An Aesthetic Approach to Teaching Mathematics: A Proposed Framework Using Children's Picturebooks

Lorraine Gaunt
Charles Sturt University
lgaunt@csu.edu.au

Mellie Green
Southern Cross University
Mel.green@scu.edu.au

Georgina Barton
University of Southern Queensland
Georgina.Barton@unisq.edu.au

Hannah Deehan
Charles Sturt University
hdeehan@csu.edu.au

Danielle Sparrow
Charles Sturt University
dsparrow@csu.edu.au

Research shows primary teachers report negative dispositions towards teaching mathematics, impacting their confidence and student outcomes. One approach to improve teacher and student enthusiasm is using picturebooks. While research supports the use of picturebooks in mathematics learning, specific guidance for teachers to implement this practice effectively is lacking. Using a methodology of metalogue, we developed a framework to support teachers in providing engaging mathematics activities through aesthetic perceptions. We reflect on the development of the theoretically informed framework and discuss how it might support teachers' work.

Research shows that teachers and preservice teachers often lack confidence to teach mathematics (Albay & Çetin, 2023), and struggle to teach mathematics engagingly (Pennell et al., 2021), in ways that highlight its aesthetic value. Consequently, this struggle impacts teacher self-efficacy, with many educators reporting negative dispositions towards teaching mathematics (Albay & Çetin, 2023). One approach offered in the literature to improve confidence in teaching mathematics is using quality children's picturebooks (Cox, 2016). Research explores the use of children's books with perceived, explicit, or embedded content (Marston, 2010). Perceived content is the unintentional and incidental inclusion of mathematical concepts in authentic texts. Explicit content is where books, such as mathematical picturebooks, are written explicitly to teach a mathematical concept. Embedded content occurs where books have been written to entertain but include purposefully embedded mathematics concepts. Further research explores frameworks to support teachers in selecting appropriate books (c.f. Marston, 2010). Frameworks can support teachers to implement the use of literature in the mathematics classroom by guiding them to design mathematical activities (c.f. van den Heuvel-Panhuizen & Elia, 2012) that support student learning. However, many teachers are still unsure about how to effectively use quality children's picturebooks in mathematics activities and lessons, highlighting the aesthetics of mathematics (Cox, 2016).

In his seminal theory of aesthetics, Dewey (1934) emphasises the vital importance of a teacher's role in preparing students to notice and appreciate aesthetic attributes. By recognising the inherent aesthetic qualities in mathematics, such as depth or symmetry, educators can foster a deeper connection between mathematical concepts and students' learning experiences. This conference paper begins with an analysis of research on the use of children's picturebooks in mathematics, and existing frameworks designed to support teachers' effective use of picturebooks in mathematics. Based on this literature and a process of metalogue, we answer the research question: How can we develop a framework that would be useful in guiding teachers to authentically incorporate children's literature into mathematics lessons, and to take an aesthetic stance for enhanced engagement and improved outcomes?

(2024). In J. Višňovská, E. Ross, & S. Getenet (Eds.), *Surfing the waves of mathematics education. Proceedings of the 46th annual conference of the Mathematics Education Research Group of Australasia* (pp. 223–230). Gold Coast: MERGA.

Consequently, we designed an innovative *Beauty of Numeracy (BoN) framework* that teachers and preservice teachers can use as a guide when teaching mathematics engagingly in classroom contexts. Our framework is informed by Dewey's (1934) theory of aesthetics and the transformative potential of aesthetic education. It is also informed by the work of Krathwohl et al (1964) on a classification of educational objectives in the affective domain. This project specifically focuses on the aesthetic value of mathematics (Gadanidis et al., 2016). After reviewing the literature, we discuss the design process of our proposed BoN framework as experienced in its development and suggest how it might best support teachers' work.

Overview of Literature: Teaching Mathematics Through Picturebooks

Children's literature is a useful resource for mathematics instruction (van den Heuvel-Panhuizen & Elia, 2012) and can provide a diverse range of contexts to demonstrate mathematical concepts and applications, and foster connections to real-world scenarios. Selecting high-quality literature for mathematics tasks, designing practical activities, and challenging problem-solving tasks, leads to active learning processes (Cox, 2016). Active learning encourages students to explore mathematical concepts independently (Peter-Koop, 2005), and can be effective in helping students develop a deeper understanding of mathematical concepts (Cox, 2016). We examined research on the use of children's books to teach mathematics, identifying ways research supports teachers to use children's literature in the classroom. Research fell into three themes: (1) research that highlights storytelling to provide context for and support of students' understanding of mathematical concepts; (2) research that provides examples of activities and lessons for specific books; or (3) research on frameworks incorporating children's literature in mathematics instruction.

