness of trade books. After the introduction of the first NCTM standards (1989), criteria were set for the inclusion of trade books in California's mathematics program; these included relevance to the maths concepts, grade appropriateness, suitability for integration, accessibility of resources, and literacy quality (Donahue, 1996). Schiro (1997) and Whitin and Whitin (2001) also emphasised the importance of the literary quality of the books that were to be considered for their mathematical content. The flood of books developed to address the second NCTM standards (2000) was not always of a high literary standard and they were often described as "glorified textbooks" (Hellwig, Monroe, & Jacobs, 2000, p. 139).

Schiro (1997) developed an instrument for both evaluating the mathematical and literary value of books that has been widely used and adapted by others. His eleven mathematical standards, with various sub-categories, consider mathematical accuracy, worthiness, visibility, appropriateness, involvement of the reader in the mathematics, the effectiveness of the presentation, the complementing of the mathematics and story, the availability of resources and mathematical information, the application of the content, and the view it presents of mathematics. Hellwig et al. (2000) produced an instrument with five categories (accuracy, visual and verbal appeal, connections, audience, and the 'wow' factor), while Whitin and Whitin (2001) only emphasised two criteria: books that invite varied response, and books that reflect an aesthetic dimension. Hunsader (2004) reduced Schiro's (1997) mathematical criteria to six categories to speed up the assessment process

and eliminate trivial and repeated or overlapping questions. She also included a five-point scale that allowed books to be scored against each other. Halsey (2005) added a Likert scale to score results and two more criteria to Schiro's (1997) original instrument: overall literary quality and overall mathematical quality.

Developing the Framework

Previous studies using picture books for mathematical concept development have not compared the efficacy of different types of books. The planned study required the selection of appropriate mathematical picture books that addressed the three categories of mathematical picture books described previously. Currently, teachers do not have contemporary criteria on which to base their choice of picture books for use in the classroom. They often impose mathematics on any book or miss mathematical opportunities. Schiro's (1997) instrument is a comprehensive and valuable tool to evaluate children's mathematical trade books. However, this and the subsequent frameworks are limited because they all only appear to address the category of trade books.

The development of a new framework integrates aspects in previous instruments but also takes into consideration the complex range of factors that contribute to the effective use of picture books to promote mathematical problem solving, including recent research in young children's development of mathematical concepts, the importance of the interaction of text and visual images, changes in curriculum (policies and principles), and current pedagogy.

Procedures

A collection of 122 picture books was originally sourced. These included 114 picture books and ten mathematical trade books. To ensure the picture books were current and examples of quality literature, a list of 240 books that had won Australian (e.g., Children's Book Council of Australia, 2009) or international awards in the past ten years was compiled and the books were obtained from libraries or booksellers for the collection. It was anticipated that many, but not all, of these would contain "perceived" or "embedded" mathematics; some are already included in teacher resource books (McDonald, 2009). The trade books were sourced from American book sellers via the internet, as they are not readily available through Australian booksellers or libraries. Two recent books by award-winning authors with researcher-identified "embedded" mathematics and 12 books used by teachers in mathematics learning and teaching for many years (e.g., *Alexander's Outing*, Allen, 1992) were also added to the collection to test the framework's reliability against previous usage.

The books were then read, categorised, and analysed by the researcher for features previously illustrated in the literature. The procedure involved labelling visible mathematical concepts in the text and visual images, identifying the interaction between text and visual images, recording mathematical inaccuracies, and noting opportunities for classroom learning experiences. This process, which occurred concurrently with the development of the framework, also assisted its refinement.

It became clear to the researcher that the three categories of books with mathematical content did exist. Every book analysed by the researcher was found to have some degree of mathematical content; however, the quantity, quality, and potential for use in mathematical learning experiences needed to be evaluated against the framework. To trial the framework, a total of 50 books from each category (34 with perceived mathematics, eight

with embedded mathematics and eight trade books) was randomly chosen by the researcher from the original collection. These books were then evaluated against the expanded version of the framework (see Table 1 below) by the researcher and a Research Assistant, both with education/classroom teacher backgrounds. They independently coded clean copies of the books and the research assistant also categorised the books.

The Framework's Classification Scheme

The classification scheme developed is summarised in Table 1. This new instrument contains seven categories, each with a series of elements, which are included in the expanded version of the framework, along with examples of books displaying each element. A Likert scale of five levels is included for each element against which a book's mathematical content and potential for use can be evaluated. A description of each category follows.

Table 1
Classification Scheme

Code	Categories	Definition
MC	Mathematical Content	The content is visible, displayed with accuracy and authenticity in mathematical contexts, and provides opportunities for developing mathematical language.
CPP	Curriculum Content, Policies, and Principles	Mathematical content is consistent with relevant curricula and reflects policies of gender equity, cultural and socioeconomic diversity, inclusiveness, and environmental awareness.
IMC	Integration of Mathematics Content	Mathematical content is linked within and across mathematical strands, across other disciplines, and with Information and Communication Technology.
MM	Mathematical Meaning	The text and visual images are presented in authentic contexts; concepts are developed in an effective, sequential, and interrelated way.
MPS	Mathematical Problem Solving and Reasoning	The text and images afford opportunities for problem solving, problem posing, co-operative strategies, and creative multiple solution paths.
AML	Affordance for Mathematics Learning	The learning experience is motivating, engaging, and enjoyable, and promotes positive values and attitudes towards mathematics and creative intellectual endeavour.
PI	Pedagogical Implementation	The mathematical content in quality picture books is applicable to a variety of learning situations.

