

Teachers' Use of Mathematical Picturebooks to Engage Children in the Upper Primary Years in Mathematics

Lorraine Harbison, Mary Kingston and Sue Miller

DCU Institute of Education

The use of picturebooks to engage children in developing mathematical proficiency is well documented. However, there is limited evidence as to their use with children in the upper primary years. Therefore, we developed a novel initiative in which we would source picturebooks that contained mathematical topics appropriate to this age cohort and trial them in the classroom. In this paper, we present the findings from the seven teachers who took part. The thematic analysis is aligned with the three core principles of Universal Design for Learning. Results demonstrate that use of picturebooks offer learners multiple means of accessing and engaging with mathematical concepts, multiple means of building conceptual representations of mathematics, and lend themselves to multiple means of action and expression in extending, internalising and showcasing learning.

Background

The Primary School Mathematics Curriculum is currently under redevelopment with the new specification due to be launched in 2022. Informed by commissioned research reports on children's mathematical learning in primary school, a draft specification was released for consultation, heralding a shift away from content objectives aligned to class level, to learning outcomes aligned along progression continua. Stemming from an ideology of what it means to be proficient in mathematics, teachers are encouraged to "use appropriate and evidence-based pedagogical approaches and strategies to foster engagement, ownership and challenge while connecting with children's life experiences and their interests" (National Council for Curriculum and Assessment [NCCA], 2020, p. 6). One such approach, and the one of focus in this research, is for teachers to plan "Experiences with mathematically-related stories [as these] have the potential to promote aspects of mathematical proficiency, including procedural fluency, adaptive reasoning and a productive disposition" (Dooley et al., 2014, p. 53).

In a recent study in Ireland, pre- and in-service teachers (n=154) reported perceived benefits to children's mathematical learning such as promoting engagement and inclusion, allowing for integrated learning across the curriculum, embedding mathematics in real-life problem-solving situations, supporting revision of concepts, and helping children visualise concepts (Prendergast et al., 2019). Despite this, the use of mathematically-related stories seems somewhat limited to the lower primary years. This appears to be quite consistent with research in the field and points to a dearth in the literature about suitability for use with older children. This was further confounded by a reported lack of availability of stories that would work for a specific mathematical topic and exacerbated by a lack of confidence and pedagogical knowledge (Prendergast et al., 2019). This motivated us to develop an initiative in which we would source and trial suitable mathematically-related stories in classrooms. In particular, we wanted to get feedback from teachers on how these stories could best be

leveraged to support all learners to engage in challenging and meaningful ways of thinking and working mathematically.

Theoretical Framework

The focus of this study was to examine teachers' experiences of using mathematically-related stories in the classroom so as to engage all learners in mathematics. Thus the researchers drew on an *appropriate and evidence-based* teaching and learning framework, Universal Design for Learning (UDL). The three core principles of UDL comprise multiple means of engagement, representation, and action and expression. These principles are each expanded into guidelines and checkpoints which offer a set of concrete suggestions to help ensure that all learners can access and participate in meaningful, challenging learning opportunities. They further help teachers to identify different methods of engagement, representation, and expression that can be used in a particular lesson to allow learners to *access* the learning outcomes, remain engaged and *build* on their learning, and begin to *internalise* the approaches to learning in order to become *proficient* learners of mathematics (Center for Applied Special Technology [CAST], 2018). In the context of this initiative, the UDL framework was to act as an organiser, rather than a checklist, to highlight how mathematically-related stories can be used to meet the needs of all learners in the upper primary school mathematics classroom and to intentionally reflect on how quality learning interactions can be designed from the outset. In particular, we wished to consider:

1. If mathematically-related stories can engage all children in learning?
2. How representations of mathematical content in stories can support all learners to access and build understanding?
3. What opportunities mathematically-related stories afford all learners to demonstrate mathematical proficiency?