Research That Highlights Storytelling to Provide Context for and Support of Students' Understanding of Mathematical Concepts

Storytelling is a vital form of communication (Cox, 2016; Griffiths & Clyne, 1991). Mathematical stories can be used to focus student attention on mathematical ideas, although Cox (2016) argues that quality children's literature, without a mathematical focus, can be used to connect ideas for teaching mathematics in the classroom. Griffiths and Clyne (1991) state many concepts are embedded in stories, such as human relations, geography, and morality, but often, mathematics is not considered, making it difficult to embed literature in the mathematics classroom. Cox (2016) suggests teachers identify less obvious content within literature using Fermi problems (Peter-Koop, 2005) ─ non-traditional problems without numbers but with open beginnings and endings. Fermi problems encourage investigations and problem-solving amongst students. Cox (2016) argues they support teachers to integrate children's literature in mathematics, engaging students in meaningful, nonroutine mathematics explorations.

The power of story supports student engagement in the affective domain by learning mathematics through emotionalised and imaginative thinking (Griffiths & Clyne, 1991). In their work in Victorian schools (Australia), these researchers argued stories can: a) provide a context, b) provide a model, c) pose a problem, and d) stimulate an investigation or illustrate a concept. Stories can humanise mathematics, helping students see it as an integral part of everyday life and experience its aesthetic value. By using children's literature, teachers can vary concepts or topics, provide practice with different materials and methods, and provide opportunities for students to share ideas. This storied approach allows students to see how peers: solve problems, challenges students' thinking, and provides opportunity to reflect on learning. While providing a variety of examples, using specific books with explicit mathematics content, the research fails to provide a clear approach for teachers to see the mathematical and aesthetic potential of any children's book.

In a USA study (Barber & Neff, 2019), preservice teachers established *Math Night* events for students and their families. After completing studies in their university course on the use of picturebooks in mathematics, preservice teachers developed games and activities, potentially highlighting the aesthetic value of the chosen texts. While examples are provided of the mathematical goal of the chosen books, the process of developing activities is not described in this article. Research in this section demonstrates the value of children's literature in providing context and stimulus for mathematical thinking but does not provide clear guidance to teachers on how to implement the practice in the classroom.

Research That Provides Examples of Activities and Lessons From Specific Books

Some research describes mathematical tasks and lessons that use specific children's books, providing teachers with practical assistance in the mathematics classroom. For example, Larson and Rumsey (2018) used a picturebook and mathematics manipulatives, to integrate literacy skills into mathematics instruction. Their lesson vignette demonstrated how the book, combined with hands-on activities, supported learning goals and improved outcomes in both literacy and numeracy. The use of picturebooks and manipulatives progressed learning, "students [moved] beyond traditional, passive practices of learning by incorporating creativity, critical thinking, and the presentation of ideas" (Larson & Rumsey, 2018, p. 595). This approach supports teachers to "focus on mathematics worthy of attention, worthy of conversation, worthy of children's incredible minds (Gadanidis et al., 2016, p. 225) Further, Jenkins (2010) demonstrated the development of students' understanding of position, direction, and mapping skills using four picturebooks. Providing a range of activities suited to different year levels and linked with the NSW curriculum relevant at the time (Board of Studies NSW, 2002), Jenkins (2010) pointed out that the suggested texts "also lend themselves to mathematical discussions that cover a variety of other strands" (p. 31). Jenkins' work highlights the need for teachers to explore more deeply the mathematical content within children's literature ─ beyond what might be immediately obvious in the book.

Marston (2018) explored an *explicit* mathematical picturebook that was specifically developed and marketed to teach the concept of doubling. Marston analysed the mathematical content of the book using her framework (Marston, 2010) and found only 28% of the text related to the concept. Also identified in the text were: number, measurement, and geometry concepts. Three teachers in the UK and Australia used the book with three groups of 6–7-year-olds through a shared reading activity. Teachers were not given instructions on how to use the book. After the shared reading, the researcher asked students to "draw a picture or write about what comes into your mind when you think about the story" (Marston, 2018, p. 22). She then interviewed students and teachers. Teachers focused on the concept of doubling but had not considered the other concepts within the text. They used strategies such as pausing reading to explain mathematical content but provided limited opportunities for deep mathematical discussions arising from the content. Students' visual or written responses mostly reflected the doubling concept focused on by the teachers. While the explicit mathematical content in the text provided support for the teachers to integrate literature into mathematics, Marston (2018) found opportunities for deep mathematical exploration were missed, with students mostly engaging in teacher led questioning and discussion. While this research supports the value of children's literature to develop mathematical thinking in students, it also highlights the need for teacher support in effective implementation of picturebooks in mathematics instruction.

