Identifying and using picture books with quality mathematical content

Moving beyond *Counting on Frank* and *The Very Hungry Caterpillar*

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This article by Jennie Marston provides a framework to assist you in selecting appropriate picture books to present mathematical content. Jennie demonstrates the framework by applying three specific examples of picture books to the framework along with examples of activities.

Using picture books to develop mathematical concepts

Teachers are always keen to use picture books in their teaching, both for intrinsic enjoyment and to develop literacy skills and knowledge. Each year a plethora of picture books is released onto the market and teachers are guided by awards, such as those given by the Children's Book Council (CBCA, 2012), in their choice of books with high literary quality. However, research in mathematics education also demonstrates that picture books can afford opportunities to develop mathematical concepts in young children (Anderson, Anderson & Shapiro, 2005; van den Heuvel-Panhuizen & van den Boogaard, 2008). The benefits of integrating picture books into a mathematics program, including the increased engagement of students and teachers, have been discussed by Clark (2007), Jenkins (2010) and Marston (2011; 2012). Over the past 20 years, teachers have successfully used story books such as *Counting on Frank* (Clements, 1990) and *The Very Hungry Caterpillar,* (Carle, 1969), resource books (e.g., Griffiths & Clyne, 1988) and journal articles (e.g., Clark, 2007; Marston, Muir & Levy, 2013) to promote mathematical concept development. However, there is presently little assistance for teachers in identifying quality mathematical content and learning opportunities in recently released picture books.

This article describes three different types of 'mathematical' picture book and a framework (Marston, 2010) to assist teachers in selecting and evaluating picture books for promoting quality mathematics learning. It then evaluates three Australian picture books against the framework and suggests how these books could be used in the primary classroom for mathematical concept development.

Identifying mathematical picture books

'Mathematical' picture books are defined here as picture books with mathematical content present in both the text and images. The mathematical content may be perceived, explicit or embedded (Marston, 2010; see Table 1).

Table 1. Mathematical picture books

Type	Definition
Perceived	Books written principally to entertain; the mathematical concepts are unintentional and incidental.
Explicit	Books written in picture book format to specifically teach or develop one or more mathematical concepts; these include counting books and 'trade' books.
Embedded	Quality picture books written principally to entertain but with mathematical language and concepts purposefully embedded within them.

The framework developed by Marston (2010) contains seven categories (Table 2); each with a series of elements to assist teachers in evaluating the mathematical potential of a book. It considers recent changes in curriculum (particularly in Australia), research on the development of mathematical concepts in young children, and the role of visual images and text in conveying mathematical meaning—both independently and together.

Table 2. Framework classification scheme.

Code	Categories
MC	Mathematical content
CPP	Curriculum content, policies, and principles
IMC	Integration of mathematics content
MM	Mathematical meaning
MPS	Mathematical problem solving and reasoning
AML	Affordance for mathematics learning
PI	Pedagogical implementation

Using the framework to develop opportunities for mathematics learning

To demonstrate the use of the framework, three Australian picture books, *At the Beach: Postcards from Crabby Spit* (Harvey, 2004), *How Big is Big?* (Watson, 2009) and *Uno's Garden* (Base, 2006), have been evaluated against its categories. These three books have been chosen by the author as representative of the three different types of mathematical picture books. Learning experiences are then suggested for each book to highlight the mathematical concepts and opportunities for learning. Learning experiences or mathematical investigations should not be limited just to activities evidenced by the text or illustrations, or those perceived by the teacher. The story and illustrations should be a stimulus for both the teacher and students for problem-solving, problem-posing, and for the application and integration of concepts into everyday or relevant situations.

At the Beach: Postcards from Crabby Spit

In *At the Beach: Postcards from Crabby Spit* (Harvey, 2004), Henry, Penny and Frankie go on the iconic Australian camping holiday to the beach with their parents. Each day they send their grandmother a postcard describing the location and events of the day.

The mathematical content (MC) is not evident in the title or the cover. However, as

soon as the book is opened, the use of maps throughout clearly suggests opportunities for developing two-dimensional mapping skills. The book is not intended by Roland Harvey to 'teach' mathematical concepts, but, because of his personal fascination with mathematical and scientific ideas (Harvey, personal communication, 2011) and his illustrative style, he does hide both concept areas in the visual images. During a personal interview between Harvey and this author, Harvey classified this book as having perceived content.

