LEARNING MATHEMATICS WITH PICTURE BOOKS

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This paper describes a field experiment with a pretest-posttest-control group design in which the potential of reading picture books to children for supporting their mathematical understanding was investigated. The study involved 384 children from eighteen kindergarten classes in eighteen schools in the Netherlands. Data analyses revealed that the experimental group showed a significantly larger increase than the control group in their mathematics performance in a project test containing items on a variety of mathematical topics including arithmetic, measurement, and geometry.

PICTURE BOOKS IN MATHEMATICS EDUCATION IN KINDERGARTEN

One way of supporting children's mathematical understanding is making use of children's literature. This approach has become increasingly popular in recent years (Haury, 2001). Even though activities such as reading picture books might not seem very suitable for teaching mathematics, stories narrated in books may contain mathematics, and as such can offer children opportunities to face mathematics (Anderson, Anderson, & Shapiro, 2005). A very important reason why reading picture books to children may help them in learning mathematics has to do with the meaningful context of the stories included in picture books (e.g., Columba, Kim, & Moe, 2005). Research suggests that learning within a story context increases the retention and recall of the learned knowledge (e.g., Mishra, 2003).

Earlier studies about effect of using picture books on mathematics achievement

Several studies have been carried out that investigated the effect of reading picture books on young children's learning of mathematics. In a study by Hong (1996), kindergartners in Korea with highly educated parents were involved. In this study, the intervention was based on mathematics-related storybook reading and play with mathematical materials that were associated with the content of the storybook. Children who received this intervention exhibited a more positive disposition towards mathematics and significantly greater performance in task about classification, number combination and shapes, than children of the control group.

Young-Loveridge (2004) investigated the use of a program including number books and games. She examined the immediate effect of this program as well as its endurance on the improvement in the numeracy of 5-year-old children. The findings of the study showed that the program was highly effective in enhancing the numeracy learning of young children immediately after the intervention. Moreover, although later the performances decreased, children who participated in the intervention still performed significantly better than children who were not involved.

Furthermore, the findings of a study by Casey, Erkut, Ceder, & Mercer Young (2008), which included storytelling instead of story book reading, gave evidence for the advantages of using a storytelling context as a means for improving early geometry learning in children.

A common characteristic of all aforementioned studies is that the book reading or storytelling sessions in class were always combined with other activities such as playing with story-related (mathematical) materials (Hong, 1996; Young-Loveridge, 2004), singing mathematical rhymes (Young-Loveridge, 2004) or composing geometrical puzzles (Casey et al., 2008).

The present study

The present study is meant to gain more knowledge about the effect of the book reading itself, i.e., without inclusion of additional (book-related) mathematical activities. The study was carried out in the Netherlands and was part of the PICO-ma project (PIcture books and COncept development MAthematics).

Our research question was: *Can an intervention involving picture book reading contribute to children's mathematics performance?* Based on earlier research, our prediction was that kindergartners' performance in a mathematics test would increase due to the picture book reading program, i.e., we hypothesized a positive intervention effect.

METHOD

To investigate the effect of reading picture books on young children's mathematics performance, a field experiment was carried out in kindergarten classes based on a pretest-posttest-control-group design with a three-month picture book reading program as an intervention in which each week two books were read in class to the children.

Participants

Our sample was based on a stratified sampling procedure resulting in pairs of schools that were approximately similar regarding urbanization level, school size and average SES of their children. The schools in each pair were assigned randomly to the experimental group or the control group. In total we had 384 four- to-six-year-old kindergartners participating in our study: 199 in the experimental group and 185 in the control group. Both groups were quite similar. They had about the same average class size, proportions of children in Kindergarten year 1 and Kindergarten year 2, proportions of girls and boys, of children with non-Dutch and Dutch home language, and also the children's age did not differ between the experimental and the control group. The same is true for the children's mathematics and language abilities as measured by the Cito mathematics test and the Cito language test before the intervention took place.