Methods

Collection Development

To create a list of titles for consideration, searches were performed within DCU Library's Juvenile Literature Collections, on Amazon.co.uk and Amazon.com and on educational publisher websites from the UK, US and Australia. The reference management tool *Zotero* was used to create a shared list of titles discovered during the initial search and to facilitate evaluation of the list. Titles considered had to meet the following selection criteria; (a) be in print; (b) have literary and aesthetic merit; (c) reflect numeracy themes contained in the curriculum; (d) have illustrations; (e) have an explicit emphasis on mathematical content through engaging in a narrative. Typically, the story would focus on a protagonist or group of characters that face some form of crisis which requires them to draw on understanding of mathematical concepts to solve the problem that they face (Trakulphadetkrai et al., 2019). We considered visuals necessary to inform, inspire and captivate learners. Therefore, from now on we are working with the definition of picturebook(s), written as one word, where the story or narrative is both implied and assumed. Furthermore, we narrowed our selection to titles that addressed mathematical concepts in the fourth to sixth class curriculum from the

Charlesbridge series comprising; Data: *Sir Cumference and the Off-the-Charts Dessert* (Neuschwander, 2013); Chance: *A Very Improbable Story* (Einhorn, 2008); Fractions: *Fractions in Disguise* (Einhorn, 2014); Ratio: *Pythagoras and the Ratios* (Ellis, 2010); Multiplication: *Multiplying Menace. The Revenge of Rumpelstiltskin* (Calvert, 2006).

Participants

A convenience sample of three teachers, one from 6th (T6), one from 5th (T5) and one from 4th (T4) class were invited to take part in the research. We also invited teachers from one senior national school. This case study comprised one 6th class (CS6), two 5th (CS5a), (CS5b), and two 4th (CS4a), (CS4b), class teachers. Packs were collated and distributed to classes in time for Maths Week 2020. Thus, a pack for a class of 30 pupils would contain six picturebooks of each of the five titles. This would allow flexibility in use from individual, pair-work, group-work or whole class activity. A Google Form was designed to capture teachers' initial response to the packs which formed the basis for the semi-structured interviews that followed.

Semi-structured Interviews

The interviews took place individually via Zoom and were audio-recorded and autotranscribed using Otter. A learning support teacher in the case study school collated feedback from colleagues and reported back to the research team. In summary, the interviews comprised three key question prompts which aligned with the principles of UDL: What book did you feel was most engaging for children and why? [multiple means of engagement]; Choose a book you consider represents mathematics best. Tell me about it. [multiple means of representation]; What activities did the children engage in to demonstrate and extend their learning? How did this book link with the engagement/representation/action and expression on the UDL framework? [multiple means of action and expression].

Coding

A deductive approach to data coding and analysis was adopted in this study. This technique enables the codes and themes to derive more from concepts and ideas the researcher brings to the data (Braun & Clarke, 2012). This top-down approach allowed us to code the data using the UDL principles of multiple means of engagement, multiple means of representation, and multiple means of action and expression. It should be noted that although the three UDL principles and associated guidelines are presented separately, they are interconnected with each other. Changes in practice, such as designing new tasks for children to demonstrate their understanding, may impact on the child's engagement with the mathematics. Thus, we have employed a 'best fit' model in coding the data comprising teachers' initial appraisal of the books and subsequent utility for the particular class level.

Findings and Analysis

Multiple Means of Engagement

In considering the ‘why’ of learning, we sought to ascertain teachers’ perspectives on using the picturebooks to increase engagement, stimulate motivation and sustain enthusiasm for learning mathematics (CAST, 2018).

