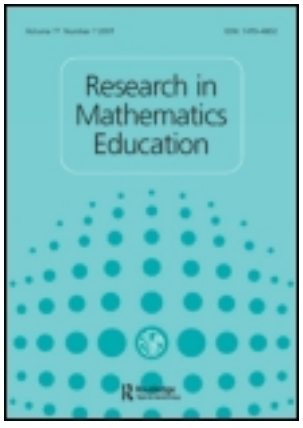

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Developing a framework for the evaluation of picturebooks that support kindergartners' learning of mathematics

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The purpose of this study was to investigate what experts in the use of picturebooks in mathematics education consider powerful characteristics of such books in the support of young children's learning of mathematics. The study started by investigating experts' views of such characteristics, as reflected in academic and professional publications on the use of picturebooks in mathematics education. This resulted in a first version of a framework of learning-supportive characteristics of picturebooks. In the second part of the study the framework was refined, and its tenability was tested through a four-round Delphi method, in which seven experts were asked to comment on, and work with, the framework when evaluating three picturebooks. The experts' evaluations of these books showed that a larger number of learning-supportive characteristics were identified when using the framework than when not using it.

Keywords: mathematics in kindergarten; picturebooks; Delphi method

Context of the study

Although most studies on the reading of picturebooks to children investigate the effect on learning language and literacy abilities, such as vocabulary, word recognition, and phonological awareness (Anderson, Anderson, and Shapiro 2005; Blok 1999; Korat 2009), there is a growing number of studies (Hong 1996; Jennings et al. 1992; O'Neill, Pearce, and Pick 2004; Young-Loveridge 2004) which provide evidence that the use of picturebooks in the early years of schooling can also contribute to the learning of mathematics. For example, Hong (1996) found that kindergartners in a program that included mathematics-related storybook reading, did better in classification, number combination, and shape tasks. Moreover, picturebook programs often resulted in a more positive attitude to mathematics (Hong 1996; Jennings et al. 1992). Furthermore, Young-Loveridge (2004) showed that the influence of picturebooks is not restricted to their use in the classroom. She found increased numeracy levels and significantly larger gains in numeracy in a group of five-year olds who participated in an outside-the-classroom program, using number books and games, compared with a group of children not involved in the program. The study by O'Neill, Pearce, and Pick (2004) is interesting as well. They signalled a relationship between children's early narrative ability and their later mathematics achievement.

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A characteristic feature of the aforementioned studies – and this is especially true for Jennings et al. (1992) and Hong (1996) – is that the picturebooks were used as a starting point for doing mathematical activities in classroom. This means that after a book was read, activities were conducted that were inspired by the mathematical content of the book. In these experiments, the follow-up activities organised by the teacher rather than the books themselves were seen as the treatment.

This and other uses of picturebooks by the teacher tell only half the story. It is not only the way teachers work with picturebooks that stimulates children's mathematical thinking. The picturebooks themselves can do this as well. This was shown, for example, by our analysis of the spontaneous utterances of children when they are read a picturebook (Elia, Van den Heuvel-Panhuizen, and Georgiou 2010; Van den Heuvel-Panhuizen and Van den Boogaard 2008). Furthermore, there is evidence that picturebooks can differ in the kinds of utterances they evoke. According to Anderson, Anderson, and Shapiro (2000), different books can generate different amounts and different kinds of mathematical talk.

This means that some picturebooks might have more power than others to offer children a setting in which they can learn mathematics. Nevertheless, it is unclear what characteristics of picturebooks yield this power. The present study was carried out to gain more knowledge about this. In fact, our research question was: *What characteristics should picturebooks have to contribute to the initiation and further development of mathematical understanding in young children?*

This research question refers to children who have not yet been taught mathematics in a systematic and formal way, but have only been involved in playful mathematics-related activities. In many countries these children, aged four to five or six, are called kindergartners after the kindergarten classes they attend.

By 'picturebooks', we mean books containing text and pictures in which pictures have an essential role in full communication and understanding (Nicolajeva and Scott 2000). Arizpe and Styles (2003, 22) stress that a picturebook is a "book in which the story depends on the interaction between written text and image and where both have been created with a conscious aesthetic intention."

The learning-supportive characteristics of a picturebook are the characteristics of the book itself, irrespective how it is read to children. All the characteristics together constitute the learning environment that a picturebook can provide to children. For example, for the development of literacy ability, the interrelations between image and text are considered as an important feature of picturebooks from an educational perspective. According to Graham (2000, 61), a basic characteristic of a "perfect" picturebook used for enhancing children's literary understanding is that the words and the pictures they include do not carry the same meaning, and thus are not simply connected. The various and complex interactions between image and text (Nicolajeva and Scott 2000) do not only enhance children's attention and engagement, but also help children discover different ways of connecting words and illustrations to construct meaning, and thus extend and develop their interpretive sophistication (Wolfenbarger and Sipe 2007). In a way, these authors identify what we would consider the learning-supportive characteristics of picturebooks for developing literary understanding.

In a more general way – in the sense that there is no specific reference to a particular competence – the learning-supportive qualities of picturebook are also indicated by Wolfenbarger and Sipe (2007, 279–80) when they state that:

> [t]he best picturebook authors/illustrators are in tune with human needs and desires. The best picturebook authors and illustrators illuminate places within the reader's experiences and cast light in those shadowy corners that lurk alongside the pathways to new understandings. The new understanding can be self-understanding or a greater awareness of one's place in the world.

In the present study, it is our goal to identify the learning-supportive characteristics of picturebooks for learning mathematics.

To answer the research question, we first concentrated on experts' voices as reflected in literature. Here, we consider experts as researchers who have carried out studies about the role of picturebooks in the learning of mathematics, as well as authors who have written professional guides about the use of picturebooks and other children's literature for mathematics education purposes. Based on a literature review of these academic and professional publications, a first version of a framework of learning-supportive characteristics of picturebooks for supporting the learning of mathematics was conceptualised.

In the second part of the study, we conducted a consultation with a group of Dutch experts who have experience with using children's literature in mathematics education. They were asked to comment on the first version of the framework, and come up with adaptations if necessary. By means of this so-called Delphi method, the framework was refined and further evidence was collected for its tenability.

Our approach to the literature review

The stream of publications on children's literature in mathematics education was particularly boosted by the *Curriculum and Evaluation Standards for School Mathematics* published by the American National Council of Teachers of Mathematics (NCTM 1989, 2000). Although the interest in using picturebooks in teaching children mathematics was also present in other countries – see, for example, the work of Mooren (2000) and Veltman (1999, 2004) in the Netherlands – much of the literature on the use of picturebooks that we collected originates from the United States. This literature mostly consists of annotated lists of useful picturebooks. These publications are meant to be used by teachers as source books for how to use picturebooks and other children's literature in mathematics lessons (see, for example, Burns and Sheffield 2004; Kolakowski 1992; Thiessen 2004; Thiessen, Matthias, and Smith 1998).

The use of picturebooks and other children's literature in mathematics education is not self-evident. Therefore, several authors emphasise why this use is so important (see, for example, Columba, Kim, and Moe 2005; Griffiths and Clyne 1991; Schiro 1997; Thiessen 2004; Whitin and Wilde 1992). Besides offering annotated lists of useful picturebooks and guides for how to use them in education, some authors also pay attention to the selection of suitable books (see, for example, Schiro, 1997).

Despite the large body of academic and professional publications on the use of children's literature in mathematics education, we could hardly find any information about the learning-supportive characteristics of picturebooks for the development of mathematical understanding. Therefore, we decided to apply an indirect way of exploring literature to identify these characteristics (see Figure 1). We made an inventory of what is mentioned in the available publications about (a) the

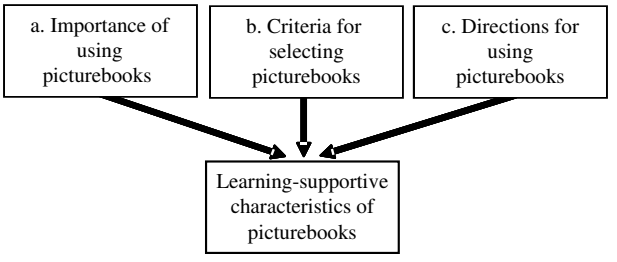

Figure 1. Indirect search for learning-supportive characteristics of picturebooks for learning mathematics.

importance of the use of picturebooks in mathematics education, (b) the criteria for selecting picturebooks to be used in mathematics education, and (c) the directions for the use of picturebooks in mathematics education. From what was found in (a), (b), and (c) we derived the learning-supportive characteristics.