The category of *Mathematical Content* addresses the mathematical content presented within the text and visual images — perceived, explicit or embedded. The mathematical content of the book needs to be visible to or recognised by the reader in the title, text or representations (symbols, diagrams, pictures, and actions); this category includes the appropriate positioning, size and clarity of the mathematical ideas. However, visibility

does not determine the amount or quality of the mathematical content. Mathematical content (linguistic terms, concepts, and calculations) and representations should be portrayed accurately. The content ought to provide opportunity for the development of mathematical knowledge and skills (content and concepts) and for students to verbalise mathematics ideas using mathematical language. The text and visual images should demonstrate real life experiences, as mathematical content portrayed in everyday situations provides authenticity.

All countries (and some individual states) have developed a mathematics curriculum for their compulsory years of schooling and/or include guidelines for the early or pre-school years. For example, in Australia there is the Early Years Learning Framework and a national mathematics curriculum (ACARA, 2010) is currently being developed. Therefore the category of *Curriculum Content, Policies, and Principles* is included. However, some education systems not only include policies on content, they also consider principles such as gender, cultural, and socioeconomic equity, inclusiveness, and environmental awareness. In Australia, policy is not developed without the accompanying principles, but this is not the case in all countries. These principles are included in this framework, although it is realised that they may not have the same importance everywhere. As the prime purpose of integrating picture books into the curriculum is to facilitate student learning, the mathematical content needs to correspond to or complement the relevant school curriculum policies and principles at the relevant stage of development.

Integration of Mathematics Content, within mathematics curriculum (e.g., number and patterns), across the mathematics curriculum (e.g., measurement and number), across disciplines (e.g., Mathematics and Science), and with ***Information and Communication Technology*** are included elements. Integration is considered to make lessons more relevant to student learning; for teachers, it also facilitates the delivery of knowledge and skills in mathematics and a variety of disciplines.

The category of *Mathematical Meaning* incorporates four elements. It is important that the mathematics itself is authentic (that is, it arises naturally from the text and is not contrived to present a mathematical concept) and it should develop in an effective and sequential way. The text and visual images should also work together to aid meaning of mathematical concepts. Although there should be connections between the text and visual images, Lewis (2001) stated the degree of interaction can range from symmetrical to contradiction; it is the effectiveness of the interrelationship of the text and visual images that facilitates mathematical meaning.

Mathematical Problem Solving and Reasoning addresses the process strands of the mathematics curriculum. This category explores opportunities in the text and visual images for students to apply the mathematical content of the picture book to everyday situations, to solve and pose problems, and to work collaboratively. It also identifies books with multiple paths and multiple solutions to problems posed explicitly within the text or derived from the text.

Schiro (1997) recognised the importance of a positive view of mathematics in mathematical picture books. *Affordances for Mathematics Learning* includes the way the book motivates and engages students in mathematical concepts and activities, promotes an enjoyable atmosphere, and encourages positive attitudes towards mathematics and mathematics learning. Students should perceive mathematics as a social, useful, intellectual, and worthwhile activity involving active participation, reasoning and creativity.

Pedagogical Implementation identifies how the mathematical content of the picture book promotes inquiry for children without adult intervention and encourages students to revisit the story for its mathematical aspects. For teachers, this category addresses how easily the mathematical content is identifiable and accessible, how easily it can be used and integrated in teaching and learning programs, and whether the ensuing teaching and learning experiences can be adapted for different levels of ability and learning styles. The accessibility and practicality of the resources required or implied for teaching and learning for both teachers and students are also addressed.

Results and Further Research

Analysis of the book categorisation showed intercoder reliability between the Researcher and the Research Assistant of 0.92. The only area of difference was whether the mathematics in four of the books was deliberately placed (“embedded”) by the author or whether it was incidental or “perceived” by the reader. The Research Assistant identified mathematical concepts in all the books, but this does not imply that all of them would be useful for mathematical learning; further coding against a framework is needed. The Researcher and the Research Assistant found the framework easy to use, although both suggested a few minor amendments for clarity of understanding several elements. Further trialling is needed before reliability can be achieved. The Research Assistant reported:

This framework really required me, as a teacher, to think beyond reading a book to what I could do with a book to plan and implement valuable and contextual learning experiences for children making maths both fun and accessible in a non-threatening format.

The purpose of developing this new framework was both to aid effective selection of books for the pilot and main studies and to facilitate the selection and evaluation of any picture book by teachers. However, in the process, it will also identify a range of current picture books with mathematical content for the use of all teachers.