The used picture books and reading guidelines

The reading program used in the intervention consisted of 24 trade books of high literary quality which have mathematics-related content. Yet, the authors did not

include this content purposely to teach children mathematics. To cover a rich variety of mathematical domains, we chose picture books dealing with arithmetic, measurement, or geometry. Within these domains we focused respectively on numbers and number relations, growth and perspective. Altogether, eight books were selected within each domain on the basis of their learning-supportive characteristics (Van den Heuvel-Panhuizen & Elia, 2012).

For each book a reading guideline was developed that explains how to read the book. In general, the reading guidelines requested the teachers to maintain a reserved attitude and not to take each aspect of the story as a starting point for a class discussion, since lengthy or frequent intermissions could break the flow of being in the story and consequently diminish the book's own power to contribute to the mathematical development of the children. To promote the children's mathematical thinking the teachers were suggested to show behavior such as (1) asking oneself a question out loud about the mathematics, (2) playing dumb, or (3) just showing an inquiring expression at a certain page of a book.

Figure 1: Page 4 of the book *Feodoor has seven sisters*[1]

Figure 1 shows page 4 from the book *Feodoor heeft zeven zussen* [Feodoor has seven sisters] (Huiberts & Posthuma (illustrator), 2006), which is about a man who has seven sisters. The text on page 3, which is left to page 4, says: "At night before he goes to sleep, he doesn't get just one kiss. No, his seven sisters give him, altogether twenty-one kisses. Fourteen arms around him, and he is wrapped up well from head to foot. Then, he is read six stories and one poem. Finally, seven fingers reach for the light-switch."

The reading guideline says the teacher to stop after "altogether twenty-one kisses" and to show an inquiring expression by raising her eyebrows. In one of the classes this led to the following classroom conversation.

All children: [All children react together; look at each other; reactions are mumbled.]

Teacher: Twenty-one kisses!

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[1] ©(2006): Gottmer Publishing, Huiberts, M., & Posthuma, S. This material has been copied with permission of the publisher. Resale or further copying of this material is strictly prohibited.

E:	[Starts counting while tapping her cheek] 3, 4, 5
Y:	On two sides
All children:	[All children react to what Y says; only the word 'two' can be made out]
M:	[Says something inaudible to the teacher]
Y:	.... plus 13?
Teacher:	No, he received twenty-one kisses, and you just said [she looks at Y] he gets a kiss on each side from every sister, right [teacher points at the first sister in the picture in the book] because you were already starting to count. You said 2...
All children:	[The teacher points at the second sister] 4
All children:	[The teacher points at the third sister] 6
All children:	[The teacher points at the fourth sister] 8
All children:	[The teacher points at the fifth sister] 10
All children:	[The teacher points at the sixth sister] 12
All children:	[The teacher points at the seventh sister; children hesitate]
Y:	[Starts, doesn't finish the word] Thir...
Teacher:	F...
All children:	14
Teacher:	Fourteen, but then it's not right. They say twenty-one kisses.
E:	Okay, then it's here, here and here [points at her own face to show where the kisses are placed; one on the left cheek, one on the right cheek, and one on the forehead.]

Then, the teacher invited all children to check whether this is correct by giving Feodoor the kisses as child E suggested. Indeed, then they ended up with twenty-one kisses. All children shouted that Feodoor got three kisses from each of his sisters. This is quite an achievement for a group of kindergartners who have not yet been taught multiplication or division.

The PICO test

To investigate the effect of the picture book reading program we developed the so-called PICO test consisting of multiple-choice items for the domains of arithmetic (including the topics number and number relations), measurement (with the topic of length with emphasis on growth), and geometry (addressing the topic of perspective). Every item covers one page and contains an illustration depicting a situation and four small illustrations that represent the possible answers. After the test instruction of an item was read aloud to them, the children had to answer it by underlining the correct answer. Figure 2 shows two items for the domain of arithmetic.