To illustrate this indirect search for learning-supportive characteristics in the literature, we take as an example a publication by Welchman-Tischler (1992), titled *How to Use Children's Literature to Teach Mathematics*. Although Welchman-Tischler does not mention any learning-supportive characteristics of children's literature, she refers to these characteristics in an implicit way. She asserts, for example, that children's books can offer interesting problems that are worthwhile for children to scrutinise. By emphasising the role of problems, she is claiming implicitly that problems included in picturebooks can make picturebooks learning-supportive.

In a similar way, we reviewed in total 26 publications which have been released in the past two decades (between 1991 and 2006, when the consultation with experts took place). In this review, we included all publications that we found when searching journal indices and educational (ERIC, PsycINFO, Scopus), scholarly (Google Scholar) and general (Google) databases on using picturebooks in mathematics education. We obtained a collection of 18 professional publications, mostly containing guidelines for teachers, and eight academic publications which were either based on empirical research or were theoretically oriented (see Appendix). To enlarge the number of publications in this review, we did not restrict ourselves to publications on picturebooks as we earlier defined them, but also included publications about other children's literature to be used in mathematics education, such as storybooks.

Results of the literature review

This section gives an overview of the reasons given by authors for the importance of using children's literature in mathematics education, the criteria they suggest for selecting children's literature, and the directions they give for how to use children's literature in mathematics lessons. Taken together, they indicate what these authors consider learning-supportive characteristics. Table 1 shows a summary of our findings.

The importance of using children's literature in mathematics education

In almost all reviewed publications, we found one or more arguments that explained why children's books have an important role in mathematics education. The authors

Table 1. Summary of results from the literature review.

Focus of review	Indicator of learning-supportive characteristic	Specification
Importance of using children's literature in mathematics education	Children's literature as a context in which children come across mathematics	Information is given about what mathematical content (topics, processes and mathematics-related attitudes) is presented in children's literature
	Children's literature as a tool that contributes to learning mathematics	Children's literature is a powerful tool because it places mathematics in a meaningful context
		Children's literature *can* make connections within mathematics (i.e., between different mathematical concepts and between different mathematical domains), between mathematics and children's life, and between mathematics and other curriculum areas
		Children's literature generates interest and motivation
		Picturebooks can show mathematical concepts visually
Criteria for selecting children's literature for teaching mathematics	Relevance of the included mathematics	Mathematics in children's literature should be worthy of being learned, should include authentic and sophisticated mathematics, and should be correct and accurate
	Possibility of making all kinds of connections	Children's literature *should* make connections within mathematics (i.e., between different mathematical concepts and between different mathematical domains), between mathematics and children's life, and between mathematics and other curriculum areas
	Appropriateness for and adaptability to children	Children's literature should cover multiple layers of levels of understanding
	Power to promote certain mathematical processes and engage children	Children's literature should promote mathematical processes (e.g., problem solving, mathematical communication and representation, reasoning and inquiry), give opportunities for different levels of engagement in mathematical processes (ranging from observing mathematical thinking to doing themselves the mathematics that is in the book) and stimulate discussions and investigations

Table 1 (*Continued*)

Focus of review	Indicator of learning-supportive characteristic	Specification
Directions for the use of children's literature in mathematics education	Different phases of the learning process in which children's literature is used	Children's literature can be used in all phases of the learning process, e.g., introducing new mathematical concepts, assessing children's previous knowledge, deepening their understanding, and reviewing topics
	Teacher's behaviour and attitude	Based on children's literature teachers can ask questions, pose problems, and offer opportunities for discussion of mathematical ideas (e.g., including different representations as well as inaccuracies); an open attitude towards the children and the reading process can function as a catalyst for mathematical wonder and exploration in children

either refer to children's books as a context in which children can come across mathematics, or as a tool that contributes to the children's learning of mathematics.

Children's literature as a context in which children come across mathematics

Various source books for teachers (for example, Braddon, Hall, and Taylor 1993; Griffiths and Clyne 1991; Thiessen 2004; Whitin and Wilde 1992) give information about what mathematical topics are presented in particular children's books. These topics can be included explicitly or implicitly (Columba, Kim, and Moe 2005). American authors of source books mostly use the NCTM standards (NCTM 1989, 2000) as a guide for identifying the mathematical content in children's literature. Therefore, it is not a surprise that many authors go beyond the usual content domains of mathematics, also referring to mathematics-related themes and even mentioning mathematical processes and attitudes. One of the mathematics-related themes that is repeatedly mentioned is that of patterns. Children's literature provides a context through which mathematical patterns can be explored (Moyer 2000). Moreover, it is often emphasised (for example, Griffiths and Clyne 1991; Whitin and Wilde 1992; Young 2001) that patterns play an important role in both mathematics and literature.

With respect to mathematical processes and attitudes, several authors point out that children's books have much to offer. It is, for example, mentioned that children's literature supports children's ability in mathematical problem solving (Columba, Kim, and Moe 2005; Griffiths and Clyne 1991; Hellwig, Monroe, and Jacobs 2000; Moyer 2000; Rubin 2004; Schiro 1997; Thiessen, Matthias, and Smith 1998; Whitin and Wilde 1992; Young 2001), developing and using mathematical language (Griffiths and Clyne 1991; Hellwig, Monroe, and Jacobs 2000; Hunsader 2004; Kolakowski 1992; Moyer 2000; Schiro 1997; Thiessen, Matthias, and Smith 1998; Whitin and Wilde 1992) and reasoning mathematically (Burns and Sheffield 2004; Columba, Kim, and Moe 2005; Hellwig, Monroe, and Jacobs 2000; Rubin 2004; Schiro 1997; Thiessen, Matthias, and Smith 1998; Young 2001). Furthermore, children's literature can promote an inquiring attitude by giving children an opportunity to raise questions (Whitin 2002), presenting investigations which interest and excite children (Griffiths and Clyne 1991), and inspiring students to explore concepts (Braddon, Hall, and Taylor 1993; Hunsader 2004). Also, children's literature fosters sensitivity to the aesthetic appeal of mathematical structures and solutions (Whitin and Wilde 1992).

Children's literature as a tool that contributes to learning mathematics

The arguments that are part of this cluster all claim that children's books are powerful tools in mathematics learning, because they provide mathematics that is relevant and meaningful for children (Evans, Leija, and Falkner 2001; Griffiths and Clyne 1991; Kolakowski 1992; Lachance 2002; Moyer 2000; Rubin, 2004; Schiro 1997; Thatcher 2001; Whitin and Wilde 1992). Placing mathematics in a meaningful context means that the mathematics makes sense to children and, therefore, it is easier to understand (Van Oers, 1996).

Another characteristic of the contextualised mathematics in picturebooks is that connections are made, or can be made, between mathematics and children's own

lives (Columba, Kim, and Moe 2005; Whitin 2002) and those of others (Murphy 1999; Rubin 2004; Whitin and Wilde 1995). Moreover, links can be made to the real world (Braddon, Hall, and Taylor 1993; Hellwig, Monroe, and Jacobs 2000; Hunsader 2004; Merenda 2000) and to other curriculum areas (Griffiths and Clyne 1991; Kolakowski 1992; Welchman-Tischler 1992; Whitin and Wilde 1992); for example, the latter is done in a children's book about growing plants, that integrates mathematics and science (Whitin and Wilde 1992). Moreover, children's literature can connect different mathematical ideas (Columba, Kim, and Moe 2005; Hellwig, Monroe, and Jacobs 2000; Hunsader 2004; Schiro 1997), and such interwoven ideas containing layers of meaning can promote deeper thinking in children (Hellwig, Monroe, and Jacobs 2000).