Engagement of the Learner. An initial consideration in the collection development was the literary and aesthetic appeal of the picturebooks which research has shown has the potential to cognitively engage the children in the mathematics (Elia et al., 2010). The response from teachers when the packs arrived was overwhelmingly positive. Teachers commented on the potential to “excite” and “motivate” the children (T5) as well as “increasing engagement with learning” (CS5b). “There was a lovely moment when the children saw the books for the first time, just after they submitted their assent forms which sparked curiosity and wonder around mathematics. As the children had their snacks, informal maths talk took place between them” (T4). Beyond the initial impressions of the picturebooks themselves, the teachers had to consider how they would use these in the classroom. Pivoting from an approach that tended to involve individual tasks with frequent opportunities for practice and consolidation to the use of picturebooks as a “teaching tool”, was perceived as quite overwhelming and “would be planning times one hundred” (CS5A). For the most part, teachers decided to implement the picturebooks to coincide with planning of particular topics as this would “allow me to integrate the books more meaningfully into my teaching” (T6). “I didn't want to just throw the picturebooks in there as a one off lesson. I kind of wanted to build it into my maybe weekly or fortnightly theme for that month, or for that period of time when it came to maths” (T5). “Content-related storybooks can be used as an introduction to build interest and create a feeling of anticipation and focus for the lesson or as a culminating activity” (Capraro & Capraro, 2006, p.35). This was similar to how the teachers used the picturebooks, likening it to the teaching of English, “Children were asked to predict from the front cover, what the story was about and after one reading of the story (or having the story read to them), they were asked to make a summary” (T6). Teachers also concurred that “The problem presented in each story will be used to stimulate problem solving and talk and discussion in the lesson” (T5). Such practices in integrative contexts is supported by research which highlights the multiple opportunities that picturebooks offer in providing rich contexts for “learning activities that arise from children’s interests, concerns, and questions and the educators links these to learning goals” in developing mathematical proficiency (Dooley, et al., 2014, p. 45).

Engagement with the Wider Community. It was hoped that engagement with the picturebooks would help to extend the learning of mathematics beyond the confines of the classroom as “Primary mathematics education should provide children with opportunities to engage with deep, meaningful and challenging mathematics in educational settings, including social and familial settings. Such engagement will result in children co-constructing knowledge and skills as they interact and collaborate” (NCCA, 2018, p.18). There were

mixed feelings with regards to upscaling the use of mathematical picturebooks. “As a school community, the teaching and learning of mathematics is under review, with a push to move away from traditional “textbook” teaching, particularly in senior classes” (T4). This was reiterated by other teachers whose “colleagues are generally open to trying out new ways of teaching and learning in their classrooms” (T6) and would see this as “a different yet engaging way to teach maths” (CS4a). Although the potential of using picturebooks as part of Maths Week was highlighted (T5), there was caution expressed about use at home. “Parents may be interested but I think, would need a lot of hand holding/explicit direction” (CS5b). Others were more positive “Many of the consent forms were accompanied with thank you notes from parents” (CS6), and considered engagement with picturebooks at home “might give them [parents] also a better understanding of how to explain certain concepts in maths” (CS6).

Multiple Means of Representation

In this section we consider the ‘what’ of learning, with an explicit focus on how mathematics is represented in the picturebooks. “One key strength of that format is the way mathematical concepts can be represented in different ways, be it visually (through page illustrations), symbolically (through mathematical models and notations), and contextually (through meaningful contexts in which mathematical concepts are found)” (Trakulphadetkrai et al., 2019, p. 204). It has further been shown that strengthening children’s ability to move between and among representations; pictures, oral/written language, real-world situations, written symbols and manipulative models; improves the growth in mathematical proficiency (Lesh et al., 2003, cited in Chigeza, 2013, p. 179).

Representations of Mathematics through Story. Picturebooks can be a powerful vehicle for providing a meaningful context for representing mathematics and demonstrates that many mathematical concepts develop out of human experiences and interactions (Chigeza, 2013). This was particularly evident in *Pythagoras and (his musical rock group) the Ratios*. Whereas Pythagoras is infamous for his theorem on right-angled triangles, the underlying mathematical concept of this story is the particular mathematical relationship between musical notes. This picturebook, however, was used less frequently than others. One teacher commented that the children couldn’t even attempt to sound out the word *Pythagoras*. She considered pre-teaching the language involved but felt “it would take some of the magic out of the story” (T4). However, ratio is only introduced in the 6th Class curriculum and therefore this concept might be slightly beyond the reach of most children whereas an understanding of fractions is a key concept of the fourth and fifth class curriculum. *Fractions in Disguise* follows the story of a brand-new fraction, stolen at auction, and the subsequent invention of a *Reducer* machine which could be used to simplify fractions to their lowest terms, and thus reveal their true identity; “Quickly I spotted my first fraud. “That $\frac{3}{21}$,” I said. “It’s really a $\frac{1}{7}$, isn’t it?” I pointed my reducer at the fraction and dialled a 3. Both the numerator and the denominator were divided, and now I had a $\frac{1}{7}$ before me, as I had suspected” (Einhorn, 2014, p. 17). It was seen that quite an abstract mathematical concept, when embedded in a meaningful context that children can relate to, gave children the opportunity to make sense of the mathematics involved (Elia et al., 2010). “This character

created a really child-friendly, fun representation of a concept that helps simplify fractions efficiently and requires children to extend their use of multiples in a natural way” (CS4b).