The PICO test was administered as a pretest before the intervention took place and as a posttest afterwards. At the same time points the PICO test was also administered in the control classes. At the start of the project, the teachers of these classes were not

informed about the aim of the study. The teachers were just told that a test would be administered at two time points to gain information about how kindergarten's understanding of mathematics grows over a three-month period in normal school practice.
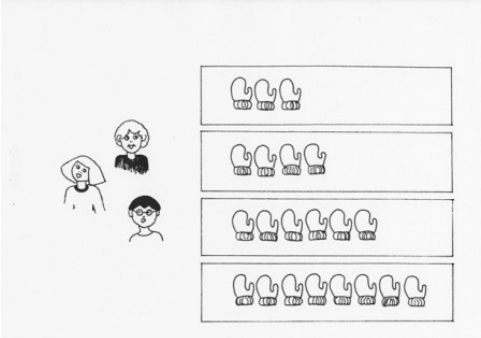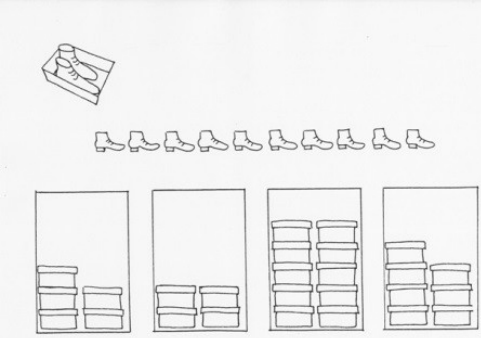
Mittens	Shoe boxes
Test instruction: These children have cold hands. They all like to put on the warm mittens. Underline the amount of mittens they need in total.	Test instruction: Two shoes fit into one box. How many boxes are needed for the other shoes? Underline the number of boxes you need for the other shoes.

Figure 2: Two PICO test items

The initial version of the test consisted of 42 items. After calculating the item discrimination based on the pretest data, we removed two items which had negative item discriminations. This led to a test with 40 items in total that all have a positive correlation with the total score. The calculation of the Cronbach's alpha of this final version of the test resulted in a sufficient reliability of $\alpha = .79$ for the whole sample, and $\alpha = .71$ for the sample of K1 children as well as for the sample of K2 children. Furthermore, within the experimental and the control group, we found correlations between the PICO pretest and posttest score ranging from .62 to .83, indicating a high test stability.

To further investigate the properties of the items in the PICO test, we conducted a confirmatory factor analysis at the item level (using WLSMV estimation implemented in Mplus; Muthén & Muthén, 2007) with the three mathematical topics number and number relations, growth, and perspective as dimensions. Due to very large correlations between these dimensions, we treated the test as essentially one-dimensional. Coherent with these findings, a one-dimensional factor analysis resulted in an almost equally well-fitting model (CFI = .96, TLI = .97, RMSEA = .02). Therefore, we used the total score of the PICO test for analyzing the intervention effect.

Statistical analysis

We investigated the intervention effect by using two linear regression models, namely One-Way ANCOVA models. In Model 1, we used the PICO posttest score as a dependent variable and as independent variables the experimental group (as a dummy variable) and the PICO pretest score (as a covariate). In Model 2, further covariates

were added, including kindergarten year, age, gender, home language, SES, and Cito mathematics and Cito language.

Despite the nested structure of the data – children belonging to classes which belong to schools – we applied a single-level linear regression model, because our unit of inference was at the level of children. Moreover, our clustered sampling procedure in which matched pairs of schools were randomly assigned to either the experimental or the control group decreased the standard errors of the parameters of interest. Yet, to be sure about using a single-level linear regression model, we calculated the residual intra-class correlation of the PICO posttest score controlling for the pretest score by means of a multilevel random intercept model in lme4 (Bates et al., 2013). It turned out that the residual intra-class correlation was .025. This finding supported the conclusion that ignoring the multilevel structure in our analyses did not lead to notable underestimation of standard errors (Hox, 2010).

RESULTS

In Table 1 the descriptives are presented of the PICO test total scores in the pretest and posttest for the whole sample and specified for the experimental and control group, and for the two kindergarten years. For the PICO pretest score no differences between experimental and control group were found. For the PICO posttest score the experimental group scored slightly, but not significantly higher than the control group.