Mathematics included in the familiar context of children's literature generates interest and motivation (Kolakowski 1992). Several authors mention that bringing mathematics and literature together in children's literature prompts children to become actively involved in learning and exploring mathematical ideas (Evans, Leija, and Falkner 2001; Hunsader 2004; Thiessen, Matthias, and Smith 1998; Whitin 2002); for example, by using the many mathematics-related questions (Lachance 2002).

Another advantage of picturebooks is that they can show mathematical concepts visually (Murphy 1999), which is considered as particularly supportive for students' understanding of abstract concepts (Arnheim, 1993). This is also supported by our own findings in a study in which the children, without any intervention by the researcher, produced mathematics-related utterances based on mathematical components in the pictures (Elia, Van den Heuvel-Panhuizen, and Georgiou 2010).

Criteria for selecting children's literature for teaching children mathematics

Although several authors (for example, Austin 1998; Welchman-Tischler 1992; Whitin and Whitin 2004) gave guidance for selecting books to be used in teaching mathematics, only a few instruments are available that contain standards for a systematic evaluation of picturebooks for mathematics education purposes (Hellwig, Monroe, and Jacobs 2000; Hunsader 2004; Schiro 1997).

Criteria mentioned to select children's books can be classified in four clusters: (1) the relevance of the mathematics included; (2) the possibility of making all kinds of connections; (3) the appropriateness for, and adaptability to, the children; and (4) the power to promote mathematical processes and engage children.

The relevance of the mathematics included

Several authors emphasise that the mathematics should be worthy of being learned (Columba, Kim, and Moe 2005; Schiro 1997; Thiessen 2004; Thiessen, Matthias, and Smith 1998). Furthermore, children's literature should provide opportunities for the reader to use mathematics for authentic purposes (Austin 1998), and reflect functional use of the mathematics in believable contexts (Whitin and Whitin 2004). Moreover, it is mentioned that a children's book should introduce children to more sophisticated mathematics, rather than simply to arithmetic (Thiessen, Matthias, and Smith 1998). In addition, a book's mathematics should be correct and accurate (Hellwig, Monroe, and Jacobs 2000; Hunsader 2004; Schiro 1997; Thiessen 2004; Whitin and Whitin 2004). Schiro (1997) gives several examples of incorrect or

inaccurate mathematics, and one of the books he criticises is *One Was Johnny* (Sendak 1962), in which cardinal numbers are used instead of ordinal numbers for nine different creatures entering Johnny's room. Besides the claim of avoiding mistakes, it is also suggested (see Thatcher 2001) that under certain conditions, errors and inaccuracies may be instructive. Ambiguity can be solved by hints from the teacher and, by discovering and discussing flaws, the children's understanding can be broadened.

The possibility of making all kinds of connections

Another major cluster of criteria emphasises the importance of connections between mathematics and the learner's own experiences and interests, between mathematics and the real world, and between mathematics and other content areas (Columba, Kim, and Moe 2005; Hellwig, Monroe, and Jacobs; Schiro 1997; Thatcher 2001; Whitin 2002). Furthermore, children's literature should show connections between different ideas within mathematics (Columba, Kim, and Moe 2005; Hellwig, Monroe, and Jacobs 2000; Hunsader 2004; Schiro 1997).

The appropriateness for, and adaptability to, children

Several authors mention that the mathematics of a children's book should be cognitively and developmentally appropriate for its audience (Columba, Kim, and Moe 2005; Hunsader 2004; Schiro 1997). In addition, it is stressed that a book should present concepts in such a way that they are accessible for children of different attainment levels (Hellwig, Monroe, and Jacobs 2000; Whitin and Whitin 2004). That is, a book should make multilayered connections to existing knowledge (Austin 1998; Hellwig, Monroe, and Jacobs 2000; Thatcher 2001). Through reading such books, young children have an opportunity to play with important mathematical ideas that are studied more formally in later grades (Thiessen, Matthias, and Smith 1998). Even when the mathematical concepts in a book are beyond the mathematical knowledge of the children, the book can still be interesting and thought-provoking for them (Lachance 2002).

The power to promote certain mathematical processes and engage children

When mentioning selection criteria, some authors focus on particular mathematical processes like problem solving (Lachance 2002; Moyer 2000; Thatcher 2001; Whitin and Whitin 2004), mathematical communication and representation (Lachance 2002; Whitin and Whitin 2004), and reasoning (Whitin and Whitin 2004).

Furthermore, several authors pay attention to a book's power to stimulate children and get them involved in the mathematics the book contains (Austin 1998; Hunsader 2004; Schiro 1997; Thiessen, Matthias, and Smith 1998), or even make them enthusiastic about mathematical inquiry or learning something new (Austin 1998; Thatcher 2001; Whitin and Whitin 2004).

Books can stimulate different modalities. Children can be involved intellectually when thinking about the mathematics, physically when carrying out a mathematics-related action, and emotionally when the book's mathematics has impact on its characters or on the children's own lives. Moreover, children's literature can give

students opportunities for different levels of participation, ranging from observing the results of mathematical endeavours without being told how the mathematics is done, to listening to a character's mathematical thinking, and to doing the mathematics that is in the book (Schiro 1997).

An important reason for selecting a book is that it can serve as a natural point of departure for discussions and investigations (Moyer 2000; Thatcher 2001). Furthermore, it is emphasised that a book should provide an experience that will enable children to use, apply, transfer, or generalise its mathematics. A book can do this by presenting the story's characters in such a way that children would want to imitate the characters' mathematical endeavours (Hunsader 2004; Schiro 1997). Involvement is more likely to occur when the children are surprised in some way (Hellwig, Monroe, and Jacobs 2000), when the book employs a humorous or conversational tone (Austin 1998), or stimulates curiosity and a sense of wonder (Thatcher 2001).

Directions for the use of children's literature in mathematics education

Although the focus of this literature review is on what are considered learning-supportive characteristics of picturebooks, guidelines on how to use them in classes contain implicit indications of what makes them powerful in themselves. On the whole, the guidelines explain (1) in which phases of the learning process the books can be used and (2) what kinds of teacher behaviour and attitude makes them more learning-supportive. Guidelines for follow-up activities are not included in this review.

Use of children's books in different phases of the learning process

The literature emphasises that teachers can use children's books in different phases of the learning process. They can use them for introducing new mathematical concepts (Evans, Leija, and Falkner 2001; Lachance 2002; Rubin 2004; Schiro 2004; Thiessen 2004; Welchman-Tischler 1992; Whitin and Whitin 2004), including the assessment of children's prior experience and knowledge (Whitin and Whitin 2004), but also for deepening children's understanding of a mathematical concept or skill. Teachers can use children's books to explain (Welchman-Tischler 1992) and illustrate mathematical concepts (Braddon, Hall, and Taylor 1993; Griffiths and Clyne 1991; Welchman-Tischler 1992), provide their children with background information (Rubin 2004), give them opportunities for further exploring mathematical concepts (Griffiths and Clyne 1991; Lachance 2002), and for expanding their children's mathematical understanding (Rubin 2004), including revision of mathematical concepts or skills (Welchman-Tischler 1992) and addressing mathematical misconceptions (Whitin and Whitin 2004).

Teachers' behaviour and attitude

Most of the directions for teachers refer to asking questions and posing problems, which should always arise naturally from the story (Thatcher 2001). For example, teachers can ask the students to determine the number of objects in illustrations by counting or estimating (Braddon, Hall, and Taylor 1993; Griffiths and Clyne 1991; Jacobs 2000; Whitin and Whitin 2004), or can stimulate them to use ordinal numbers,

for example, by asking them what Harriet is doing on the fourth page (Braddon, Hall, and Taylor 1993). Moreover, teachers can ask students to make predictions about a mathematical pattern (Whitin and Whitin 2004).