Representations of Mathematics through Pictures and Text. The relationship between the pictures and the text in exemplifying the mathematical concepts was another important consideration. Predominantly the pictures were related to representing the story-element with the main exception, *Sir Cumference and the Off-the Charts Dessert*. The two protagonists, *Lady Di of Amater* and *Bart Graf*, engage in a bake-off with the pictures clearly illustrating the complete data cycle culminating in a representation of the data using pie and bar charts. Elia et al. (2010) contend that pictures which illustrate mathematical concepts support children’s learning of mathematics and elicit mathematical thinking; “As they worked in pods there was good opportunity for orally explaining their maths findings related to the concepts, simplifying fractions, collecting and analysing data” (CS4a). The clever use of language and naming of the characters enabled the children to develop an appreciation of mathematics that was new to them, such as *Octavius* (Pythagoras is attributed with discovering that a string exactly half the length of another will play a pitch that is exactly an octave higher) and *Odds* the cat, where in one class, children assumed incorrectly that the story was going to be about odd and even numbers and led to a rich exploration of the story on probability (T4). Thus from a UDL perspective, we can see the potential use of picturebooks to enable all learners to “access powerful mathematical ideas relevant to their current lives and also learn the language of mathematics vital to future progression” (Chigeza, 2013, p. 182).

Multiple Means of Action and Expression

This principle focuses on how the teachers used the picturebooks in their classrooms and the options offered to the children to demonstrate their learning as it is particularly important that picturebooks offer participation opportunities for children (Elia et al., 2010). In this section, we examine how the teachers planned tasks in which the children could engage and develop new understandings. We also explore the various methods by which the teachers organised the learning environment to facilitate the children in expressing and sharing ideas.

Task Development. Tasks were developed by each of the teachers to ensure the active participation of the children and to provide opportunities for them to take action in the lessons. Many of the teachers utilised the tasks that were explicitly presented in the picturebooks. This often involved pausing the reading of the picturebook and encouraging the children to solve the problems faced by the characters. The teachers praised these tasks due to their cognitive demand and the richness of the learning opportunities they provided. One teacher stated that he “was amazed at the amount of learning” that emerged from bringing these tasks to life in the classroom (T5). From a UDL perspective, a number of the teachers identified that the tasks in the picturebooks challenged the thinking of all learners in the classroom. For example, one teacher reported that the tasks “had a low entry point but also had high challenge, [providing] optimal learning for all” (CS4b). A number of the teachers also designed their own follow-on tasks based on the events depicted in the picturebooks. For example, in *Multiplying Menace*, Peter is faced with saving the kingdom using a magic

multiplier stick. In one classroom the teacher presented the children with her own imaginary activity involving the multiplier stick: “Imagine you are on a deserted island and when you look around you see the following: sand, the sea, a shark, a wooden box filled with treasure, a coconut palm tree, a pile of rocks and a multiplier stick” (T6). The children were required to describe how they would use the multiplier stick to escape from the island. A range of responses were provided by the children including “I’ll multiply the shark by zero to get rid of the shark”, “I’ll multiply the tree by 1,000 and make a bridge” and “I’ll multiply the sea by zero and then I can just walk back”. In each of the classrooms, children were encouraged to use their own approaches to solve the tasks which allowed for multiple means of action. This was particularly evident in one classroom where the children were provided with access to a range of resources that they could physically manipulate to solve the problems and the children presented their work in various ways including through the use of drawings, symbols, numbers and letters (T5).

