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The role of pictures in picture books on children's cognitive engagement with mathematics

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ABSTRACT: The present study examines the cognitive activity that is evoked in young children when they are read a picture book that is written for the purpose of teaching mathematics. The focus of this study is to explore the effects of pictures on children's spontaneous mathematical cognitive engagement. The study is based on the assumption that the pictures in a picture book that is aimed at supporting children's learning of mathematics can have story-related components and mathematics-related components. The story-related components of the pictures contribute to grasp the global story context of the text and the mathematics-related components help to understand the mathematical content of the story. All of the pictures of the book under investigation, *Six brave little monkeys in the jungle*, have both story-related and mathematics-related components included. The pictures have a representational or an informational function. Four 5-year-old children were read individually the book by one of the authors without any probing. A detailed coding framework was used for analyzing the children's utterances that provided an in-depth picture of the children's cognitive activity. The results show that the picture book as a whole has the potential for cognitively engaging children. However, the pictures with a representational function were found to elicit mathematical thinking to a greater extent than the pictures with an informational function. Moreover, this was found for both types of components included in the pictures. Findings are discussed, practical implications for using picture books in kindergarten are drawn and suggestions for further research are made.

RÈSUMÈ: La présente étude examine l' activité cognitive évoquée chez des jeunes enfants quand il leur est lu un livre illustré destiné à l'enseignement des mathématiques. L' étude est centrée sur l' exploration des effets des images sur l'engagement cognitif mathématique spontané des enfants. L'étude s'appuie sur l'hypothèse que les images dans un livre illustré visant à soutenir l'apprentissage des mathématiques peuvent avoir des composantes liées à l'histoire et des composantes liées aux mathématiques. Les composantes des images liées à l'histoire contribuent à saisir le contexte global du texte et les composantes liées aux mathématiques aident à comprendre le contenu mathématique de l'histoire. Toutes les images du livre étudié, 'Six braves petits singes dans la jungle', possèdent les deux composantes. Les images ont une fonction représentative ou informative. Le livre a été lu à quatre enfants de 5 ans individuellement par un des auteurs de cet article sans autres explications. Un cadre détaillé de codage a été employé pour analyser les énoncés des enfants, fournissant une image détaillée de leur activité cognitive. Les résultats montrent que le livre illustré dans son ensemble a le potentiel de provoquer l'engagement cognitif des enfants. Cependant, les images avec une fonction représentative se sont avérées développer

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davantage la pensée mathématique que les images avec une fonction informationnelle. D'ailleurs, ceci a été trouvé pour les deux types de composantes incluses dans les images. Les résultats donnent lieu à une discussion, des implications pratiques pour l'usage des livres illustrés au jardin d'enfants sont proposées ainsi que des suggestions pour des recherches ultérieures.

ZUSAMMENFASSUNG: Die vorliegende Studie untersucht die kognitive Aktivität bei jungen Kindern, die durch das Vorlesen eines für den Mathematikunterricht geschriebenen Bilderbuches hervorgerufen wird. Der Schwerpunkt liegt auf der Untersuchung der Auswirkungen der Bilder auf das spontane mathematisch-kognitive Engagement der Kinder. Die Studie basiert auf der Annahme, dass die Bilder in einem Mathematikbuch sowohl mathematische als auch geschichtenbezogene Komponenten aufweisen. Die geschichtenbezogenen Komponenten der Bilder tragen demnach dazu bei, den globalen Geschichten-Kontext des Textes zu erfassen, während die auf Mathematik bezogenen Komponenten helfen, den mathematischen Inhalt der Geschichte zu verstehen. Alle Bilder des untersuchten Buches "Sechs tapfere kleine Affen im Dschungel" enthalten sowohl geschichtenbezogene als auch mathematikbezogene Komponenten. Die Bilder haben dabei gleichzeitig eine repräsentierende und eine informierende Funktion. Vier 5-jährigen Kindern wurde einzeln das Buch von einem der AutorInnen vorgelesen, ohne dass mathematisch geübt wurde. Ein detaillierter Kodierungsrahmen für die Analyse der Äußerungen der Kinder wurde genutzt, mittels dessen ein eingehendes Bild der kognitiven Aktivität der Kinder gewonnen werden konnte. Die Ergebnisse zeigen, dass das Bilderbuch als Ganzes das Potenzial hat, die Kinder kognitiv zu engagieren. Dabei wurde ebenfalls deutlich, dass die Bilder mit einer repräsentierenden Funktion in einem größeren Ausmaß mathematisches Denken aktivieren als die Bilder mit einer informierenden Funktion. Dies gilt für beide Arten von Komponenten. Die Ergebnisse werden diskutiert, praktische Bedeutungen für die Nutzung von Bilderbüchern in Kindergärten skizziert und Anregungen für die weitere Forschung gegeben.

RESUMEN: El presente estudio examina la actividad cognitiva que se suscita en los niños pequeños cuando se les lee un libro ilustrado escrito con el propósito de enseñar matemáticas. El objeto de este estudio es investigar los efectos de las ilustraciones sobre el interés cognitivo matemático espontáneo de los niños. El estudio se basa en el supuesto de que las imágenes de un libro ilustrado cuyo propósito es apoyar el aprendizaje de las matemáticas en los niños pueden tener componentes relacionados con el relato y componentes relacionados con las matemáticas. Los componentes de las ilustraciones relacionados con el relato contribuyen a la comprensión del contexto global del relato del texto, y los componentes relacionados con las matemáticas ayudan a entender el contenido matemático del relato. Todas las ilustraciones del libro que se investiga, "Seis monos pequeños valientes en la selva", incluyen componentes tanto relacionados con el relato como relacionados con las matemáticas. Las ilustraciones tienen una función de representación o de información. A cuatro niños de 5 años les fue leído individualmente el libro por uno de los autores sin hacer ningún sondeo. Se utilizó un marco de codificación detallado para analizar las expresiones verbales de los niños que ofrecían una imagen a fondo de su actividad cognitiva. Los resultados muestran que el libro ilustrado, como un todo, tiene el potencial para interesar cognitivamente a los niños. Sin embargo, se halló que las ilustraciones con función de representación suscitaban un razonamiento matemático en mayor medida que las ilustraciones con función de información. Además, esto se halló con respecto a ambos tipos de componentes incluidos en las ilustraciones. Se analizan los resultados, se infieren implicaciones prácticas respecto al uso de libros ilustrados en el jardín de niños y se hacen sugerencias con miras a una investigación adicional.