Much attention is also given (see, for example, Braddon, Hall, and Taylor 1993; Griffiths and Clyne 1991; Thatcher 2001; Whitin and Whitin 2004) to offering occasions for discussing mathematical ideas included in picturebooks, like patterns, geometrical shapes, measurement issues, and topics related to number. Other suggestions for increasing the learning-supportive quality of picturebooks are to use inaccuracies to have children involved in investigations of misinformation (Thatcher 2001), and to show different representations of a mathematical concept (Griffiths and Clyne 1991; Whitin and Whitin 2004).

The abovementioned activities sometimes require an expansion or adjustment of the story. Yet, some authors warn against distortion of the literary quality and enjoyment of the book by focusing too much on mathematical aspects (Welchman-Tischler 1992), or by interrupting the story to ask mathematical questions (Hunsader 2004; Whitin and Wilde 1992).

Along with instructions on behaviour, authors point out the importance of teachers' open attitudes, i.e. asking open-ended questions, and allowing children to lead the way: listening to children's spontaneous observations and questions, and being ready to move in another direction than planned (Whitin 2002; Whitin and Wilde 1992; Whitin and Whitin 2004). This open attitude towards both children and the reading process is considered to be a catalyst for mathematical wonder and exploration in children (Whitin 2002). By modelling a sense of wonder and by demonstrating asking questions, searching for solutions, and representing findings (Thatcher 2001), teachers can function as a role-model for children.

First version of framework of learning-supportive characteristics

The threefold literature review resulted in an extensive list of qualities that can be taken as a first description of characteristics of picturebooks that can support

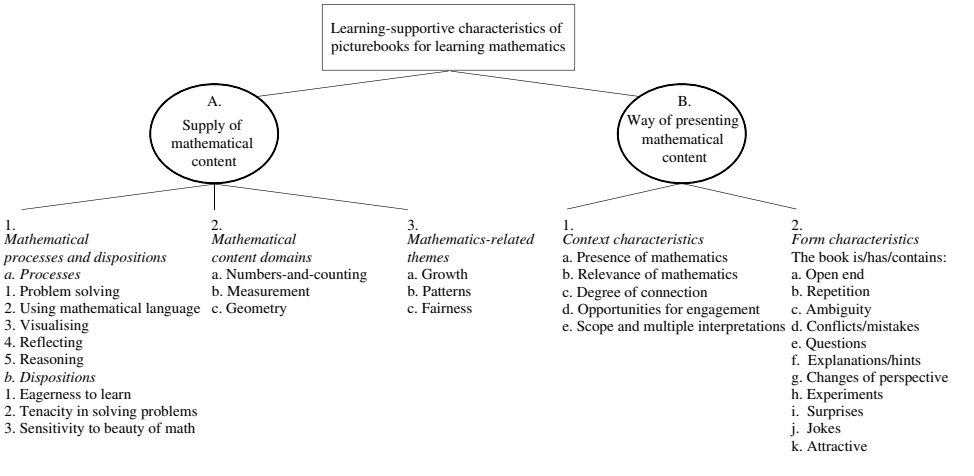

Figure 2. First version of the framework of learning-supportive characteristics of picturebooks for learning mathematics.

young children's learning of mathematics. These characteristics were structured into a framework which has two main sections (see Figure 2). Section A zooms in on the mathematics that can be addressed in a picturebook, and Section B describes the way in which this mathematics can be brought up.

Section A refers to the fact that a picturebook should at least contain some mathematical content to make it supportive for learning mathematics. In agreement with what we found in the literature, we see content in a broad sense. Besides the usual topics, such as numbers and counting, measurement, and geometry, we also count mathematical processes and dispositions, and mathematics-related themes, as mathematical content. The themes include phenomena children know from daily life which have a mathematical component, such as growth, patterns and fairness.

Section B describes the way in which the mathematics can be presented in order to be learning-supportive. We found that a distinction can be made between context and form characteristics. The context characteristics refer to how the mathematics is presented, including the nature of the presence of mathematical content (presented explicitly or implicitly, and presented integrated or in isolation), the relevance of the mathematics (in particular, worthwhile mathematics, in meaningful contexts and without misconceptions), the degree to which connections are realised (between mathematical concepts and children's interests, reality, other mathematical concepts, and other subject areas), the opportunities for children's engagement (cognitively, emotionally, or physically), the scope of the mathematical content, and the possibilities for multiple interpretations (in particular, offering the possibility of understanding at different levels). The form characteristics refer to the elements included in a picturebook that might trigger certain behaviour in children. For example, if a picturebook contains a specific repetitive pattern, children may well anticipate what is coming next, and predict how the pattern develops. In other words, the form characteristics of how the mathematics is presented in the book give children food for thought, and make them cognitively engaged.

Further development of the framework by consultation with experts through a Delphi method

The first version of the framework of learning-supportive characteristics of picturebooks was developed only through a literature review. As we have noted above, the literature base was limited and largely professional in focus. Hence, in order to provide a stronger evidential basis for the framework, we tested it through consultation with a group of experts, using a four-round Delphi method. This investigation additionally enabled us both to refine and to examine the tenability of the framework.

The Delphi method

In the 1940s, the Delphi method was developed in a series of studies carried out by the American RAND Corporation to forecast technological and social developments and inform military decision-making (Dalkey 1969; Gupta and Clarke 1996). Later, the method was used for corporate planning and decision making related to education and health-care policy. In short, the Delphi method implies that a group of experts is consulted about a particular problem. The method is based on the

assumption that the collective judgment and wisdom of several experts is better than the estimates and predictions of an individual expert (Dalkey 1969). According to Linstone and Turoff (1975, 3):

> Delphi may be characterised as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.

The process is structured in such a way that it creates the maximum opportunity for the individual experts to contribute their knowledge, and at the same time makes the mutual fertilisation of expertise possible. Characteristic of the method is that knowledge is generated by a process of iteration and controlled feedback that takes place in several rounds, and that, at least at the beginning of the process, there is no direct face-to-face interaction among group members. Instead, they are informed anonymously about each other's responses. This means that they can respond in a way that is not influenced by group dynamics.

In the field of education, Delphi methods have been applied for a wide variety of purposes (Clayton 1997), for example, to identify features of effective in-service practices (Van Tulder, Veenman, and Sieben 1988), and to reach a consensus about a science curriculum (Osborne et al. 2003) and the skills and abilities of numeracy that will be needed in the future (Galbraith et al. 1992).

The Delphi method in the present study

Set up of the Delphi method

The Delphi method that we applied in the second part of our study consisted of four rounds, in which experts were questioned about the learning-supportive characteristics of picturebooks. In the first three rounds, covering a time period of two months, the experts were contacted individually through e-mail. After each round, their reactions to the questionnaires were processed anonymously, and the resulting report was sent to the whole group. The fourth round consisted of a joint meeting with the experts in person.

In the first round, we invited the experts to explain what came to their mind when they thought about the learning-supportive characteristics of picturebooks that can help kindergartners to learn mathematics. They had to write down these thoughts without consulting the framework. Next, they were asked to give their opinion about which points in the framework could be removed, added to, or reformulated.

In the second round, the experts had to respond to the adaptations from the first round. Furthermore, we asked them which aspects they would pay attention to when evaluating the learning-supportive characteristics of picturebooks. To test the tenability of the characteristics included in the framework, we asked the experts to answer the question firstly without using the framework, and then with reference to it. In the third round, we presented the experts with the final revision of the framework, and asked them to evaluate three picturebooks that were sent to them. They were told that we had to select picturebooks for a program aimed at giving support to kindergartners in developing mathematical skills and understanding, and that we would like to hear from them, for each picturebook, whether or not it should be included in the program. Again, we asked the experts to answer the question

both without, and with, reference to the framework. Finally, we asked them a few questions to evaluate the Delphi method.

In the fourth round, in which the experts met in person, we discussed the results of the Delphi method. During this meeting we asked them to fill in a questionnaire in which they had to indicate on a five-point scale the importance of the characteristics included in the revised framework.