Research That Applies Frameworks to Incorporate Children's Literature in Mathematics

Recognising the need for implementation support, other research has developed frameworks to assist teachers. For example, Marston's (2010) framework guides teachers in selection of appropriate picturebooks to teach mathematics concepts. With an analysis of 122 award-

winning children's books, Marston categorised mathematical content into perceived, explicit, or embedded categories to support teachers in evaluating the appropriateness of a text for teaching and learning in mathematics. The resultant framework includes sub-categories of mathematical content, problem-solving, reasoning, and pedagogical implementation. While Marston's framework provides a tool for teachers to consider texts for mathematics, limited detail on how to implement literature into the mathematics classroom is provided.

Interactive read alouds using picturebooks can enhance mathematical learning. Courtade et al. (2013) demonstrated the value of interactive read alouds using picturebooks in supporting students with moderate to severe disabilities to build mathematical knowledge. By selecting children's books that pose interesting problems and showcase solutions, the authors suggested that educators can integrate real-world connections into mathematical concepts. A special education teacher and a mainstream Year 3 teacher, worked with a Year 3 student with an intellectual disability who was assessed before, during and after an interactive read aloud activity within a mainstream classroom setting. The teachers collaboratively planned ways to support the student to access the mathematical content within their inclusive classroom. They developed four key steps to support teachers to incorporate children's literature into mathematics for students with intellectual disabilities: (1) choosing a book relevant to a mathematical concept; (2) adapting it to meet individual student needs; (3) employing concrete examples with systematic instruction; and (4) incorporating assessment to guide instructional decisions effectively. Using these four key steps, the teachers planned further experiences with other texts demonstrating the usefulness of the steps in guiding the incorporation of literature into inclusive educational settings for diverse students.

A problem-solving pedagogy utilising challenging and engaging tasks has shown success in recent mathematical research (cf. Stein et al., 2008). One example that has developed from this rich research is a recent study by Ingram et al. (2020) who demonstrated a framework to support 12 New Zealand primary teachers with implementation of challenging geometric reasoning tasks in inclusive classrooms as part of the Encouraging Persistence, Maintaining Challenge (EPMC) project. The research team provided professional learning sessions, sample problems and resources, and classroom anchor charts to support a problem-solving culture in the classroom. This framework proved successful in supporting teachers who stated they are now incorporating notions of challenge and struggle across other curriculum areas in their planning and teaching. Students reported how teachers focused instruction on the process of problem-solving and expected them to solve problems, to support them in their mathematics learning. This focus on problem-solving authenticates the development of critical thinking skills (Larson & Rumsey, 2018). This research focused on challenging tasks to provide an authentic context to develop critical thinking skills. How to provide the meaningful context to engage students in problem solving remains a challenge.

Using picturebooks provides meaningful contexts for mathematical learning and supports students' active engagement leading to better conceptual understanding. Forbringer et al. (2016) conducted a study in three classrooms; kindergarten, a multi age classroom, and a year 1 class, to develop a framework for teachers to use children's literature in a differentiated mathematics lesson. This framework comprises six steps: (1) select book that serves as an inspiration for mathematical problem-solving; (2) determine the mathematical focal point of the lesson and align it with the curriculum; (3) use the narrative to craft a mathematical problem or question; (4) list the concepts or skills that students must possess to successfully solve the problem; (5) consider additional questions to differentiate the task; and (6) plan how to facilitate students to engage in differentiated problem-solving tasks. Findings showed that the framework supported teachers to use children's literature to teach mathematical concepts, allowing differentiated tasks in an inclusive classroom. Research of frameworks demonstrates their potential value in mathematics instruction but also reveals some limitations.

Limitations of Existing Frameworks

While research demonstrates that using children's literature to support mathematical development is helpful (e.g., Cox, 2016; Marston, 2018), it provides scant ideas on how teachers might implement this practice in the classroom. Some literature provides advice for only specific titles (Larson & Rumsey, 2018). While Marston (2010) suggests mathematical content is perceived, explicit or embedded, she implies that not all children's literature could be useful in a mathematics classroom. Further, some frameworks provide guidance on the types of mathematical activities that support students' critical thinking skills (Forbringer et al., 2016), but explicit support for teacher implementation through children's literature is limited.