Keywords: picture books; pictures; story; mathematics; cognitive engagement; kindergartners

Introduction

The role of picture books in the learning of mathematics

In pre-school education children have the opportunity to interact with picture books on a regular basis. Teachers use picture books as a means of instruction and children can have access to the small library or corner of books that are available in the kindergarten school during free play time.

The great significance of reading picture books to young children in their development was revealed by previous research, which concentrated mainly on the learning of language and literacy (Anderson, Anderson, and Shapiro 2005). In the past few years this situation has changed. Linking mathematics teaching to children's literature has become an increasingly popular subject (Haury 2001). It has been acknowledged that children's literature can motivate children to pose and investigate problems and communicate their thinking (Harland 1990). Furthermore, picture books may contribute to the development of children's attitudes toward mathematics (Griffiths and Clyne 1991). In general, picture books can provide children with an informal world of experiences which embodies mathematical concepts and structures (Ginsburg and Seo 1999).

In the present study, we focus on the nature of the cognitive activity and in particular the mathematical thinking that a picture book, which – as is indicated by the publisher – is written for the purpose of teaching mathematics, evokes in 5-year-old children without explicit instruction or any prompting by the reader. Our special interest is to explore the role of the different functions of pictures of the storybook on children's spontaneous cognitive engagement by identifying and analyzing their utterances. Thus, the study was designed to investigate the power of the picture book itself and, in particular, the pictures included in the book.

Theoretical perspectives

The use of picture books in the teaching of mathematics can be supported by three theoretical perspectives for learning: a constructivist approach to learning, the position of contextualized learning and the importance of learning by interaction which is incorporated in the first two perspectives (Van den Heuvel-Panhuizen and Van den Boogard 2008).

According to the constructivist approach to learning, picture books may offer an environment in which children actively construct mathematical knowledge (Phillips 1995). Children resolve cognitive conflicts that occur within the text and the pictures. They process the new information by associating it to existing knowledge and by reflecting on it. Through this activity, children develop new ideas, structures and schemata and achieve a higher level of understanding. The position of constructivism is grounded in the work of Piaget, who considers the aforementioned procedure indispensable to learning. Constructivism also involves a social perspective based on the sociocultural theory of learning of Vygotsky. Within this view, children's acquisition of knowledge is a result of social interaction, which enables children to communicate knowledge and stimulates reflection (McLaughlin et al. 2005).

The view of contextualized learning is based on the theory of situated cognition (Brown, Collins, and Duguid 1989) and situated learning theory (Lave and Wenger 1991). Both theories highlight that knowledge is situated and learning is influenced by the activity, the content and the culture in which it is developed and used. A common

characteristic of the situated cognition and the view of constructivism is the importance that is given to the social interaction between learners. There is a difference though in the conceptualization of the conditions under which learning takes place. While the constructivist approach stresses the need of a meaningful, authentic context for learning, situated learning occurs to a considerable extent unintentionally rather than deliberately (Lave and Wenger 1991).

The three aforementioned theoretical perspectives are important for the learning of mathematics. Griffiths and Clyne (1991) conceptualize mathematics as an indispensable component of human experience, and thus as an integral part of the stories narrated in picture books. Through picture books, children, as active participants in the learning process, intentionally or unintentionally, have the opportunity to communicate and discuss ideas for solutions, develop mathematical knowledge and reach higher levels of understanding in a meaningful context.

Previous research on the impact of picture books

Even though it is well acknowledged that children's literature can support mathematics learning, only a small number of studies have examined this relationship. In such a study by Jennings, Jennings, Richey and Dixon-Kraus (1992), children's literature was used in the teaching of mathematics for five months in a systematic way. Positive effects were found not only on children's performance in mathematics, but also on the attitudes they developed toward mathematics. Hong (1996) explored the effects of a program which involved storybooks related to mathematics in the kindergarten. The experimental group was found to outperform the control group on tasks of classification, number combination and geometric figures.

The aforementioned studies have two common characteristics. First, the studies focused on picture books as a starting point for a mathematical learning activity and did not examine whether the picture book by itself could contribute to the children's cognitive development. Lovitt and Clarke (1992) maintained that picture books may offer a framework with cognitive stimuli which may initiate the children's exploration of mathematical concepts and development of mathematical skills. A recent study carried out by Van den Heuvel-Panhuizen and Van den Boogaard (2008) showed 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). Moreover, this is even true when a book that is not written with the purpose of teaching mathematics is used. A second commonality of the previous studies is that they explored the contribution of picture books as a whole. However, a picture book consists of pictures that have a significant role in telling the story by serving different functions.

The role of pictures in text processing and in the learning of mathematics

Schnotz (2002) suggests that text and visual displays belong to different classes of representations, namely descriptive and depictive representations respectively. Descriptive representations consist of symbols that have an arbitrary structure and are associated with the content they represent simply by means of a convention. Depictive representations include iconic signs that are associated with the content they represent through common structural features on either a concrete or more abstract level. Descriptive representations and depictive representations serve different functions and

have different purposes. Descriptive representations have a rather general and abstract character, whereas depictive representations are of a more concrete and specific nature. Numerous studies have shown that combining texts (descriptive representation) and pictures (depictive representation) is beneficial for learning (see Levie and Lentz 1982; Mayer 2001).

According to Carney and Levin (2002) pictures may serve different functions in text processing: decorative, representational, organizational, interpretational, and transformational. Decorative pictures simply decorate the page, bearing little or no relationship to the text content. Representational pictures illustrate a part or all of the text content. Organizational pictures provide a useful structural framework for the text content. Interpretational pictures help to clarify a difficult text. Finally, transformational pictures include mnemonic components that are designed to improve recall of information by the thinker. In picture books most of the pictures are representational as they depict what is described in the text.

Drawing on this model of picture classification in text processing Theodoulou, Gagatsis and Theodoulou (2004) and Elia, Gagatsis and Demetriou (2007) proposed a categorization of pictures based on their function in the context of arithmetic problem-solving, including a decorative, a representational, an organizational and an informational function. Decorative pictures do not provide problem-relevant information. Representational pictures illustrate a part or the entire content of the problem. They are not necessary for the understanding or the solution of the problem. These pictures can help the children understand the meaning of the problem or solve it, but they can be also neglected. Organizational pictures provide directions for the organization of the problem's information or drawing or written work that support the solution procedure. Similarly to the representational pictures, they are not essential for the solution of the problem. Informational pictures provide information that is essential for the solution of the problem, because the content of the problem is based on the picture. That is, they represent visually the problem situation often with groups of elements that may frame the counting process. It should be noted that the functions of pictures that are proposed in these tasks do not concern the global situation described in the problems, but only the mathematical content and structure of the problems.