Participating experts

Based on our knowledge of the mathematics education community in the Netherlands, we selected a number of people who are known as experts in the field, and who have either expertise on the use of children's literature in early childhood mathematics education, or on the use of literature in mathematics education in higher grades. The group comprised eight people, including four mathematics educators with experience in preservice teacher education and in developing materials for teaching mathematics to young children, one developer of mathematics education for secondary schools with extensive knowledge on the topic of mathematics and literature, one educational publisher who did a study into counting books, one teacher-advisor who specialises in mathematics for kindergartners, and one youth librarian. We contacted these eight people, and all agreed to participate in the study. However, after the first round, the youth librarian stopped, because she felt her expertise did not fit our questions. The remaining seven experts stayed with the project. Unfortunately, only three could attend the closing session in the fourth round, but two of the other four completed the questionnaire afterwards.

Results from the Delphi method

Because it is impossible to describe the Delphi method in detail within the limited space of an article, we decided to focus on the results from four types of data (see Table 2).

Experts' ideas on learning-supportive characteristics

To find clues for revising the first version of the framework (see Figure 2), the data collection and analysis in the first Delphi round focused on finding similarities and

Table 2. Overview of data used in the results from the Delphi method.

Type of data	Delphi round in which data was collected
The experts' own ideas about learning-supportive characteristics of picturebooks that can help kindergartners to learn mathematics	First round
Experts' indications for revising the framework	First and second round
The experts' evaluations of three picturebooks examined without and with the revised version of the framework	Third round
The experts' opinions about the importance of the characteristics in the revised framework	Fourth round

differences between what the experts considered learning-supportive characteristics and the characteristics included in the framework. The experts' ideas, shown in Table 3, are almost all already included in the framework. In other words, the framework fits quite well with the thoughts of the experts. Only four of the thirty-five statements given by the experts could not (directly) be classified within the framework's categories, but these characteristics were only mentioned once, and only by two of the experts. Moreover, two of the four statements refer to the general quality of the picturebooks ("aesthetic pictures" and "carefully edited") and the other two ("strong story" and "philosophical nature") can be considered as referring to the context characteristics (B1), and particularly to opportunities for engagement (B1d).

Another conclusion that can be based on Table 3 is that the experts were more focused on the way of presenting mathematical content (B) than on the supply of it (A). Within section B, the emphasis was mostly on the context characteristics (B1), especially on the degree of connection (B1c), the opportunities for engagement (B1d), and on scope and multiple interpretations (B1e).

That less attention was paid to the supply of mathematical content (A), is not as remarkable as it might seem at first view. The experts agreed that there should be something mathematical in a picturebook to make it supportive for learning mathematics, but did not mention this. In later discussion, it became clear that they considered this as a self-evident requirement. Moreover, not mentioning characteristics related to the supply of mathematical content (A) also turned out to be the result of the fact that the experts were not asked to evaluate a concrete set of picturebooks in this first Delphi round.

Revision of the first version of the framework

Data collected in the first Delphi round showed that there was a large degree of agreement between the experts' own ideas on learning-supportive characteristics and the characteristics included in the first version of the framework. The same was true for what emerged in the second round, where we asked the experts to indicate which of the characteristics they would use if they had to select picturebooks in order to support kindergartners' learning of mathematics. Four out of seven replied that their own criteria were already incorporated in the framework, and the other three gave, in their own words, comparable criteria to those included in the framework.

A general remark uttered by all the experts was that they found it difficult to specify why they would choose a particular picturebook or not. Yet, most of them gave descriptions that indicated that they had well-considered ideas about learning-supportive characteristics. For example, they emphasised that the picturebooks should provide children with mathematics that is worthwhile and relevant, and that the text and pictures should have the quality to evoke mathematical activities in kindergartners. Similar to the experts' reactions in the first round, most of the characteristics mentioned in the second round included context characteristics (B1), in particular characteristics that refer to the degree of connection (B1c) and the opportunities for engagement (B1d).

The experts' reactions made it clear that it was not always easy to make a distinction between the form characteristics (B2) and the subcategory opportunities for engagement (B1d). The reason for this confusion is that the opportunities for

Table 3. Frequencies of learning-supportive characteristics for learning mathematics mentioned by experts in the first Delphi round.

Learning-supportive characteristics	*f*	Examples	Place in framework ($n = 31$)
Opening up new horizons	7	- "A picturebook should show things that normally cannot happen." - "A picturebook should show content that pushes back frontiers for the child (cognitive conflict)." - "Giving opportunities for interpreting pictures."	B.1.e B.2.c/d
Prompting mathematics-related acting and thinking	6	- "Picturebooks have to contribute to the discovery of relationships and structures and should offer the opportunity to make connections between cause and effect." - "A picturebook has to ask or evoke questions."	B.1.d B.2.e
Linking to the interests of children	3	- "The real experiences of the child should be recognisable in the picturebook." - "Recognisability of contexts and themes."	B.1.c
Not teaching mathematics explicitly	2	- "The mathematics should be implicitly in the picturebook; so no counting books."	B.1.a
Linking mathematics to concrete world	2	- "Offer possibilities for making concepts concrete."	B.1.c
Evoking further explorations	2	- "Describes a theme that offers a rich environment for exploring, e.g. by creating a special corner in the class-room."	B.1.d
Including meaningful mathematics	1	- "Supply meaningful content."	B.1.b
Evoking emotions	1	- "The book should be attractive, evoking emotions."	B.1.c B.2.k
Containing jokes and humour	2	- "The picturebook should be 'amusing' for children; should contain humour for kindergartners."	B.2.j
Giving reason for repetition	1	- "The picturebook should stimulate the children to want to read it again."	B.2.b
Referring to mathematics-related processes and dispositions	2	- "On orientation in space and time, sequence of events, mental acts, imagining." - "The story contains an investigative character."	A.1.a/b

Table 3 (*Continued*)

Learning-supportive characteristics	*f*	Examples	Place in framework ($n = 31$)
Referring to mathematical content domains	2	- "Contains sometimes numbers, proportions, sizes, measure, distance, area, volume, weight, time and other quantities."	A.2
Other learning-supportive characteristics	4	- "Should contain a strong story." - "The picturebook should have a philosophical nature." - "Contain aesthetic pictures." - "The picturebooks should be carefully edited."	Not included in framework ($n = 4$)
Total	35		