Research supports the benefits of teachers using picturebooks in mathematics to develop engaging and challenging tasks and resources. The aesthetic aspect of this approach, however, is largely missing in the research literature. Our study emphasises the significance of aesthetic appreciation in mathematics learning (Green et al., In press). We sought to develop a framework that progresses student learning in mathematics through perceptions of picturebooks, which enhance the aesthetic value of mathematics. This led to our research question: How can we develop a framework that would be useful in guiding teachers to authentically incorporate children's literature into mathematics lessons, and to take an aesthetic stance for enhanced engagement and improved outcomes?

Methods

To collaboratively bring together the different ideas and expertise of the authors, we used the methodology of metalogue. Metalogue involves conversation about a problematic matter, with subsequent discussion of the conversation in relation to the same matter (Bateson, 1972). Both the form and content of the discourse is analysed, and meaning made through reflexive practice (Willis et al., 2014). Metalogue is different from a conversation analysis (Toerien, 2014) in that researchers revisit the experience of an initial conversation through a reflexive lens, analysing the subsequent conversation. Emphasis is placed on the aesthetic dimension of the discussion (Yared & Davis, 2014). Metalogue provides space for participants to engage in generative dialogue, listen, and learn from each other (Willis et al., 2014). We conversed on the problematic matter of students' aesthetic engagement in picturebooks for mathematics learning, and then discussed the value of the conversational aesthetic experience (Green et al., in press). This reflexive exercise impelled the development of the BoN framework.

Developing the *Beauty of Numeracy (BoN) Framework*

The development of the BoN framework was informed by research on frameworks that support children's literature in mathematics instruction (e.g., Courtade et al., 2016; van den Heuvel-Panhuizen & Elia, 2012). This comprised frameworks designed to support teaching in mathematics (E.g., Ingram et al., 2020), promote the aesthetic value of mathematics (Gadanidis et al., 2016), and meet education objectives in the aesthetic domain (e.g., Krathwohl et al., 1964). Additionally, the BoN framework is underpinned by Dewey's (1934) aesthetic theory, often drawn on to advance mathematics instruction (e.g., Gadanidis et al., 2016) for its enculturating, long-term, transformative potential. Bloom's taxonomy of educational objectives in the affective domain (Krathwohl et al., 1964) also provides theoretical underpinnings.

The Design Process

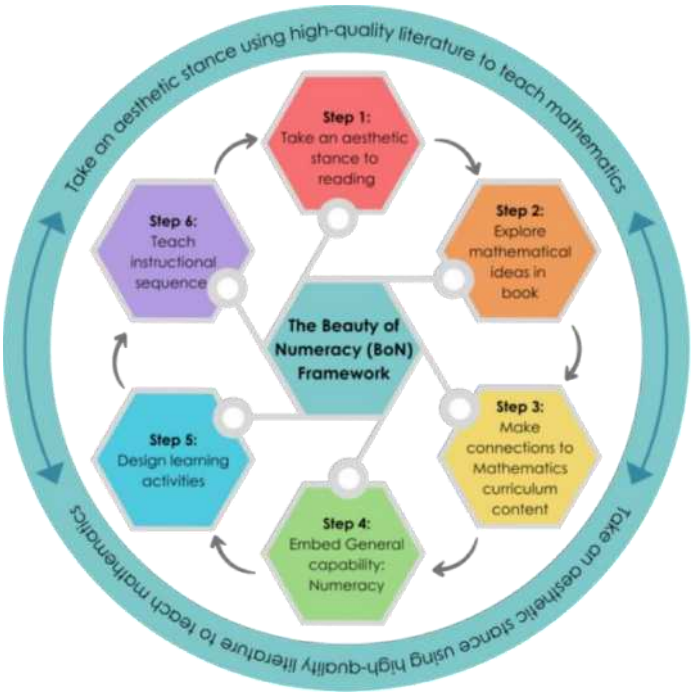
In the first conversation, the first two authors examined their own journeys towards planning and designing mathematics activities and challenging tasks. Following the process of metalogue (Green et al., in press), each author developed an initial framework. These frameworks were then discussed and analysed to identify key areas of innovation, agreement, and disagreement in a dynamic and interactive exchange, characterised by a rich diversity of perspectives, ideas,

and insights. Through metalogue conflicts were resolved, and the initial six steps of the framework developed. Next, all five authors worked on different developmental steps of the framework, which were then brought back for further discussions and analysis by the first two authors. From the finalised design, the procedures for each step were fine-tuned by the first two authors. The final two authors incorporated the steps into an easy-to-follow diagram, displayed on an A3 placemat with the framework on one side, and explanations of each step on the other (see Figure 1). With the visual representation of the process in the centre of the placemat, brief points for each step were provided around the outside. A clear outline of the purpose was included at the top of the framework. The front page provides a quick reference guide for teachers. On the reverse side of the placemat, detailed explanations of each step were provided so that teachers could refer to this if they were unsure of their next steps.