Elia, Galatsis, and Demetriou (2007) investigated the role of different modes of representation, i.e., verbal description, decorative pictures, informational pictures and number line pictures, in solving additive change problems by children in Grades 1, 2, and 3. The results provided a strong case for the differential effects of the representations on the general arithmetic problem solving ability. In other words, students' abilities to solve change problems in different representations were found to be basic components of the additive problem solving ability. Nevertheless, this study's findings as well as the findings of the study by Berends and van Lieshout (2009) showed that the informational pictures have a detrimental effect in solving arithmetic problems. This was attributed to the switching between information in the two different sources (text and picture) and the combination of these streams of information, which entail additional increase in the cognitive load of the task (Berends and van Lieshout 2009).

Purpose of the study and research questions

Van den Heuvel-Panhuizen and Van den Boogaard (2008) suggested that more evidence is needed for using picture books as an impetus for young children's

mathematics-related thinking. Anderson, Anderson, and Shapiro (2005) showed that different books can produce various amounts of mathematical remarks and different types of mathematics. In light of the above, we decided to examine again whether and to what extent mathematics-related thinking evolves when young children are read a picture book. However, compared with the previous studies we decided to apply a more analytic approach by exploring the contribution of the picture book's pictures on children's cognitive activity. We chose for this approach because we think that this focus on pictures may give new insights on how picture books as a whole can support the learning of mathematics.

In most picture books (Van den Heuvel-Panhuizen and Van den Boogaard 2008) the illustrations play a significant role in telling the story. They usually represent the text content of the story, but may even go beyond the representational role by adding further details (Stewig 1992). In this case, children construct meaning through the interplay of text and image, which are different in content (Sipe 1998). Therefore, images in picture books may also have an informational function. In mathematics-related picture books pictures can include also mathematical information, which may support the understanding of the mathematical content of the story.

The purpose of the present study is to investigate the mathematical cognitive activity that is stimulated by a picture book and the effects of the pictures of the book on the frequency of appearance of these cognitive processes. We attempt to offer insight into the processes that take place when children of 4.5-years-old see the pictures of the book and hear the story.

More precisely, our research questions are:

(1) What mathematics-related thinking does a picture book that involves mathematics evoke during the process of reading the book to young children?
(2) How does mathematics-related thinking vary over the different pictures of the book (a) from the perspective of the global story content, on the one hand; and (b) from a mathematical point of view, on the other hand?

Method

Participants

The participants of the study were four children (three girls and one boy) of a private kindergarten in Nicosia, Cyprus.[1] The children had the same age, i.e., 4.5-years-old, were in the same class and had received organized instruction in mathematics. In this kindergarten school picture books are used on a daily basis. Furthermore, there is a book corner which the children can use during the free play hour.

The picture book – a priori analysis of the function of pictures

The picture book that we used was not familiar to the children; thus, they did not know its content. The picture book *Watch out in the jungle* is written and illustrated by John O'Leary and was first published in the UK by Tango Books, in 2005. The book is translated into Greek by Stella Zoumba. The English translation of the Greek title is *Six brave little monkeys in the jungle*.[2]

The story is about six monkeys that live in the jungle. In every page there is a hidden jungle animal that scares the playful monkeys and as a result a monkey

disappears. In the end, the monkey that is left comes up with an idea so as to get back at the scary animals.

This picture book has been written with the purpose of being used in the teaching of mathematical concepts and skills and not exclusively to tell children a fascinating story. Specifically, apart from the information that is given about the jungle and the animals that live there, it aims at the teaching of counting backwards.

All pages of the picture book contain story-related components as well as mathematics-related components. With respect to the function of the pictures – and using the classification developed by Theodoulou, Gagatsis, and Theodoulou (2004) and Elia, Gagatsis, and Demetriou (2007) – two types of functions can be distinguished. Of the story-related components included in the pictures, seven pictures have a representational function and eight have an informational function. Of the mathematics-related components included in the pictures, eight pictures have a representational function and seven pictures an informational function.

Table 1 shows that each page of the picture book has a dual nature by having two types of components: story-related and mathematics-related. Moreover, the components on one page have either both a representational or an informational function, with the exception of page 11. The difference between the informational and the representational function of the mathematics-related or the story-related components is that the mathematics or story information in the informational picture is not in the text, whereas the mathematics or story information in the representational picture is also included in the text.

To make the type of components included in the pictures and the functions of these components clearer, the front cover, the French page front, pages 2, 5, 11 and the back cover of the picture book are given in the appendix.[3] Each page of the book (see, e.g., pages 2, 5, 11) consists of a left and a right side which are joined together to form one picture. This also applies to the front and back cover.

The pictures in the front cover, the back cover and page 5 have both for the story-related and for the mathematics-related components a representational function. Although the pictures in the front cover and the back cover are designed as a functional whole (so that all six monkeys are illustrated), they were read to the children separately at the beginning and the end of the reading session. Therefore, they are analyzed as two distinct pictures. Specifically, the picture in the front cover contains story-related components with a representational function because the picture represents visually the content of the title, that is, the monkeys in the jungle. At the same time the front cover also contains mathematics-related components which also have a representational function because they illustrate a part of the numerical information of the title, that is, five out of the six monkeys that the title refers to. In the back cover, the story-related components in the picture have a representational function, as they express

Table 1. The function of pictures per type of components and per page.

	Book page														
Type of components	CF	FF	1	2	3	4	5	6	7	8	9	10	11	12	CB
Story-related	R	I	R	I	R	I	R	I	R	I	R	I	I	I	R
Mathematics-related	R	I	R	I	R	I	R	I	R	I	R	I	R	I	R

Abbreviations: CF = front cover, FF = French page front, CB = back cover, R = representational function, I = informational function.

what the text refers to, that is, monkeys playing in the jungle even though it illustrates only one monkey playing in the jungle. The mathematics-related components of the picture have also a representational function as they depict a piece of the numerical information of the text, that is, one out of the six monkeys that the text refers to. In page 5 the story-related components illustrate a part of the text, namely, that the monkeys are running on the grass and are flying the kite. The mathematics-related components represent visually the numerical information that is described in the text of the page with a group of four monkeys that may frame the counting process. A similar rationale applies for categorizing the rest of the pictures that have a representational function for both the story-related and the mathematics-related components.