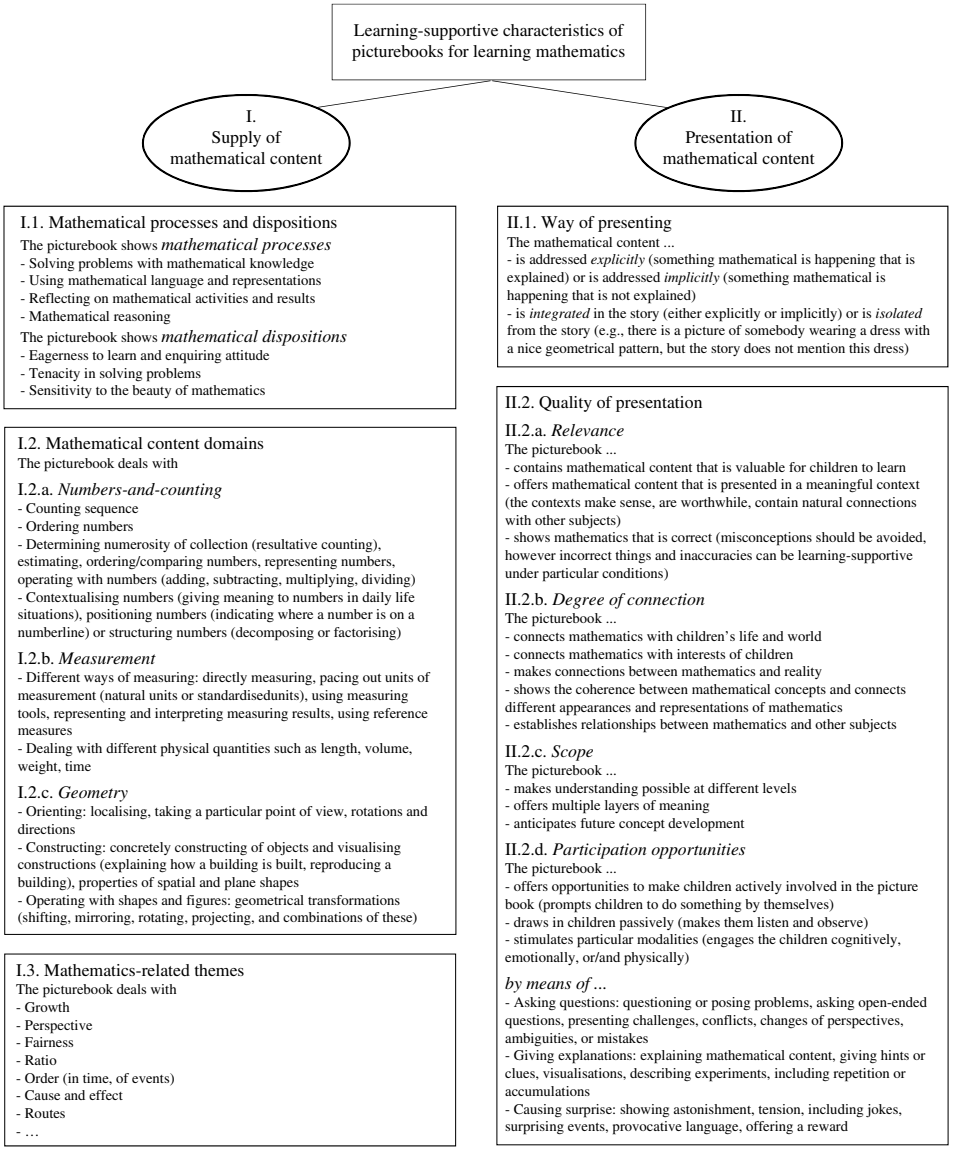

Figure 3. Revised version of the framework of learning-supportive characteristics of picturebooks for learning mathematics.

engagement that belong to the context characteristics (B1) are mostly evoked by form characteristics (B2). To avoid this overlap, we decided to revise the first version of the framework, and particularly rearrange the B section.

The revised framework (see Figure 3) has the same division into two main parts as the first version, but to prevent mixing up both frameworks, we changed the numeration of A and B into I and II. Section I was left virtually unchanged, except for extending the list of mathematics-related themes (I3) to give a broader idea of possible situations in which mathematics can play a role.

As said before, the greatest change was in the former section B. Within section II, covering presentation of mathematical content, we included way of presentation (II1) and quality of presentation (II2). Way of presentation (II1) distinguishes whether the mathematics is addressed explicitly or implicitly, and whether the mathematics is integrated in a story or presented in an isolated way. Quality of presentation (II2) encompasses relevance (II2a), degree of connection (II2b), scope (II2c), and participation opportunities (II2d) offered by asking questions, giving explanations, and causing surprise.

Results revealed by evaluating picturebooks with and without the revised framework

The evaluated picturebooks

To test whether the framework is useful for identifying learning-supportive characteristics we sent the experts three picturebooks for evaluation: *De verrassing* [*The surprise*] (Van Ommen 2003), *De lievelingstrui* [*Favourite sweater*] (Veldkamp 2001) and *Ga je mee?* [*Let's go*] (Dematons 2005).

We chose these books from our own collection of 24 picturebooks, which we are using for a picturebook project aimed at investigating the use of picturebooks in mathematics education (Van den Heuvel-Panhuizen and Elia 2011). We have chosen these books because they contain mathematical concepts. Furthermore, while using these books in reading sessions in kindergarten classes, we noticed that these picturebooks triggered many mathematics-related utterances in children (see, for example, Van den Heuvel-Panhuizen, Van den Boogaard, and Doig 2009).

The surprise (Van Ommen 2003) is a wordless picturebook; the pictures alone tell the story. The leading character of the book is a sheep. It is weighing itself and measuring the thickness of its fleece. The picturebook shows measuring tools and even a line graph with the measuring results (see Figure 4).

A few pages later, the sheep takes its motor scooter and goes to a shop to buy some paint. Back home, the sheep dyes, washes, dries and shears its fleece. Then it takes its wool to a poodle for spinning. Next, the sheep knits a sweater from the wool, wraps it into a table-cloth, and gives it to a giraffe as a present. The sheep is rewarded for this nice gesture by a kiss from the giraffe.

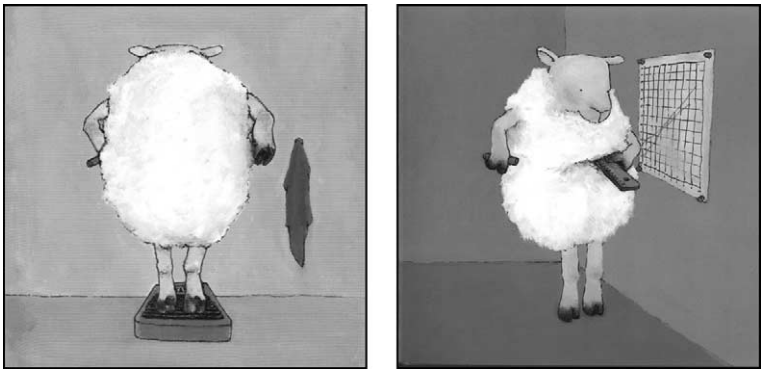

Figure 4. *The surprise* (Van Ommen 2003) (illustrations by the author, Sylvia van Ommen). Page 1 (left) and page 3 (right). Reproduced with permission.

Favourite sweater (Veldkamp 2001) contains a few lines of text on each page, telling the story of a little pig named 'Little Toon'. Little Toon is eager to grow and looks at the measuring strip on the wall (see Figure 5).

Because the growing goes very slowly, he finds comfort in being able to put on his favourite sweater by himself. Yet, another day, Little Toon can no longer wear his favourite sweater any more. He gets angry with his, now no longer favourite, sweater, kicking it into the river outside the house. Walking back inside, he bumps his head against the door. His friends ask him whether he knows how he came to bump his head, and why the sweater would not fit any more. They propose he measures himself, and Little Toon discovers he has grown. Little Toon is very happy. He leaves the house, sails the river, and returns with a beautiful flag on his raft: his former favourite sweater has turned into his favourite flag.

In *Let's go* (Dematons 2005) the main character, a young boy, invites the reader to join him on the way to the greengrocer's, to buy apples for his mother. From a bird's eye perspective, the reader can accompany the boy on his way through a scary wood, a rock formation, and a wide ocean with a dragon, a giant, a bear, sharks and even pirates (see Figure 6).

The boy asks the reader to help him safely find his way, since the reader has a broader overview. After visiting the shop, the boy decides to take the 'short' way back home, along the path around the garden. The book then shows a drawing revealing that all the adventures took place in the boy's own garden.

For each of the three picturebooks, the experts were asked to indicate which learning-supportive characteristics they could identify. They first evaluated the books in their own way without using the framework, and then evaluated them using it.

Figure 5. *Favourite sweater* (Veldkamp 2001) (illustrations by Gerdien van der Linden). Page 3: Little Toon with the measuring strip. Reproduced with permission.

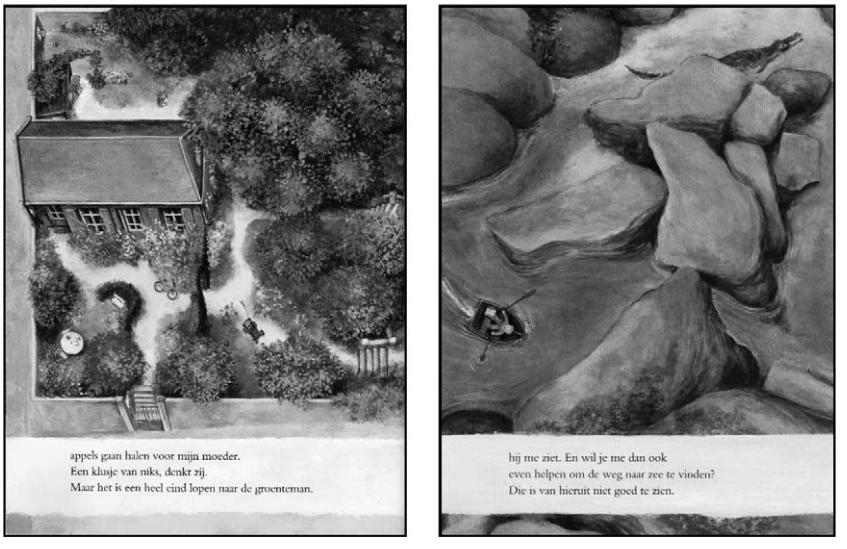

Figure 6. *Let's go* (Dematons 2005) (illustrations by the author, Charlotte Dematons, reproduced with permission).
Page 3 (left): the boy leaves his house [translated text: getting apples for my mother. A small chore, she thinks. But it is a very long walk to the greengrocer's.];
page 12 (right): the boy asks the reader to help him find the way over the river [translated text: he sees me. And would you help me find the way to the sea? I cannot see it properly from here.].