The BoN framework was designed to provide in-service and pre-service teachers with a guide to authentically incorporate children's literature into mathematics lessons, through taking an aesthetic stance for enhanced engagement. The A3 size placemat was easy for teachers to keep on their desks to be readily available to support them in their planning and practice.

Figure 1

Beauty of Numeracy (BoN) Framework



With the visual representation of the process in the centre of the placemat, a clear outline of the purpose of taking an aesthetic approach to mathematics was stepped out into six clear principles. The aesthetic approach is the subject of a subsequent publication but briefly, it encourages teachers to appreciate and value:

1. An aware willing, open, and free exploration of mathematical concepts.
2. Satisfaction in responding to the sensory experience of mathematical inquiry.
3. Commitment to the development of perception associated with mathematical thinking.
4. Formation and organisation of ideas associated with mathematical beauty and reasoning.
5. Readiness to revise judgements associated with mathematical observations, evaluations, and reasoning.
6. Internalised, consistent belief in oneself as a highly numerate person who thoroughly enjoys mathematics.

The front side provides a quick reference guide for teachers with brief points for each step provided around the outside. With each step listed below, the key research literature that inspired and supported the importance of the inclusion of that step into the framework is listed:

1. Prepare the physical and mental space for taking an aesthetic stance to read (Gadanidis et al., 2016).
2. Explore high-quality children's literature with selective attention directed towards mathematical concepts (Cox ,2016).
3. Make connections between the mathematical concepts presented in the book and relevant mathematics curriculum content (Marston, 2018).
4. Identify any relevant General capability: Numeracy elements/sub-elements to broaden and extend learning (Forbringer et al., 2016).
5. Draw inspiration for the children's book, to develop a challenging learning activity/experience/inquiry/problem (Larson & Rumsey, 2018).
6. Inspired by Ingram et al. (2020):
    - *Prepare* for aesthetic engagement in reading and mathematics;
    - *Launch* the mathematical challenge;
    - *Explore* a range of possible responses;
    - *Discuss* ideas, potential to build on others' ideas, reasonableness of ideas and value the learning experience.

The detailed steps of the BoN framework, as shown on the reverse side of the placement, provide guidelines to teachers to explore quality children's literature, make connections to mathematical concepts and link that to the curriculum content for the context of their own class. Step 6, based on the problem-solving approach of Ingram et al. (2020), provides guidance for teachers in planning and implementing problem-based lessons with their students, with a reminder to consider an aesthetic stance. To support teachers to effectively implement the BoN framework in classroom planning and practice, a series of professional development sessions are currently being trialled. The trial is beyond the scope of this paper.

Discussion

The process of planning and developing a framework, through collaborative consultation and metalogue between all authors supported a progressive fine tuning of the BoN framework. The generative process led to a comprehensive and complete framework that is valuable for teachers' curriculum design and enactment. The framework offers support for in-service and preservice teachers in taking potentially any quality children's picturebook and using it as the basis for mathematical investigations. The aesthetic stance and problem-solving pedagogical approach offer support for both teachers and students to appreciate the aesthetic qualities of mathematical concepts, structures and content. This supports both teachers and students to see the beauty and value of mathematics in their world. The problem-solving, challenging task approach (Ingram et al., 2020) supports creativity and critical thinking as valued by Larson and Rumsey (2018), and Dewey (1934).

The next phase in the research project provides professional development (PD) sessions for in-service and pre-service teachers to trial and provide feedback on application of the BoN framework for improved engagement and outcomes. Initial feedback from the first two PD sessions, in which the BoN framework was introduced and explained, indicated 98% of teachers felt they had learnt something new and valuable. Further research will investigate teachers' implementation of the framework in classroom settings as well as impact on engagement and outcomes.

References

Albay, A., & Çetin, H. (2023). A mixed method research study on pre-service primary school teachers' mathematical disposition. *Journal on Mathematics Education, 14*(2), 311–338. https://doi.org/10.22342/jme.v14i2.pp311-338

Barber, K. A., & Neff, S. (2019). Through the eyes of a preservice teacher: Developing mathematics instruction with picture books during math night. *PDS Partners*, *14*(2), 18–22.