This proposed study will extend previous research on the use of picture books by focussing not only on books with perceived mathematical content, as in previous studies, but also on children’s responses to purpose-written books with explicit and embedded mathematical concepts. There will be an emphasis on the source of student verbal responses and the interaction of the text and visual images. If purpose-written picture books (explicit and/or embedded) are found to provide better opportunities for developing children’s conceptual understanding of mathematical concepts, then the implications for including these picture books in the mathematics curriculum will be justified.

This paper is based on a study conducted under the supervision of Associate Professor Joanne Mulligan as part of a PhD in Education at Macquarie University.

References

- Anderson, A., Anderson, J., & Shapiro, J. (2005). Supporting multiple literacies: Parents’ and children’s mathematical talk within storybook reading. *Mathematics Education Research Journal*, 16 (3), 5-26.
- Allen, P. (1992). *Alexander’s outing*. Ringwood, Victoria: Viking.
- Anno, M. (1977). *Anno’s counting book*. London: Bodley Head.
- Australian Curriculum, Assessment and Reporting Authority (ACARA). (2010). *Australian curriculum*. Retrieved March 15, 2010, from <http://www.acara.edu.au/curriculum.html>
- Bosma, B. & De Vries Guth, B. (1995). *Children’s literature in an integrated curriculum*. Newark, DE: International Reading Association; New York: Teachers College Press.
- Casey, B., Kersh, J. E., & Mercer Young, J. (2004). Storytelling sagas: An effective medium for teaching early childhood mathematics. *Early Childhood Research Quarterly*, 19, 167- 172.

- Children's Book Council of Australia (2009). *Welcome*. Retrieved September 28, 2009, from <http://cbca.org.au/>
- Commonwealth of Australia. (2009) *Belonging, being and becoming*. (EYLF). Retrieved November 3, 2009 from: http://www.deewr.gov.au/EarlyChildhood/Policy_Agenda/Quality/Documents/Final%20EYLF%20Framework%20Report%20-%20WEB.pdf
- Dodds, D. A. (2004). *Minnie's Diner: A multiplying menu*. Cambridge MA: Candlewick Press.
- Donahue, M. R. (1996). *Literature connections in six current math series for grades K -2*. Paper presented at the Annual Literacy Conference, Anaheim, CA.
- Griffiths, R., & Clyne, M. (1988). *Books you can count on; Linking mathematics and literature*. Melbourne: Nelson.
- Halpern, P. A. (1996). Communicating the mathematics in children's trade books using mathematical annotations. In P. C. Elliot & M. J. Kennedy (Eds.), *Communication in mathematics: K -12 and beyond* (pp. 54 -59). Reston, VA: National Council of Teachers of Mathematics.
- Halsey, P. (2005). Assessing mathematics trade books: Do they measure up? *Reading improvement*, 42, 158-163.
- Hellwig, S. J., Monroe, E. E., & Jacobs, J. S. (2000). Making informed choices: Selecting children's trade books for mathematics instruction. *Teaching Children Mathematics*, 7, 138-143.
- Hunsader, P. D. (2004). Mathematics trade books: Establishing their value and assessing their quality. *The Reading Teacher*, 57, 618-629.
- Jennings, C. M., Jennings, J. E., Richey, J., & Dixon-Krauss, L. (1992). Increasing interest and achievement in mathematics through children's literature. *Early Childhood Research Quarterly*, 7, 263 - 276.
- Kress, G., & van Leeuwin, T. (1996). *Reading images: The grammar of visual design*. London: Routledge.
- Lewis, D. (2001). *Reading contemporary picture books: Picturing text*. London: Routledge Falmer.
- McDonald, S. (2009). *Myriad Maths: Maths activities for Book Week books*. Buderim: Firefly Press.
- Muir, M. (1982). *A history of Australian children's book illustration*. Melbourne: Oxford University Press.
- National Council of Teachers of Mathematics (NCTM). (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*, Reston, VA: National Council of Teachers of Mathematics.
- Neuschwander, C. (1997). *Sir Cumference and the first round table*. Watertown MA: Charlesbridge.
- NSW Department of Education and Training (2003). *Quality teaching in NSW public schools. Discussion paper*. Sydney: Author.
- Schiro, M. S. (1997). *Integrating children's literature and mathematics in the classroom: Children as meaning makers, problem solvers, and literary critics*. New York: Teachers College Press.
- Shatzer, J. (2008). Picture power: Connecting children's literature and mathematics. *Reading Teacher*, 61, 649-653.
- Thomas, N. D., Mulligan, J. T., & Goldin, G. A. (2002). Children's representation and structural development of the counting sequences 1-100. *Journal of Mathematical Behavior*, 21, 117-133.
- van den Heuvel-Panhuizen, M., & van den Boogaard, S. (2008) Picture books as an impetus for kindergarteners' mathematical thinking. *Mathematical Thinking and Learning*, 10, 341-373.
- Whitin, D. J. (1992). Explore mathematics through children's literature. *School Library Journal*, 38(8), 24-28.
- Whitin, D., & Whitin, P. (2001). What counts in math-related books for children. *Journal of Children's Literature*, 27(1), 49-55.
- Young-Loveridge, J. M. (2004). Effects on early numeracy of a program using number books and games. *Early Childhood Research Quarterly*, 19, 82 -98