The pictures in the French page front and page 2 have both for the story-related and for the mathematics-related components an informational function. The pictures with informational function offer additional information to the content of the text, that is, 'Watch out! The jungle is dangerous!' For the story-related components of most pictures this information concerns the cause of the decrease of the monkeys, e.g., attack by a wild animal, such as a leopard (page 2). For the mathematics-related components this information concerns the number of the monkeys that leave (always one) and the number of the monkeys that are left. The story-related components in the French page front provide the information that there are some monkeys playing in the jungle and being in danger. For the mathematics-related components the information involves the total number of the monkeys.

In page 11 the story-related and mathematics-related components in the picture do not have the same function. In page 11 the story-related components have an informational function, as they provide additional information to the text, that is, what kinds of jobs the monkey is involved in. The mathematics-related components, however, have a representational function, since they illustrate visually the numerical information of the text, that there is one monkey (working). It should be noted that this picture as a whole consists of 14 vignette illustrations. Therefore it is possible that a child who does not understand how the mathematical components of the picture are related to the mathematical text that is represented (one monkey), sees these illustrations as 14 monkeys rather than as one monkey doing 14 jobs. As a result of such an incongruence between the mathematical content of the text and the mathematical components of the picture, which applies also for the front cover and the back cover, the representational pictures may fail to help children understand the mathematical content of the text. However, this type of picture can motivate children to resolve the cognitive conflict between text and picture, and therefore can have a positive impact on children's mathematics-related thinking. The differences between the effects of representational pictures which are mathematically 'congruent' (e.g., page 5) or 'incongruent' with the content of a text in the learning of mathematics by young children while being read mathematics-related picture books or in other educational settings would be an important and interesting topic to investigate. Yet, this is not our focus in the present study.

Book reading procedure and data collection

The book was read individually to the children by the same reader, who gave them many opportunities to react. To reduce the intervention of the reader as much as possible we used specific guidelines for the reading procedure. A part of these guidelines are presented in Table 2.

Table 2. Part of the book reading scenario.

Page	Guidelines for reading the book
Front cover	Show the cover page to the child. The child may react spontaneously saying what he or she sees in the picture. If the child does not react spontaneously, ask what he or she thinks the subject of the book is.
1	Show page 1 to the child. Wait for reactions. When the child does not have anything to add, read the text '6 small monkeys play cheerfully in the jungle. They hang from the trees, make somersaults, play with a big colorful ball… But, they do not understand that some hidden creatures are looking at them.' Wait a while to see if the child reacts to this text.
2	Show page 2 to the child. Wait for reactions. When the child does not have anything to add, read the text: 'Grrrr!!! Watch out! The jungle is dangerous!' Wait for a little to see if the child reacts to this text.

Children's cognitive processes were examined through their reactions and utterances which were video-recorded or written down. These reactions could involve counting, predicting what will happen, describing a picture while mentioning time and spatial concepts and so on. These reactions can be considered as being a sign of mental processing. The mind receives, uses, stores and retrieves from the environment and reacts. Children's reactions have been organized and analyzed on the basis of the coding scheme that was used by Van den Heuvel-Panhuizen and Van den Boogaard (2008). This coding scheme draws on a synthesis of the various categories identified by Ginsburg et al. (2003), of the framework of thinking skills developed by Quellmalz (1985) and of the cognitive processing categories proposed by Moschovaki and Meadows (2005).

Results

First, we describe children's utterances that can be considered as indications of cognitive activity in general. Then, we concentrate on the mathematics-specific utterances. Subsequently, we focus on the book and explore the power of the different functions of the two types of components in the pictures in evoking cognitive activity in the children.

Tables 3 and 4 present the coding scheme that was used for the classification of children's utterances that can be considered expressions of cognitive activity. Table 3 concerns children's utterances of a general nature, while Table 4 focuses on the domain-specific utterances.

The domain-specific utterances were related to the concepts of number, space, topology and shapes, and measurement.

Table 5 shows the children's general utterances which can be considered expressions of their cognitive activity that occurred during the reading sessions.

As shown in Table 5, during the reading sessions with the picture book 'Six brave little monkeys in the jungle' we identified 287 general utterances in total. The dynamic descriptions were the kind of utterances with the highest frequency; 34% of the utterances belonged to that category. In 24% of the utterances children gave a static description of what they saw on the picture. Explaining their own utterances was the third highest category; 10% of the utterances fit into this classification.

Table 3. Framework for coding children's general utterances made during picture book reading.

	General qualification of utterances
1.	Description static: Child describes a static aspect of the picture [L10*: The boat is broken]
2.	Description static comparison: Child describes a static aspect of the picture and makes a comparison [S6: But does it have another eye?]
3.	Description dynamic: Child describes a dynamic activity in the picture [L9: The monkeys 'push' the water]
4.	Description dynamic comparison: Child describes a dynamic activity in the picture and makes a comparison [A6: And the other monkey is going to climb]
5.	Posing question: Child asks a question [P1: What are these?]
6.	Assumption story line: Child makes an assumption about how the story will continue [S6: The bee will sting the monkey]
7.	Assumption next picture: Child makes an assumption about what will be in the next picture (the animal that scares the monkeys) [A9: It must be a crocodile]
8.	Explanation own utterance: Child gives an explanation about his or her own utterances [S4: (After S said that this monkey tries to catch another monkey:)… so that it doesn't fall here because it could be hard and they will get hurt]
9.	Comments on text: Child comments on the read-aloud text [S4: (After the reader reads the text: Watch out! The jungle is dangerous!:) Is this (animal) really dangerous?]
10.	Comments on picture: Child comments on a picture: [A3: (While pointing to the monkeys:) The monkeys who are happy…]
11.	Repeating text: Child repeats the read-aloud text [S5: Cruts cruts]
12.	Continuing text: Child continues the read-aloud text [A6: (After the reader reads the text 'The jungle is …':) dangerous]
13.	Correction text: Child corrects the text [A-CF**: (after the reader reads the text: Six brave little monkeys in the jungle:) Six? But there are only five.]
14.	Self reflection own utterance: Child reflects on his or her own utterance: [A8: (After A said that it may be an elephant:) … I have found it]
15.	External reference: Child makes an external reference that has nothing to do with the book or story [S2: I saw a tiger when I went to the circus]

Notes. * The letter refers to the child: S = Skevi, A = Andrew, P = Pamela, L = Leni. These names are pseudonyms which have been used throughout the article. The number refers to the page number of the book. ** CF = front cover.