Although the mapping content is an obvious opportunity for mathematical concept development, the 'maps' are more aerial pictures/photographs. This also applies to some of the top and side views portrayed, e.g., the "Treasure Trove". Although these are not 'true' or accurate maps, it does not mean that the book contains inaccuracies and therefore should be avoided, as they can still be used as valuable teaching points in the child's development of mathematical concepts such as views and transformations.

The story is very realistic and allows for authentic mathematical activities to be developed including the mathematics involved in planning a trip/holiday (MM, MC) and the daily activities of that holiday. The entertaining presentation enables mathematical knowledge and skills to be developed in an enjoyable atmosphere, thus fostering a positive attitude to mathematics (AML). It is doubtful that students would recognise the mathematical content/potential of the book, initiate mathematical activities themselves (even though they may engage independently in the ideas) or revisit the book for the mathematical content as there is so much else to explore in the intricate illustrations (PI). However, teacher-initiated activities or questions may lead to students posing their own mathematical problem (MPS), such as investigating who can throw a frisbee the furthest. Teachers will find the content and ensuing activities (Table 3) easily accessible and usable in an integrated program (PI).

The mathematical opportunities of the book encompass all strands of current State curricula and the *Australian Curriculum: Mathematics* (Australian, Curriculum, Assessment and Reporting Authority [ACARA], 2013; CPP). However, there is also the potential for rich integration with other curriculum areas: e.g., the postcards on each page could provide stimulus for experiencing different text types in English writing (IMC). Harvey has several other books in this same genre that afford similar learning experiences that teachers may wish to incorporate.

Table 3 suggests teaching and learning experiences with associated Australian Mathematics Curriculum Content Outcomes and Proficiency Strands, general capabilities and cross curriculum priorities (ACARA, 2013). This example is designed for students in Years 3 and 4 (CPP), however the activities could easily be adapted for either younger or older age groups. Activities for integration with other Key Learning Areas are also included.

How Big is Big?

How Big is Big? written and illustrated by the students of the composite Year 1/2 class at Curl Curl North Public School and Gretel Watson (2009), is also a holiday story. After Mrs Watson poses the question, "How big is big?" the students offer their ideas about what they consider to be 'big'. The idea of a class excursion to all the 'big' Australian landmarks ensues. Together the teacher and students plan and prepare for their trip and then take a six-day journey around these landmarks posing mathematical problems using all strands of the mathematics curriculum.

The title, text and visual images clearly relate to and portray mathematical concepts and ideas (MC), including mathematical language (tall, tally, rows, columns, equal, odd and minutes; MC), a number line/ruler on each double page, and problems constantly posed; for example, "The sun set at 5.07 pm and we sang campfire songs for two hours. What time did we go to bed?" (p. 14). It is therefore an example of an explicit mathematics picture book. These are not common on the Australian market, but are prevalent in the USA, e.g., *One Hundred Hungry Ants* (Pinczes, 1993).

Table 3. At the Beach: Postcards from Crabby Spit (Harvey, 2004).

Mathematics activities	Australian Curriculum content strands		General capabilities and cross-curriculum priorities	Proficiency strands
	Year 3	Year 4		
	Measurement & Geometry			
• Draw a map of a place (caravan park, resort, etc.) you go to on holidays showing the location of all the facilities and activities. • Create a map of your ideal holiday location. • Draw a map of your school, local area. • Give grid directions between two locations on a map for Crabby Spit or another location. • Create an orientation course with grid directions, distances and directional language (e.g., move west to B2 / move west 15 paces/ move west 10 metres) for Crabby Spit or another location. • Plan a weekend to the beach/to the bush. How far could you go? What you will do over the two days? Construct an itinerary/ timeline. • Conduct a Frisbee throwing (or other item) competition; record the results.	ACMMG061 ACMMG062 ACMMG065	ACMMG090	• Critical and creative thinking • Intercultural understanding • Numeracy • Asia and Australia's engagement with Asia	• Understanding • Fluency • Problem solving • Reasoning
	Number & Algebra			
• Plan a five day holiday for your family of four people. You have a budget of $1000, how will you spend it?	ACMNA059	ACMNA0800	• Literacy • Critical and creative thinking • Intercultural understanding • Numeracy • Asia and Australia's engagement with Asia • Information and communication technology capability	
	Statistics & Probability			
• Graph results of a Frisbee throwing competition or other activities. • Graph the tide heights for a week and predict best time for e.g., fishing, collecting shells.	ACMSP068 ACMSP069 ACMSP070	ACMSP095 ACMSP096 ACMSP097	• Literacy • Critical and creative thinking • Numeracy • Sustainability	