One expert's evaluation of the three picturebooks

To show in detail what kinds of responses we received when the three picturebooks were evaluated without and with the framework, we first focus on the responses of one of the experts, who was chosen at random. Table 4 shows the evaluations given by this expert. An asterisk (*) indicates that a particular learning-supportive characteristic is based on the expert's own ideas without using the framework. All the responses that were given without using the framework fit into its categories. A learning-supportive characteristic with an (x) results from the evaluation with the framework.

The results shown in Table 4 make it clear that fewer characteristics were mentioned when the books were evaluated based on the expert's own ideas than when they were evaluated with the help of the framework. The difference is especially strong for the learning-supportive characteristics related to the presentation of mathematical content (II). In particular, the framework helped the expert in recognising characteristics that belong to the quality of presentation (II2). Another finding is that, for this expert, *The surprise* has more learning-supportive characteristics than the other two picturebooks.

All experts' evaluations of the three picturebooks

Table 5 shows that similar results were found for the other experts. More learning-supportive characteristics were found when the experts used the framework. Contrary to the expert in Table 4, the other experts mentioned a few characteristics that could not be classified in the framework. For example, one particular mathematical topic

Table 4. One expert's evaluation results for three picturebooks without and with the framework.

Learning-supportive characteristics of picturebooks for learning mathematics	*The surprise*	*Favourite sweater*	*Let's go*	Learning-supportive characteristics of picturebooks for learning mathematics	*The surprise*	*Favourite sweater*	*Let's go*
I. Supply of mathematical content				II. Presentation of mathematical content			
I.1. Mathematical processes and dispositions				II.1. Way of presenting			
I.1.a. Processes				- Explicit			
- Problem solving	x			- Implicit	x		
- Using mathematical language	*x		x	- Integrated in the story	x	x	x
- Reflecting	x			- Isolated from the story			
- Reasoning	*x	x		II.2. Quality of presentation			
I.1.b. Dispositions				II.2.a. Relevance			
- Eagerness to learn	x			- Content is valuable	x	x	
- Tenacity in solving problems				- Content in meaningful context	x		
- Sensitivity to mathematics beauty				- Mathematics is correct			
I.2. Mathematical content domains				II.2.b. Degree of connection between			
I.2.a. Numbers-and-Counting				- Mathematics and children's interests		*x	
- Counting sequence				- Mathematics and real world	x	x	x
- Ordering numbers				- Mathematical concepts/representations			
- Resultative counting	x	*x		- Mathematics and other subjects			
- Context/position./struct. numbers				II.2.c. Scope			
I.2.b. Measurement				- Understandable at different levels	x		
- Methods of measuring	*x	*x	*x	- Multiple layers of meaning	x		
- Physical quantities	*x	*x	*x	- Anticipating future developments			x
I.2.c. Geometry				II.2.d. Participation opportunities			
- Orienting		*	*x	- Actively	*x		x
- Constructing				- Passively		x	
- Operating		x		- Completedognitively	x		

Table 4 (*Continued*)

Learning-supportive characteristics of picturebooks for learning mathematics	*The surprise*	*Favourite sweater*	*Let's go*	Learning-supportive characteristics of picturebooks for learning mathematics	*The surprise*	*Favourite sweater*	*Let's go*
I.3. Mathematics-related themes				- Emotionally	*	*x	x
- Growth	x	*x		- Physically			
- Perspective			*	By			
- Patterns				- Questioning/problem posing			
- Fairness				- Explaining mathematical content			
- Ratios	x			- Causing surprise	x	x	x
- Order	*x						
- Cause and effect	x	*					
- Routes			*x				

* Evaluation based on expert's own ideas
x Evaluation based on framework

was mentioned twice (“Sphere” and “S-curve”) and it was stated three times that the book was generally useful (“Can be used to develop mathematical understanding”). Because these remarks were either rather specific for one particular book or too general to be included, we did not revise the framework further.

The totals in Table 5 show that the framework helped the experts to recognise particular learning-supportive characteristics that had remained unnoticed when they based their evaluation on their own ideas. For mathematical dispositions (I1b), way of presenting (II1), relevance (II2a), and scope (II2c), the number of recognised learning-supportive characteristics was at least seven times larger than the number that was recognised based on the evaluation without the framework. For mathematical processes (I1a), degree of connection (II2b), and participation opportunities (II2d), the number was at least three times larger in the evaluation with the framework than without.

The overall evaluation results of the seven experts show that, as with the results of the one expert in Table 4, *The surprise* was judged to have more learning-supportive characteristics than the other two picturebooks. This is true for the evaluation both without and with the framework. In other words, the use of the framework did not lead to contradictory results, but in fact sharpened the eyes of the experts.

The highest score of learning-supportive characteristics for *The surprise* was in agreement with the experts’ answer to the question about whether they would include these picturebooks in a program aimed at supporting children’s mathematical development. All seven experts answered “Yes” for *The surprise*, both with and without the framework. *Let’s go* and *Favourite sweater* received a “No” two and four times respectively in both evaluations.

Experts’ opinions about the importance of the learning-supportive characteristics

In the fourth round we asked the experts to indicate on a five-point scale the importance of the learning-supportive characteristics included in the revised framework. We focused on the characteristics related to the quality of presentation (II2).

Figure 7 shows that the experts gave the largest value to participation opportunities (II2d) and to connections with children’s life and world, which is a subcategory of degree of connections (II2b). Within this latter category, the lowest importance was attached to coherence within mathematics, connecting mathematics and reality, and establishing relationships with other subjects. Within the category scope (II2c), in particular, anticipating future concept development was not considered to be very important.

Discussion

The goal of this study was to gain a better understanding of the characteristics that picturebooks should have to contribute to young children’s learning of mathematics. In the first part of this study, a literature review was carried out that resulted in a first version of a framework of learning-supportive characteristics of picturebooks. In the second part of the study we revised the framework, and provided evidence for its tenability by conducting a four-round Delphi method with seven experts in the field.

The literature review provided us with a good foundation for the learning-supportive characteristics of picturebooks, and this was backed up by the experts’

Table 5. All experts' evaluation results for three picturebooks without and with the framework.