Out of the 15 types of general utterances, four were found in the responses of all four children. All children spontaneously provided explanations for their own utterances, commented the pictures and made static and dynamic descriptions.

Three types of general utterances were only found in the responses of one child. Two of them were found in Andrew's reactions. These concern the categories description dynamic comparison and correction text. In concern with the latter category, it is noteworthy that Andrew detected the conflict between the mathematical content of the text and the mathematics-related components of the picture in the front cover, which have a representational function, and expressed his disagreement with the text of the page. Skevi was the only child who scored in utterances of the category repeating text.

Description utterances were found in 61% of the total number of utterances. Of the 173 descriptions 57% contained a dynamic description, 39% involved a static

Table 4. Framework for coding the domain-specific utterances made by the children during picture book reading.

	Number-related utterances
N1.	Counting: Child makes a statement about the numerosity of a collection, with or without precisely counting including subitizing and estimation [L9: Two monkeys hold two oars]
N2.	Recognition numerical symbol: Child recognizes a numeric symbol written in the text [S1: This is six]
N3.	Comparison numbers: Child compares the numerosity of a collection in the current page to the numerosity of the collection in previous pages or to the number in text [A9 : Now there are two monkeys]
N4.	Establishing numerosity: Child analyses the numerosity of a collection [A7: Three monkeys, one climbs on the wheel, one is swinging, and the other is swinging too]
N5.	Using some: Child makes a reference to undefined quantifier some [L3: …And some monkeys hold the bag.]
N6.	Using many: Child makes a reference to undefined quantifier many [P11: …Here there are many leafs]
N7.	Using all: Child makes a reference to the undefined quantifier all [P4: All the food is scattered on the floor]
N8.	Using none/nobody: Child makes a reference to quantifier none or nobody [S3: Nobody can see them]
	Spatial and topological utterances
S1.	Specifying position: Child describes the position of an object in relation to another object [S-CF*: They try to throw it (the ball) far away from the basket]
S2.	Topological relations: Child uses topological concepts, such as closed-open. [L9: There is a closed and an open flower]
S3.	Recognition shape or figure: Child names the object based on figure contour or geometrical shape [L5: I see a rhombus that flies]
S4.	Using here and there: Child uses the words here and there [S11: They put bananas here instead of screws]
	Measurement-related utterances
M1.	Reference size: Child makes reference to the size of the objects [A1: I see a leopard, a big one]
M2.	Reference time: Child uses concepts of time, e.g. duration of a situation [S-FF**: It waits a lot of time to throw the ball]

Abbreviations: * CF = front cover; **FF = French page front.

description and only 3% included a static description with a comparison. Dynamic description with comparison occurred only in two cases (1%).

Table 6 shows the domain-specific utterances that occurred during the reading sessions by each child and by all four children together. Domain-specific utterances were found in the 27% of the total number of utterances. These utterances included about 10% (n = 27) number-related utterances covering eight categories. None of these categories involved utterances found in the responses of all four children. Three out of the eight categories were found in the responses of only one child. These categories concern the recognition of a numerical symbol and the use of the quantifiers 'none/nobody' or 'some'.

The spatial and topological utterances were the kind of utterances with the highest proportion out of the domain-specific utterances (16%). Two out of the four categories

Table 5. Frequencies and total percentage of found general utterances during the reading sessions.

	Skevi	Andrew	Pamela	Leni	Total	
	f	*f*	*f*	*f*	*f*	(%)
General utterances						
1. Description static	16	16	11	25	68	(24)
2. Description static comparison	3	1		1	5	(2)
3. Description dynamic	23	28	31	16	98	(34)
4. Description dynamic comparison		2			2	(1)
5. Posing question	14	6	2		22	(8)
6. Assumption story line	5	2	7		14	(5)
7. Assumption next picture	3	4	3		10	(3)
8. Explanation own utterance	17	6	4	2	29	(10)
9. Comments on text	4	3	1		8	(3)
10. Comments on picture	6	7	2	1	16	(6)
11. Repeating text	3				3	(1)
12. Continuing text		2	1		3	(1)
13. Correction text		2			2	(1)
14. Self reflection own utterance	1	5			6	(2)
15. External reference	1				1	(1)
Total utterances	96	84	62	45	287	(100)

were found in the responses of all four children. These concern the categories specifying position and using ‘here’ and ‘there’.

Finally, of the measurement-related utterances, three belonged to the category reference time and one belonged to the category reference size. Leni was the only child that was not found to use measurement-related utterances.

To gain a better understanding of the power of the book in evoking children’s cognitive activity we examined the type and number of the children’s utterances per book page (Table 7 and Table 8). The picture book comprises of 15 pages. Table 7 shows that the general utterances were about equally distributed over these pages. In pages 2 and 11 the scores were a little higher than in the rest of the pages. On page 2 the leopard scares the six monkeys. The children can see for the first time that the hidden figure of page 1 forms an animal in page 2. On page 11 the only monkey that is left tries to construct something to scare the wild animals of the jungle.

Concerning the domain-specific utterances, as shown in Table 8, the largest proportion of number-related utterances was found on page 7. The picture on this page is representational for both the story-related and mathematics-related components. On this page three monkeys are swinging on a tree, which in fact is the trunk of an elephant. As regards the spatial-topological utterances, remarkably high score was found on page 11. The mathematics-related components in this page have a representational function and the story-related components have an informational function. Specifically, it illustrates one monkey doing several jobs in order to construct something.

As shown in Table 7, of the introduction pages the front cover and the French page front, which have a representational function and an informational function respectively

Table 6. Frequencies and total percentage of found domain-specific utterances during the reading sessions.