Table 3 continued

Integration with other curriculum areas				
	Year 3	Year 4		
• English: language, literature and literacy activities e.g., letter writing, descriptions, procedures/ instructions and directions. • PDHPE: Explore beach and sun safety. • Science: Research the scientific facts of stars and planets and pose mathematically related problems. • Science: Research the scientific facts of tides and graph their heights for a week.	ACELY1682 ACSSU048	ACELY1694 (ACSSU078 Y5)	• Literacy • Critical and creative thinking • Numeracy • Sustainability	

There are many examples of the interrelationship between the text and illustrations/diagrams throughout the book, such as the diagram depicting the calculation of how many different clothing combinations are possible using three T-shirts and two pairs of shorts (p. 7; MPS). Each double page spread also contains either an addition or subtraction algorithm representing the page number. While these are all accurate, an unrelated illustration or question is sometimes too near the algorithm, which can be confusing. For instance, when the children are camping at the Big Banana on page 6, the algorithm states 4 + 2 but it is placed between three tents (MC). This does not necessarily detract from possible problem posing and the story line, but needs to be considered—it could even promote further discussion.

Most of the mathematical content, written by the teacher and children in 1/2W, is age-appropriate and relates well to curriculum content (CPP) but some of the problems posed, from this author's experience, are beyond stage level. This is not to say that students of this age do not ask such questions, but problems related to, for example, kilometres per hour are usually too difficult to calculate for this age group.

As well as a broad spread of problem-solving activities across all mathematics curriculum strands, there are integration possibilities with other curriculum areas (IMC). For example, the landmarks visited and scientific facts mentioned could promote further discussion or research in the Geography and Science learning areas. The key inquiry questions for the Geography curriculum for Year 1 include the use of maps and the different features of places (ACARA, 2013; IMC). As the book is based on, and promotes student enquiry (MPS), the mathematical content is not sequentially structured (MM). However, as students solve one problem, their new knowledge and skills could inform the next. It is also pleasing to see that both males and females are involved in posing and solving mathematical problems throughout the book (CPP).

The main benefit of this book is the problem-solving and problem-posing activities (proficiency strands) throughout. They are authentic as they relate to everyday situations (MC) encountered and posed by students. However, whether or not a teacher would take a Year 1/2 class on a camping trip of such distances in six days is questionable. Although there are many open-ended questions, allowing for multiple paths to the solution (MPS), there are some very repetitive closed questions which would not endear mathematics to young children or encourage them to read the book again either for pleasure or its mathematical content (PI). *How Big is Big?* is enjoyable and engaging, and teachers would find it easy to implement (PI). Teachers of any year level could use the example set by this class as a

stimulus for similar investigations (PI, MPS). Students do not need to replicate the trip activity but can plan a variety of integrated activities similar to those outlined in Table 4.

Table 4. How Big is Big? (Watson, 2009)