Classroom Organisation. The participating teachers organised their classrooms in a variety of ways to provide the children with multiple opportunities to take action in the lessons and to express their mathematical ideas. Firstly, in every classroom, the children engaged in whole class discourse around the mathematics and the picturebooks acted as a stimulus for these discussions. The opportunities presented by the picturebooks for engaging children in whole-class discussion were highlighted by a number of the teachers as having a positive impact on the children’s learning. This was echoed in a study by Capraro and Capraro (2006) pertaining to the use of children’s mathematics literature in geometry lessons. The researchers contended that children make meaningful connections through engaging in classroom discourse and responding to purposeful questioning. Questioning and open discussion was identified as a key tool in meeting the varied needs of children in a classroom. This was highlighted by one teacher who acknowledged that she was able to guide the discussion and her questioning to both support and challenge all learners (CS4a). Every teacher reported that they encouraged the children to work collaboratively on the tasks that emerged from the picturebooks. This afforded the children multiple opportunities to express their thinking and to discuss ideas with their peers. Working in pairs and small groups also provided regular opportunities for the children to hear the mathematical ideas of their classmates. Additionally, one teacher stated that children were encouraged to question and build upon each other’s ideas (CS4b). In an online learning space, one teacher shared an audio recording of *A Very Improbable Story* with her class. Although it is assumed that children at this class level could read the story for themselves, the teacher wished to provide the children with the opportunity to sit back and enjoy the story (T6). Research has shown that “children can be mathematically engaged by being read a picture book when the role of the reader is restricted to the reading of the book (without any prompting)” (Van den Heuvel-Panhuizen & Van den Boogaard, 2008, as cited in Elia et al., 2010, p. 278). However, this teacher also noted the limitations of the online environment, in particular with respect to use of maths talk. This finding reflects that of other research which states that mathematically-related stories “used without a teacher who is asking questions, may not always be as effective as expected in evoking mathematics-related thinking” (Elia et al., 2010, p. 289).

Conclusion and Next Steps

It can be deduced from the findings that the teachers involved in this research found the picturebooks to be a valuable resource in supporting children to engage with rich meaningful mathematical experiences. Whereas we did not ask the teachers to identify titles for use in the upper primary school classroom themselves, the results show that there is merit in using such a pedagogical approach and thus we are developing guidance for teachers in the identification and evaluation of titles. The aim of this work is to build the confidence and competence of teachers in selecting picturebooks that will align with best practice as outlined in the draft mathematics specification. This information will be made available via DCU Libguides.

References

- Braun, V. & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), *APA handbook of research methods in psychology. Vol. 2, research designs*. American Psychological Association.
- Capraro, R. M., & Capraro, M. M. (2006). Are you really going to read us a story? Learning geometry through children's mathematics literature. *Reading Psychology, 27*, 21-36.
- Center for Applied Special Technology. (2018). *Universal design for learning guidelines version 2.2*. Retrieved from <http://udlguidelines.cast.org>.
- Chigeza, P. (2013). Translating between and within representations: Mathematics as lived experiences and interactions. In V. Steinle, L. Ball, & C. Bordini (Eds.), *Mathematics education: Yesterday, today and tomorrow* (pp. 178-184). MERGA.
- Dooley, T., Dunphy, E., & Shiel, G. (2014). *Mathematics in early childhood and primary education (3-8 years)*. Teaching and learning. NCCA.
- Edelman, J., Green, K., & Jett, C. (2019). Children's literature to inform mathematics teaching and learning: A systematic review of the research literature from 1999-2016. *International Journal of Science, Mathematics and Technology Learning, 26*(1), 49-60.
- Elia, I., Van den Heuvel-Panhuizen, M., & Georgiou, A. (2010). The role of pictures in picture books on children's cognitive engagement with mathematics. *European Early Childhood Research Journal, 18*(3), 275-297.
- National Council for Curriculum and Assessment. (2018). *Primary mathematics curriculum. draft specification junior infants to second class*. NCCA.
- National Council for Curriculum and Assessment. (2020). *Draft primary curriculum framework*. NCCA.
- Prendergast, M., Harbison, L., Miller, S. & Trakulphadetkrai, N. (2019). Pre-service and in-service teachers' perceptions on the integration of children's literature in mathematics teaching and learning in Ireland. *Irish Educational Studies, 38*(2), 157-175.
- Trakulphadetkrai, N. V., Aerial, J., & Yrjänäinen, S. (2019). Bringing mathematics alive through stories. In K. J. Kerry-Moran & J. Aerial (Eds.), *Story in children's lives: Contributions of the narrative mode to early childhood development, literacy, and learning* (pp. 199-225). Springer.