	Skevi	Andrew	Pamela	Leni	Total	
	f	*f*	*f*	*f*	*f*	(%)*
Number-related utterances						
N1. Counting		5		3	8	(3)
N2. Recognition numerical symbol	1				1	(0)
N3. Comparison numbers		4			4	(1)
N4. Establishing numerosity		1		1	2	(1)
N5. Using some				2	2	(1)
N6. Using many			1	2	3	(1)
N7. Using all	1	2	2		5	(2)
N8. Using none/nobody	2				2	(1)
Total	4	12	3	8	27	(10)
Spatial and topological utterances						
S1. Specifying position	6	2	8	5	21	(7)
S2. Topological relations			2	2	4	(1)
S3. Recognition shape or figure		1		1	2	(1)
S4. Using here and there	6	3	9	2	20	(7)
Total	12	6	19	10	47	(16)
Measurement-related utterances						
M1. Reference size		1			1	(0)
M2. Reference time	1	1	1		3	(1)
Total	1	2	1		4	(1)

Notes. *Percentage of the total number of utterances (287).

Table 7. Distribution of found general utterances during the reading sessions per page.

Book page																	
Type of components			CF	FF	1	2	3	4	5	6	7	8	9	10	11	12	CB
Story-related			R	I	R	I	R	I	R	I	R	I	R	I	I	I	R
Mathematics-related			R	I	R	I	R	I	R	I	R	I	R	I	R	I	R
All	N	%															
Skevi	96	33	3	6	8	9	8	10	6	7	4	2	4	3	9	13	4
Andrew	84	29	5	5	8	9	5	1	6	9	8	4	7	3	7	2	5
Pamela	62	22	5	5	3	3	3	2	2	4	4	3	6	5	14	3	
Leni	45	16	1		1	3	2	5	6	3	4	1	6	1	7	5	
Total N	287	100	14	16	20	24	18	18	20	23	20	10	23	12	37	23	9
%			5	6	7	8	6	6	7	8	7	4	8	4	13	8	3

Abbreviations: CF = front cover, FF = French page front, CB = back cover, R = representational function, I = informational function.

had a higher percentage of general utterances, whereas the back cover, which has a representational function, elicited a considerably lower number of utterances. As for the domain-specific utterances, Table 8 shows that the front cover had a higher number of utterances than the French page front, which in turn evoked more mathematics-related utterances than the back cover. The few general and mathematics-related utterances prompted by the back cover are probably due to the position of the back cover which is the last page of the book and its content which actually replicates what is already known from previous pages.

Table 9 shows how the amount of children's utterances varies over the different types of components in the pictures of the storybook.

With respect to the mathematics-related components the score of children's utterances on the components with a representational function is higher than on those with an informational function. This difference is greater in the domain-specific utterances. With respect to the story-related components, those with a representational function had a higher score in number-related and measurement-related utterances than the ones with an informational function. However, the story-related components with an informational function prompted a higher score of spatial–topological utterances and all the utterances in general.

Table 8. Distribution of found domain-specific utterances during the reading sessions per page.

Book page															
Type of components	CF	FF	1	2	3	4	5	6	7	8	9	10	11	12	CB
Story-related	R	I	R	I	R	I	R	I	R	I	R	I	I	I	R
Mathematics-related	R	I	R	I	R	I	R	I	R	I	R	I	R	I	R
Number-related utterances															
Skevi	4	1			1	1							1		
Andrew	12	3	1				1		3		2		1	1	
Pamela	3					1						1	1		
Leni	8				1	1	1		2		2		1		
Total N	27	4	1		2	3	2		5		4	1	4	1	
Spatial and topological utterances															
Skevi	12	1	1	1		2	1	1		2			3		
Andrew	6					1			1			1	1		1
Pamela	19						1		2		2	1	2	11	
Leni	10	1		1				2	2		4				
Total N	47	2	1	2		3	2	3	5	3	2	5	3	15	1
Measurement-related utterances															
Skevi	1		1												
Andrew	2			1					1						
Pamela	1								1						
Leni															
Total N	4		1	1					2						

Abbreviations: CF = front cover, FF = French page front, CB = back cover, R = representational function, I = informational function.

Table 9. Mean scores of found utterances of all children during the reading sessions per type and function of components.

	Function of components in pictures	
	Representational	Informational
All utterances		
Story-related components	17.7	20.4
Mathematics-related components	20.1	18
Number-related utterances		
Story-related components	2.4	1.4
Mathematics-related components	3	0.9
Spatial and topological utterances		
Story-related components	2.7	3.5
Mathematics-related components	4.3	1.9
Measurement-related utterances		
Story-related components	0.4	0.1
Mathematics-related components	0.4	0.1

Conclusions

The present study examined young children's cognitive activity, with emphasis on children's mathematics-related thinking, when read a picture book which involved mathematics at a meaningful story-connected level. A main concern was to investigate the influence of the type of pictures involved in the book on children's cognitive activity.

In general, the variety and the number of children's utterances which reflect their cognitive activity suggest that the picture book *Six brave little monkeys in the jungle* has the power to evoke children's mathematical thinking. All four children exhibited cognitive engagement which resulted in general utterances as well as in mathematics-related utterances. This was also shown by a previous study by Van den Heuvel-Panhuizen and Van den Boogaard (2008). However, in this case the book was written for the purpose of teaching mathematics and explicitly displayed mathematics by means of numbers and number symbols. Nevertheless, the found domain-specific utterances were accounted for only 27% of the total number of utterances. These findings suggest that picture books that have been written for didactical purposes and are used without a teacher who is asking questions, may not always be as effective as expected in evoking mathematics-related thinking. Therefore, it can be deduced that it is important for pre-school teachers to follow a number of guidelines for using this kind of picture book in teaching.

Children's domain-specific mathematics-related utterances have been distinguished into three categories: number-related, spatial-topological and measurement-related. The spatial-topological utterances were the most frequently found while the measurement-related utterances were the most rarely hit upon in children's reactions. Most of the number-related utterances had to do with determining the number of a collection of objects (how many there are). The main ways children used to achieve this were subitizing and counting, which are considered as fundamental and powerful skills in the

development of children's understanding of numbers (Baroody 1987; Clements and Sarama 2009). Even though the aim of the picture book was counting backwards, this counting sub-skill was not detected in children's reactions. Only one child was found to notice that the number of monkeys altered every time. This does not mean that he understood that every time a monkey left, the number decreased by one. However, children displayed a tendency to compare the collections across pages by identifying that the collection of the current page is different from or smaller than the collection of the previous page. This indicates that without any prompting children used counting in a meaningful way, that is, comparing collections that appeared in the picture book. The picture book urged children to make inferences based on their counting in order to compare these collections. Another important process that the children explicitly used was establishing the numerosity of a collection by conceptual subitizing. Clements and Sarama (2009) suggest that children between 4- and 5-years-old can learn that a whole is made up of smaller parts. In our study, the pictures of the book enabled children to recognize that groups are composed of smaller groups. This experience can contribute to the development of composition-based ideas which provide an early basis for addition and subtraction (Fuson 1992). In sum, the picture book used in this study elicited various skills that are fundamental in the development of the understanding of number (Clements and Sarama 2009) and therefore has the potential to be supportive of learning.