Possible contexts for mathematical activities: planning an excursion, class party, menu, special event (fete, multicultural day, special celebration etc)	Australian Curriculum content strands		General capabilities and cross-curriculum priorities	Proficiency strands
	Year 1	Year 2		
	Statistics & Probability			
• Survey the class/ school about where to go, or the type of event to be held. • Report on results.	ACMSP262 ACMSP263	ACMSP048 ACMSP049	• Literacy • Critical and creative thinking • Sustainability	• Under-standing • Fluency • Problem Solving • Reasoning
	Measurement & Geometry			
• Use a calendar and clock to determine when it will be. • Create a timeline of events/ timetable. • Create maps/plans of where you are going/setting up the event? (Link to Geography)	ACMMG020 ACMMG021 ACMMG023	ACMMG039 ACMMG041 ACMMG044	• Numeracy • Literacy • Personal and social capability • Critical and creative thinking • Intercultural understanding • Aboriginal and Torres Strait Islander histories and cultures • Asia and Australia's engagement with Asia	
	Number & Algebra			
• List equipment and quantities of food needed (relate to proce-dure writing below). • Calculate clothing combinations needed (as seen in book). • Cost the activity or work within a budget.	ACMNA013 ACMNA014 ACMNA015 ACMNA016 ACMNA017	ACMNA028 ACMNA029 ACMNA030 ACMNA031 ACMNA032 ACMNA033 ACMNA034	• Literacy • Critical and creative thinking • Numeracy • Asia and Australia's engagement with Asia • Intercultural understanding • Aboriginal and Torres Strait Islander histories and cultures	

Table 4 continued.

Integration with other curriculum areas			
• Create a digital poster or menu for the event.			
• **English:** – Write letters/announcement to ask for volunteers. – Write a procedure of a recipe or process needed. – Write a report to the Principal/local newspaper etc or write a narrative/ description of the event.	ACELY1661 ACELY1664	ACELY1671 ACELY1674	• Literacy • Critical and creative thinking • Information and communication technology capability
• **History:** – Include cultural studies if planning a multicultural day.		ACHHK062 (Y3) ACHHK064 (Y3)	• Intercultural understanding • Personal and social capability • Critical and creative thinking • Information and communication technology capability • Aboriginal and Torres Strait Islander histories and cultures • Asia and Australia's engagement with Asia
• **Geography:** – Explore places around Australia – Show routes on maps	ACHGK005 ACHGS007	ACHGK009 ACHGS015	• Literacy • Information and communication technology capability • Asia and Australia's engagement with Asia • Aboriginal and Torres Strait Islander histories and cultures • Numeracy

Uno's Garden

Uno's Garden (Base, 2006) is a "storybook, puzzle book and numbers book" (back cover) about the destruction and then regeneration of a forest. While it is primarily a book with an environmental message, Base has included different levels of mathematics throughout. Each double page includes three mathematical calculations and readers can count and check their calculations in the corresponding illustration. The book can be read for the story alone, however the mathematical aspects add richness to the whole experience. Therefore, this book has been classified as having embedded mathematical content. Base includes a final page where he identifies to the reader (child, caregiver and/or teacher) the three main mathematical 'games' in the book in a similar style to the explanations Mitsumasa Anno used in *Anno's Counting Book* (Anno, 1977).

It is clear from the cover (operations signs in the border) and a glance at the double pages (mathematical equations in the top right hand corner e.g., $3 \times 3 = 9$) that there is deliberate mathematical intent (MC) in the text and illustrations (e.g., images of buildings depict growing number patterns). These are all aspects of the mathematics curriculum (CPP) but applicable to different stages of mathematical development. Thus the book can be used with a variety of year levels with the appropriate mathematical

aspect emphasised (CPP). Additionally, more able students would enjoy the opportunity to challenge and extend their thinking.

The presentation of the mathematics allows for the introduction and sequential development (MM) of a concept and/or consolidation through problem-solving and problem-posing (MPS). This book embeds mathematics in a meaningful (MM) and engaging situation, promoting the use of mathematical language (MC) and mathematics as an enjoyable activity (AML). However, students will certainly return to the book more for the story and illustrations, with their hidden treasures, than for the mathematical aspects.

Only one strand (Number and Algebra) of the mathematics curriculum is apparent in the book; attempts to include other mathematics strands would be contrived and not authentic. However, the Number and Algebra strand has been used successfully to add depth and strengthen the environmental message. Therefore this book can be used very effectively as part of an integrated program, in particular to emphasise environmental issues and the sustainability cross curriculum priority (IMC).

Table 5 suggests teaching and learning experiences, at the appropriate year level, for each of the 'games' described by Base. Examples of possible activities for integrated learning are also incorporated.

Table 5. Uno's Garden (Base, 2006).