Bateson, G. (1972). Steps to an ecology of mind. Jason Aronson. Board of Studies NSW. (2002). *Mathematics K–6 Syllabus*. Board of Studies.

Courtade, G. R., Lingo, A. S., Karp, K. S., & Whitney, T. (2013). Shared story reading: Teaching mathematics to students with moderate and severe disabilities. *Teaching Exceptional Children*, *45*(3), 34–44. https://doi.org/10.1177/004005991304500304

Cox, T. (2016). Integrating literature into the teaching of mathematics. *Australian Mathematics Teacher*, *72*(1), 15–17.

Dewey, J. (1934). *Art as experience*. Minton, Balch & Company.

Forbringer, L., Hettinger, A., & Reichert, E. (2016). Using the picture book extra yarn to differentiate common core math instruction. *YC Young Children*, *71*(2), 22–29.

Gadanidis, G., Borba, M., Hughes, J., & Lacerda, H. D. (2016). Designing aesthetic experiences for young mathematicians: A model for mathematics education reform. *Revista Internacional de Pesquisa em Educação Matemática*, *6*(2), 225–244.

Green, M., Gaunt, L. & Barton, G. (in press). The aesthetic value of mathematics in children's picturebooks: A metalogue for improving teacher dispositions. *The Australian Educational Researcher*.

Griffiths, R., & Clyne, M. (1991). Once upon a time ... . *Australian Mathematics Teacher*, *47*(1), 10–13.

Ingram, N., Holmes, M., Linsell, C., Livy, S., McCormick, M., & Sullivan, P. (2020). Exploring an innovative approach to teaching mathematics through the use of challenging tasks: A New Zealand perspective. *Mathematics Education Research Journal*, *32*(3), 497–522. https://doi.org/10.1007/s13394-019-00266-1

Jenkins, K. (2010). New voices: Positioning picture books within the Mathematics Curriculum. *Australian Primary Mathematics Classroom*, *15*(2), 28–32.

Krathwohl, D., Bloom, B., & Masia, B. (1964). Taxonomy of educational objectives: The classification of educational goals: Handbook II affective domain. David McKay Company.

Larson, L. C., & Rumsey, C. (2018). Bringing stories to life: Integrating literature and math manipulatives. *The Reading Teacher*, *71*(5), 589–596. https://doi.org/10.1002/trtr.1652

Marston, J. (2010). Developing a framework for the selection of picture books to promote early mathematical development. In L. Sparrow, B. Kissane, & C. Hurst (Eds.), *Shaping the Future of Mathematics Education. Proceedings of the 33rd annual conference of the Mathematics Education Research Group of Australasia* (pp. 383–390). MERGA.

Marston, J. (2018). Opportunities for rich teaching and learning in explicit mathematical picture books. *Primary Mathematics*, *22*(2), 21–24.

Pennell, S., Baker, K., & Fede, B. (2021). "The space between" literacy and mathematics: Interdisciplinary teaching through a graphic novel. *Voices From the Middle*, *29*(2), 64–67.

Peter-Koop, A. (2005). Fermi problems in primary mathematics classrooms: Fostering children's mathematical modelling processes. *Australian Primary Mathematics Classroom*, *10*(1), 4–8.

Stein, M. K., Engle, R. A., Smith, M. S., & Hughes, E. K. (2008). Orchestrating productive mathematical discussions: Five practices for helping teachers move beyond show and tell. *Mathematical Thinking and Learning*, *10*(4), 313–340. https://doi.org/10.1080/10986060802229675

Toerien, M. (2014). Conversations and conversation analysis. In E. Flick (Ed.), *The SAGE handbook of qualitative data analysis* (Chapter 22, pp. 327–340). Sage.

van den Heuvel-Panhuizen, M., & Elia, I. (2012). Developing a framework for the evaluation of picturebooks that support kindergartners' learning of mathematics. *Research in Mathematics Education*, *14*(1), 17–47.

Willis, L.-D., Kretschmann, G., Lewis, K., & Montes, C. (2014). An engaging pedagogy for social education: Co-teaching a teacher education program. *Social Educator*, *32*(3), 23–36. https://doi.org/10.3316/aeipt.206846

Yared, A., & Davis, H. (2014). Talking in circles: interview, conversation, metalogue. *Journal for Artistic Research*, *5*.