As already mentioned, findings showed that children exhibited cognitive activity related to spatial and topological concepts to a larger extent relative to other concepts. This is in line with the finding of the study by Van den Heuvel-Panhuizen and Van den Boogaard (2008) which showed that spatial orientation-related utterances exceeded the number-related ones when children were read a picture book that was not written with the intention of teaching mathematics. Spatial thinking is an indispensable component of human activity which is performed by children from a very early age. Spatial insight may be developed with the help of mental images that are formed as a result of children's natural perceptions and actions, such as looking at phenomena in the surrounding space and playing with different objects (Van den Heuvel-Panhuizen and Buys 2008). An explanation that can be given for this finding is that looking at the pictures of the book is a spatial activity for young children, an experience of investigating the spatial environment, which may evoke mental images and thus prompt relative utterances. Therefore, it can be deduced that besides looking at phenomena in the surrounding space and playing, looking at the pictures of a book during a reading session can also stimulate spatial thinking activities and probably contribute to the development of spatial insight.

One of the most important contributions of this study is the introduction and exploration of a new operational conceptualization of the functions that pictures serve while reading storybooks which involve mathematics. The functions of pictures in a mathematics-related storybook can be connected to both the story-related components of pictures and their mathematics-related components. In the picture book used here, we concluded that all the pictures serve two functions: representational or informational. The story-related components of a picture which have a representational function illustrate the global situation of the story, while at the same time the mathematics-related components which have this function show the numerical content, i.e., collections of a number of objects described in the text. Components with an informational function depict information having to do with the evolution of the story (this is done by the story-related components) on the one hand, and/or numerical information (this is done by the mathematics-related component) on the other hand. The information

depicted in the components with an informational function is in both types of components different from the content of the text. Analyzing the pictures of the book used in the present study in terms of the story-related and mathematics-related components showed that both components mainly served congruent functions. Only for a picture on one page the function of the mathematics-related components was not compatible with the function of the story-related components. In all the cases, though, both the mathematical content and the global situation content of the picture need to be integrated in order to support understanding.

In general, the story-related and mathematics-related components with a representational function elicited mathematical thinking to a greater extent than those with an informational function. Whereas the components with a representational function are an alternative 'description' that is additional to the text, in the case of the components with an informational function, the mathematical information can be obtained only from the picture as the content of the text is not sufficiently informative. This suggests that combining text and pictures of a similar content has a greater power to mathematically engage children than combining text and pictures of different content. This finding lends evidence for previous studies' conclusions (Schnotz 2005; Mayer 2001) that combining pictures and text of coherent or semantically related content facilitates mental model construction, whereas learning only from a diagram (or picture) is very difficult especially for novices (Kalyuga, Chandler, and Sweller 2000).

Even the pictures whose mathematical components have a representational function but are not congruent with the mathematical content of the text may have the potential to yield stimulating cognitive activity to children, especially to those children who understand the relation between the picture and the text. As shown in our study, a picture of this kind elicited meaningful mathematical thinking to a child, as it motivated him to compare the mathematical content of the text, that is, the number of monkeys, with the mathematics-related components of the picture, that is, the numerosity of the group of monkeys illustrated and to try to resolve the conflict between them.

A number of mathematics-related utterances were also evoked by the front cover, the French page front and the back cover. Furthermore, although the mathematical components of the pictures in the front (five monkeys) and the back cover (one monkey) were designed as a functional whole so that all the six monkeys are represented, none of the children under study was found to notice this. This finding suggests that children needed extra prompting by the reader in order to recognize the 'comprehensive' representational function of the mathematical content of the pictures in the cover of the book, which in this case could help children understand that the six monkeys, which the title refers to, are composed of the five monkeys in the picture of the front cover and one monkey in the picture of the back cover. The above conclusions are not in accordance with the way pre-school teachers often read picture books to children, as they often neglect these pages because they do not consider them as a part of the story. Thus, this study indicates that it is better to take into account the function that the pictures of these pages serve in relation to the corresponding text before deciding the degree and the kind of attention that should be devoted to them during the reading of the book.

Discussion

The power of the picture book that was evidenced in this study lends support to the theoretical positions that endorse the use of picture books in the learning of mathematics.

In agreement with the constructivist and the contextualized positions to learning, the study showed that the book that was used offered children a meaningful framework in which they could actively construct mathematical knowledge about number, spatial and topological concepts and relations and measurement. However, the social interaction, which is an important component of the learning process, especially when it takes place with knowledgeable others, is seen from a different perspective here. In general, the other is the one who is reading the book to the children, who is interested in the book and who is cognitively active. This means that the reader is part of the learning environment and is even creating opportunities to learn. In the present study we took a different position. In line with the study by Van den Heuvel-Panhuizen and Van den Boogaard (2008) we investigated the own power of a picture book – and especially that of its pictures – without bringing in the stimulating role of the reader. As a result we could confirm the idea from this previous study of extending the concept of the knowledgeable other with the knowledgeable material, which in this case is a picture book.

This study's findings have practical implications for how to read picture books to children. Specifically, they can be understood as an encouragement to teachers to use the power of the book and to know that the type and amount of their questions and explanations may vary while reading a picture book, according to the children's needs and book's characteristics. For instance, in the setting of this study, probing could further support children's mathematical thinking in the pages in which the components have an informational function in relation to the mathematical content of the text and children exhibited a lower level of mathematical engagement.

Despite the fact that this study gives evidence for a number of conclusions, further research is necessary before we can draw more firm and general conclusions. The study involved only one picture book. Further insight about the role and use of picture books with mathematical content in teaching in the kindergarten could be given by future comparisons between children's mathematics-related reactions to picture books that have been written for didactical purposes and other mathematics-related storybooks that are not written with the purpose of teaching mathematics.