Mathematical activities associated with embedded mathematical 'games'	Australian Curriculum content strands (Number & algebra)	General capabilities & cross-curriculum priorities	Proficiency strands
	Foundation		
• "*The Animals Number Game*" (Base, 2006 final page); counting/number sequences • Students can: – count the animals in the forest backwards from 10 as the forest disappears and then forwards again with regeneration; – use concrete materials as the book is read; – engage in "clothes line',10s frame, "guess the missing number" and number line activities; – use counting rhymes and other counting books to develop fluency; – count using the language or way of other cultures e.g., indigenous culture.	ACMNA001 ACMNA002 ACMNA289	• Literacy • Numeracy • Asia and Australia's engagement with Asia • Intercultural understanding • Aboriginal and Torres Strait Islander histories and cultures • Sustainability	• Understanding • Fluency • Problem Solving • Reasoning
	Years 1 & 2		
• "*The Building Numbers Game*" (Base, 2006 final page): the doubling concept. • Students can: – predict the number of buildings in the next page, with or without concrete materials; – explore mental strategies for doubling & doubling starting from an odd number other than 1; – explore the relationship/difference between doubling and multiplying by 2; – develop fluency in skip counting and number sequences using 2, 5, 10 and doubling through e.g., circle games; – explain and create number patterns; – find missing numbers in a number pattern, and – find patterns around them in their everyday lives.	ACMNA012 ACMNA018 ACMNA026 ACMNA035	• Numeracy • Literacy • Intercultural understanding • Asia and Australia's engagement with Asia • Critical and creative thinking	

Table 5 continued.

Mathematical activities associated with embedded mathematical 'games'.	Australian Curriculum content strands	General capabilities & cross-curriculum priorities	Proficiency strands
	Years 5 & 6		
• "*The Plants Number Game*" (Base, 2006 final page); squaring numbers • Students can: – use number lines or diagrams to create patterns; – explore patterns formed by squared numbers on the hundreds chart as opposed to patterns formed by doubling; – investigate other mathematical number patterns e.g., prime numbers (as portrayed by the number of people hidden within the pictures), additive and multiplicative patterns, triangular numbers and Fibonacci sequences; – describe and create pattern rules, and – extend number patterns to geometric patterns.	ACMNA107 ACMNA122 ACMNA133	• Literacy • Information and communication • Technology capability • Critical and creative thinking	
Integration with other curriculum areas			
	Science	**Geography**	
• Engage in environmental and sustainability activities (science and geography) at year appropriate level e.g., consider "methods of waste management and how they can affect the environment" (ACSHE062). • Engage in English, literacy and geography activities to support environmental activities at year appropriate level, e.g., make a class poster on the needs of plants and animals at the beach; debate the impact of building a new super-market on local bushland.	ACSSU002 ACSSU211 ACSHE022 ACSHE035 ACSSU043 ACSHE062 ACSHE051 ACSHE217 ACSSU073 ACSHE220 ACSSU094	ACHGK005 ACHGK021 ACHGK022 ACHGK023 ACHGK025 ACHGK029 ACHGS032	

Moving forward

Many teachers may only 'see' simple mathematical concepts such as counting and shape identification in many picture books and may need guidance to use them for rich learning and teaching activities. The aim of this framework is not to impose or contrive mathematics in all books but to aid teachers in selecting and evaluating picture books for quality mathematics learning experiences that meet the needs of their particular program and students. Some teachers using and becoming familiar with the elements of the framework have found it made them more adept in specifically identifying the actual mathematical content and realising the previously unrecognised potential of the books. It remains the teacher's prerogative as to how to incorporate the book into their program for meaningful learning experiences.

Some additional books that teachers may like to use for developing mathematical concepts and integrated learning are shown in Table 6.

Table 6. Additional books.

Book	Author	Publisher	Type
Amy and Louis	Libby Gleeson	Scholastic Press, NSW (2006)	Perceived
Are We There Yet? A Journey Around Australia	Alison Lester	Penguin Group. Vic. (2004)	Perceived
The Waterhole	Graeme Base	Penguin Group. Vic. (2003)	Embedded
Minnie's Diner: A Multiplying Menu	Dayle Ann Dodds	Candlewick Press, Cambridge MA (2004)	Explicit
One Hundred Hungry Ants	Elinor Pinczes	Houghton Mifflin Company, New York (1993)	Explicit

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