Learning-Supportive Characteristics of Picturebooks for Learning Mathematics	Number of characteristics mentioned by all experts ($n = 7$)							
	Picturebook							
	The surprise		*Favourite sweater*		*Let's go*		Total	
Evaluation on own ideas (O) / on framework (F)	O	F	O	F	O	F	O	F
I. Supply of Mathematical Content								
I.1. Mathematical Processes and Dispositions								
I.1.a. Mathematical Processes	8	16	0	7	0	8	8	31
I.1.b. Mathematical Dispositions	1	7	0	2	0	1	1	10
I.2. Mathematical Content Domains								
I.2.a. Numbers-and-Counting	2	3	2	1	0	1	4	5
I.2.b. Measurement	11	12	5	9	2	4	18	25
I.2.c. Geometry	6	6	1	3	5	8	12	17
I.3. Mathematics-Related Themes	7	19	10	15	8	11	25	45
Subtotal I	35	63	18	37	15	33	68	133
II. Presentation of Mathematical Content								
II.1. Way of Presenting	4	15	1	10	0	10	5	35
II.2. Quality of Presentation								
II.2.a. Relevance	2	11	1	7	0	8	3	26
II.2.b. Degree of Connection	0	6	3	7	1	6	4	19
II.2.c. Scope	0	7	0	1	0	4	0	12
II.2.d. Participation Opportunities	4	12	3	7	3	14	10	33
by means of ... (asking questions, etc)	4	9	2	5	3	9	9	23
Subtotal II	14	60	10	37	7	51	31	148
Total	49	123	28	74	22	84	99	281

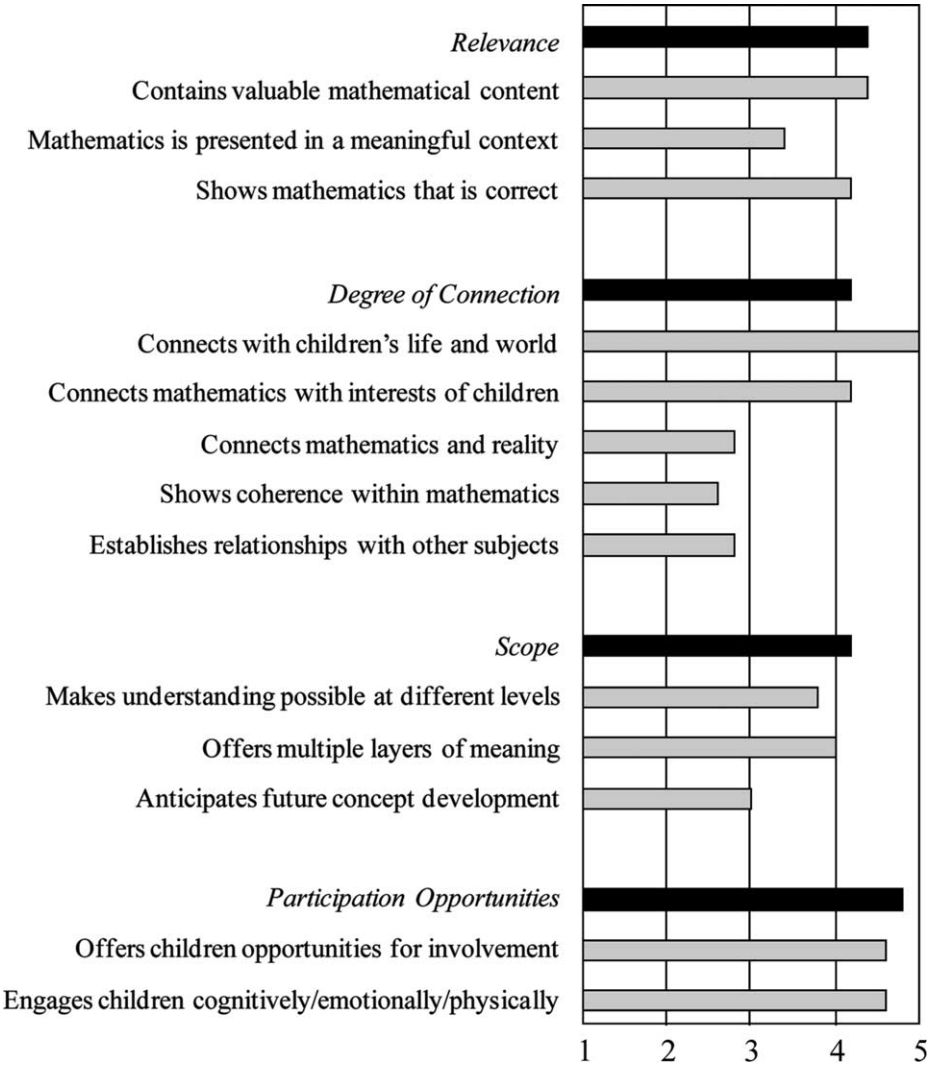

Figure 7. The importance attributed by the experts to the learning-supportive characteristics related to quality of presentation (II2).

broad agreement on the framework found in the Delphi method. We could keep most of the characteristics included in the framework based on the literature review, and only had to rearrange section B into section II, which involved the presentation of mathematical content. In the new section II, the learning-supportive aspects were characterised as 'way of presenting' (II1) and 'quality of presentation' (II2).

The revised framework turned out to be especially helpful in recognising characteristics that go beyond discerning typical content domains. It helped the experts to discover mathematical processes and dispositions and mathematical themes included in the picturebooks, which were overlooked when they did not use the framework. The framework was even more useful for detecting learning-supportive characteristics related to the presentation of the mathematical content. In all

categories of this section, we found a great difference in the results from the evaluation with and without the framework. The framework made the experts aware of issues like the relevance and the scope of the included mathematics. In other words, the framework taught the experts in this respect. However, we think that the ability of the picturebooks to show coherence between mathematical concepts and the opportunity to anticipate further concept development should have received more attention from the experts.

Another remarkable point is that seven experts, out of the characteristics related to the quality of presentation (II2), attributed the highest level of importance to connections with children's life and world, while, at the same time, they unanimously chose *The surprise* – which is about a sheep that rides on a motor scooter – as the book to be included in a picturebook program for supporting kindergartners' learning of mathematics. This apparent discrepancy can be explained by the broad interpretation that Dutch mathematics educators have with respect to what is 'real' for children. It not only includes experiences from the real world, but also what children can imagine as real. A sheep on a motor scooter belongs in this category.

Although the Delphi method contributed significantly to the refinement of the framework and gave more certainty about its tenability, the experts did not always feel comfortable with this approach. When we evaluated the Delphi method, it emerged that two of the seven experts had missed the direct communication with the other group members, and so had no chance to ask for clarification or to learn from them. These feelings are also mentioned in the literature as being inherent to the Delphi method (e.g. Landeta 2006). To avoid this discomfort, special attention should be sustaining the experts willingingness to invest their time and share their ideas. An advantage of the Delphi method compared to a face-to-face group discussion is that the participants have more time to think about their answers. Two of the seven experts indicated this explicitly, answering the questions in phases, which is feasible with the Delphi method. Another benefit of this method is that, due to its iterative nature, it was possible to approach the learning-supportive characteristics from multiple perspectives and ask different kinds of questions, which helped the experts to overcome their difficulties in explaining these characteristics.

Despite the positive findings in favour of the framework, we must acknowledge that our study was carried out solely within the context of mathematics education, and did not include expertise from literacy studies on picturebooks in general. This is also true for the literature review, which certainly could have been enriched by incorporating theoretical and empirical studies on children's literature from the perspective of literacy. We see it as a goal for further improvement of the framework to work with resources and scholars in this field. Moreover, we would also like to investigate how a framework of learning-supportive characteristics works in the hands of teachers. However, for providing the ultimate evidence about whether the learning-supportive characteristics are really helpful for kindergartners' learning of mathematics, in-depth empirical studies are necessary. These studies should investigate whether particular characteristics evoke particular learning in children. The need for such a study was also stressed by one of the experts. The present study has prepared the way for this by offering a framework of learning-supportive characteristics of picturebooks specific to learning mathematics.

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Appendix. Overview of publications used for the literature review

Publication	Academic	Professional
Austin (1998)	x	
Braddon, Hall, and Taylor (1993)		x
Burns and Sheffield (2004)		x
Columba, Kim, and Moe (2005)		x
Evans, Leija, and Falkner (2001)		x
Griffiths and Clyne (1991)		x
Hellwig, Monroe, and Jacobs (2000)	x	
Hunsader (2004)	x	
Jacobs (2000)		x
Kolakowski (1992)		x
Lachance (2002)		x
Merenda (2000)	x	
Moyer (2000)	x	
Murphy (1999)		x

Appendix (*Continued*)

Publication	Academic	Professional
Rubin (2004)		x
Schiro (1997)	x	
Schiro (2004)	x	
Thatcher (2001)		x
Thiessen, Matthias, and Smith (1998)		x
Thiessen (2004)		x
Welchman-Tischler (1992)		x
Whitin and Wilde (1992)		x
Whitin and Wilde (1995)		x
Whitin (2002)		x
Whitin and Whitin (2004)		x
Young (2001)	x	
Total	8	18