The pictures of the book used in this study containing story-related and mathematics-related components having informational or representational functions generated different amounts of mathematics-related utterances. To find more robust evidence for the power of the pictures in the picture books to prompt mathematics-related thinking and generate knowledge about the nature of this thinking we need to investigate whether the pattern of variation in types of pictures' components and functions applies also to other picture books. Further investigation could also be done with picture books that involve other types of pictures, such as pictures whose components have a decorative function or an organizational function (e.g., illustration of a walking route, simple route map of a bus), as well. Moreover, future research could be undertaken to explore the effects of representational pictures in picture books which are mathematically 'incongruent' to the content of a text and compare them to the effects of mathematically 'congruent' pictures in the learning of mathematics by young children. It is also important to examine more children and children from different backgrounds. For instance, a specific implication for future research could be to examine whether the stronger impact of the representational pictures relative to the informational pictures still applies for young children who have higher prior mathematical knowledge. Thus, further and more specific suggestions may be provided for kindergarten teachers on how to use pictures of various functions, so that reading mathematics-related picture books contributes substantially to children's engagement with mathematics.

Notes

1. Before the collection of the data, consent was obtained from the kindergarten Head about the children's participation to the research study. It is also noted that the reader of the picture book during all the reading sessions was the children's kindergarten teacher who is the third co-author of the present paper.
2. The Greek title of the picture book is 'Exi gennea maimoudakia sti zoungla' and is published by Savvalas, Athens.
3. Illustrations of the picture book in the Appendix are reproduced for research purposes with the permission of the book's editor in Greece, Savvalas.

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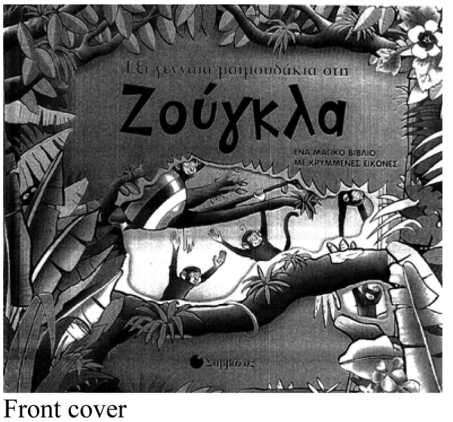
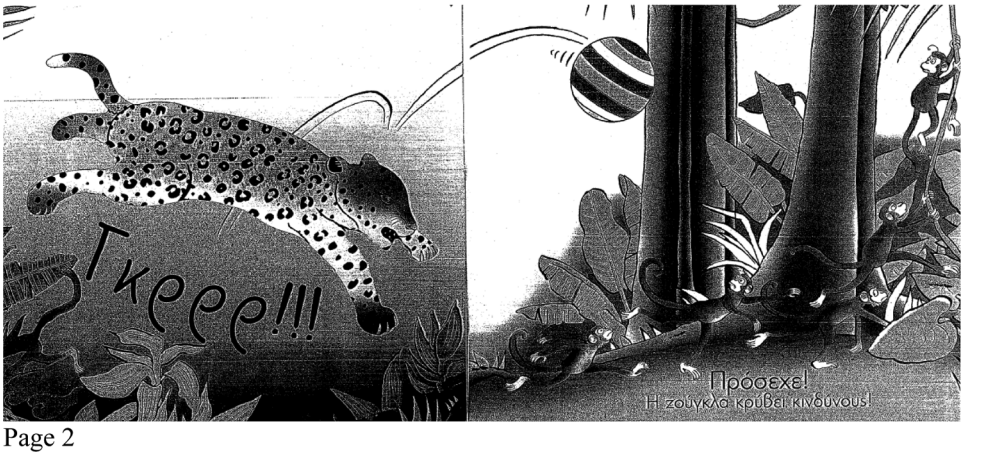
Appendix. The front cover, the French page front, pages 2, 5, 11 and the back cover of the picture book *Six brave little monkeys in the jungle*

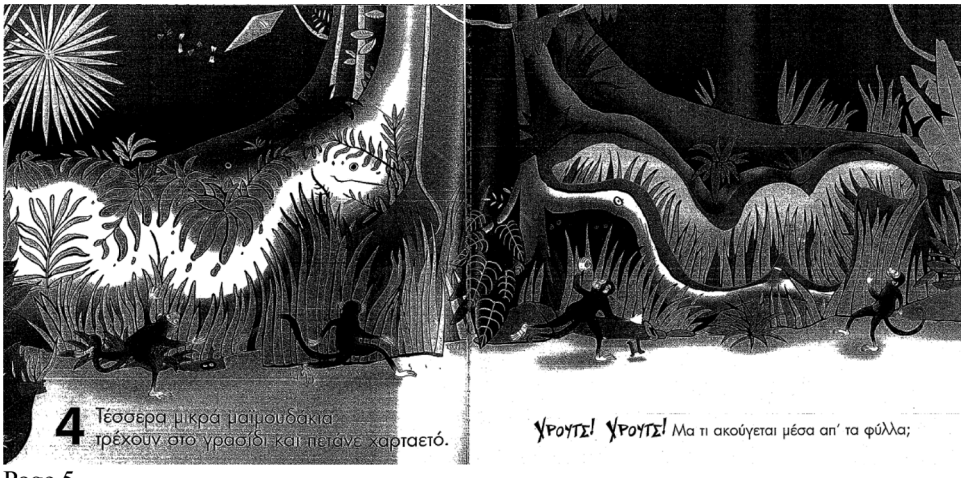


Front cover

French page front

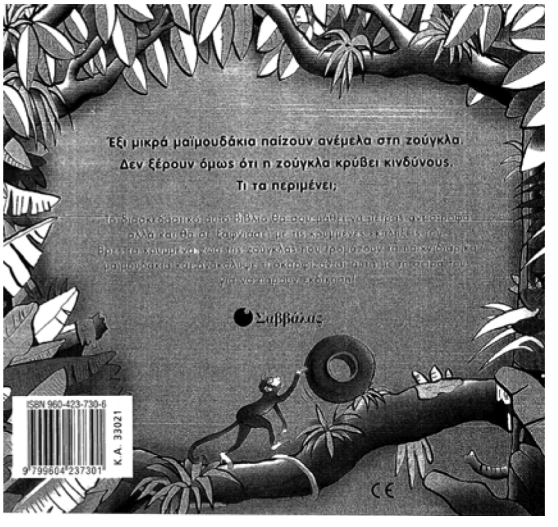


Page 2



Page 5

Page 11



Back cover