Kindergarten year	Group	N	Pretest score (total items: 40; max. score: 40)				Posttest score (total items: 40; max. score: 40)			
			M	*SD*	*d*	*p*	*M*	*SD*	*d*	*p*
K1	Experimental	84	14.0	5.5	.08	.59	18.2	6.0	.25	.11
	Control	66	13.6	4.0			16.9	4.5		
K2	Experimental	115	20.2	4.8	.02	.92	24.6	5.3	.19	.17
	Control	119	20.1	5.1			23.6	5.4		
K1 + K2	Experimental	199	17.5	6.0	-.03	.74	21.9	6.4	.11	.26
	Control	185	17.7	5.7			21.2	6.0		
Total sample		384	17.6	5.8			21.6	6.2		

Table 1: Descriptives for PICO pretest and posttest

Table 2 shows the results of the two regression models we used for investigating the intervention effect on the PICO posttest score. Both models gave comparable results. Model 1, in which we had only the PICO pretest score as a covariate, revealed a significant intervention effect ($B = .90$, $p = .01$), while Model 2, in which we controlled for seven additional covariates, resulted in a similar intervention effect ($B = .76$, $p = .02$). In this model, pretest, home language and Cito mathematics did have a significant influence on the PICO posttest score. Due to space limitations further analyses of the intervention effects in subgroups and the differential intervention effects between subgroups cannot be discussed here.

	Model 1					Model 2			
	B^a	SE	p	β		B^a	SE	p	β
Intervention	.90	.36	.01	.01	Intervention	.76	.37	.02	.06
PICO pretest [b]	.89	.03	.00	.84	PICO pretest [b]	.69	.05	.00	.64
					Kindergarten year (K2)[c]	.32	.67	.64	.02
					Age	.05	.04	.22	.06
					Gender (girl)	-.10	.35	.79	-.01
					Home language (Dutch)	1.22	.60	.04	.07
					SES (medium/high)	.20	.80	.80	.01
					Cito mathematics	.07	.02	.00	.16
					Cito language	.02	.03	.44	.05
R² (Explained variance)	.70					.73			

B: unstandardized regression coefficient of the intervention effect; *SE*: standard error of *B*; *β*: standardized regression coefficient.

[a] Because we expected a positive influence of the picture book reading program the *B* value for the intervention effect was tested in a one-tailed way.

[b] Because the covariates were only treated as control variables, the significance of the *B* value was tested in a two-tailed way.

[c] For the categorical covariates the dummy variables are placed in parentheses.

Table 2: Intervention effect on PICO posttest score

When calculating the effect size *d* by dividing the B-values by the standard deviation of the PICO pretest scores, we found for Model 1 *d* = .16 (*B* = .90 divided by 5.8) and for Model 2 *d* = .13 (*B* = .76 divided by 5.8). Comparing these effect sizes with the effect size of the change from pretest to posttest in the control group (gain score: *M* = 3.5, *SD* = 3.5, *d* = .60, *p* = .00), we found that the influence of the intervention was substantial. In Model 1, the change in the experimental group was 27% (.16/.60 = .27) larger than the change in the control group and in Model 2, the change was 22% (.13/.60 = .22) larger.

CONCLUDING REMARKS

Our study showed that a three-month picture book reading program with picture books containing mathematics-related content, had a positive effect on kindergartners' mathematics performance as measured by the PICO test. Moreover, these positive results were found based on picture book reading without additional mathematical activities. In fact, this gain from a short program is quite a lot taking into account the spurt in cognitive growth children generally make at this age, which is clearly shown by the increase in performance of the children in the control group, and which is also emphasized by other authors (e.g., Bowman, Donovan, & Burns, 2000). In sum, we can conclude that our study provided evidence for giving picture book reading a significant place in the kindergarten curriculum for supporting children's mathematical development.

However, this evidence should be considered with prudence. The participation of schools and teachers was on a voluntary basis which might have caused that only

motivated teachers were involved in the study. Another shortcoming of the study was that despite of classroom visits and teachers' logs we could not completely control the implementation of the picture book program and also not what the teachers did as regular mathematics-related activities. Therefore, we cannot be absolutely sure that the picture book reading program as intended was responsible for the effect. Further research should go more in detail at the micro-level of the classroom conversations during the book reading sessions. This would also provide opportunities to identify the specific effective elements of picture book reading that contribute to the mathematical understanding of kindergartners.

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