Journal of Cognition and Development

ISSN: 1524-8372 (Print) 1532-7647 (Online) Journal homepage: http://www.tandfonline.com/loi/hjcd20

Do objects of different weight fall at the same time? Updating naive beliefs about free-falling objects from fictional and informational books in young children

Vaunam P. Venkadasalam & Patricia A. Ganea

To cite this article: Vaunam P. Venkadasalam & Patricia A. Ganea (2018) Do objects of different weight fall at the same time? Updating naive beliefs about free-falling objects from fictional and informational books in young children, Journal of Cognition and Development, 19:2, 165-181, DOI: 10.1080/15248372.2018.1436058

To link to this article: https://doi.org/10.1080/15248372.2018.1436058

JOURNAL OF COGNITION AND DEVELOPMENT
2018, VOL. 19, NO. 2, 165–181
https://doi.org/10.1080/15248372.2018.1436058

Routledge
Taylor & Francis Group

Check for updates

Do objects of different weight fall at the same time? Updating naive beliefs about free-falling objects from fictional and informational books in young children

Vaunam P. Venkadasalam and Patricia A. Ganea

Department of Applied Psychology and Human Development, University of Toronto, Canada

ABSTRACT

This study examined whether children 4- and 5-years-old (N = 156) can revise a physical science misconception from different types of picture books. A realistic fiction book and informational book with identical images matched in word count and reading difficulty level were compared to a control book about plants. In the pretest and posttest, children were asked to make predictions about pairs of objects that either had the same or different weight. The pretest scores showed that many children began with the misconception that heavier objects fall faster than lighter objects. Posttest scores revealed that children revised this misconception after reading the realistic fiction and informational picture books but not after reading the control book. These findings provide evidence that children as young as age 4 can acquire physical science knowledge from picture books and that both realistic fiction and informational books can be used effectively to expose children to science concepts.

Misconceptions in the domain of physical science are beliefs that produce systematic patterns of error, which develop prior to teaching or from instruction (Vosniadou, 2013). Robust physical science misconceptions can persist into adolescence and can be frequently observed in adults (Kavanagh & Sneider, 2007; Pine, Messer, & St. John, 2001; Stein, Larrabee, & Barman, 2008). Given their persistence, it is essential for the educational curriculum to target misconceptions at a young age. Early science education promotes positive attitudes and enjoyment, and most importantly, it leads to a better understanding of science concepts during elementary school (Eshach & Fried, 2005; Morgan, Farkas, Hillemeier, & Maczuga, 2016). However, teaching science is a difficult task because children's naive theories mediate their ability to learn correct concepts (Pine et al., 2001). Although teachers are aware of the importance of tackling students' preconceptions prior to instruction (Morrison & Lederman, 2003; Pine et al., 2001), these misconceptions are not always addressed beforehand (Kambouri, 2016). Picture books are resources that teachers can utilize to address common science misconceptions. In this study, we investigated whether young children's misconception about falling objects could be revised using picture books.

CONTACT Patricia A. Ganea patricia.ganea@utoronto.ca Department of Applied Psychology and Human Development, University of Toronto, 252 Bloor Street West, Toronto, ON M5S 1V6, Canada.

Supplemental data for this article can be accessed here.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/HJCD.

Knowledge about free-falling objects

Research has shown that soon after birth, infants have developed intuitions about the physical world (Baillargeon, 2002). For instance, 4.5-month-olds look surprised when an object is suspended in midair, indicating that they expect unsupported objects to fall (Needham & Baillargeon, 1993). However, this observation does not mean that infants already have a concept of gravity, but rather, it means that they can reason about objects' physical relations based on their prior experience. Perceptual experiences in the 1st year of life gradually shape early physical intuitions and create rules that can be used to explain physical phenomena (Baillargeon, 2002; Hespos & vanMarle, 2012). The gravity error is an example of a naive theory shaped by experience. For example, children younger than 3 years of age search for a ball directly below the tube from which it drops, regardless of the tube's trajectory (Hood, 1995). This finding indicates that although children as young as 4.5 months are sensitive to the natural motion of objects, even 3-year-olds, children do not have a full understanding of how gravity affects objects' motion. A series of experiments by Kim and Spelke (1999) showed that knowledge of gravity develops slowly during early childhood and does not emerge until after age 3. Children in North America do not receive formal training about gravity until third grade (Next Generation Science Standards Lead States, 2013; Ontario Ministry of Education, 2007), which means that children's concept of free fall is based on their informal experiences with free-falling objects and their intuitive understanding, which may contain misconceptions.

A common misconception about free fall is that heavier objects always fall faster than lighter objects. This belief is held by individuals of a variety of ages (Hast, 2014; Kavanagh & Sneider, 2007) and is rated by teachers as one of the most difficult beliefs to overcome (Pine et al., 2001). Hast and Howe (2012) interviewed 144 children aged 5 to 11 years old about their common-sense theories of motion and speed. With respect to free fall, children associated faster motion with heavier objects across all age levels. Weight accounted for almost all justifications of vertical motion compared with a quarter of justifications for horizontal motion and even fewer justifications for incline motion. Given the prevalence of this misconception, it is important to consider ways in which we can address it. In this study, we designed age-appropriate picture books of different genres to determine whether preschool and kindergarten children could learn that gravity affects heavy and light objects similarly.

Teaching science concepts with picture books

One reason why misconceptions are difficult to overcome is that people often tend to discount negative evidence for their beliefs and are influenced by a confirmation bias (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). Research has shown that students have difficulty making correct observations when data are anomalous with their own beliefs (Chinn & Malhotra, 2002). When engaging in experimentation and watching demonstrations, students tend to focus on aspects that support their existing belief system (Pine et al., 2001). Using educational materials that will help children attend to gaps in their own knowledge and provide them with an accessible alternative theoretical framework has the potential to lead to conceptual change in the face of existing misconceptions

(Weisman & Markman, 2017). In this study, we focused on the use of picture books as a medium to achieve this goal.

Science books can present children with alternative and detailed conceptual information, which may not be available through direct observation or other forms of interaction (Pringle & Lamme, 2005). Picture books have been used successfully in previous empirical studies to teach young children science concepts, particularly in the domain of biology. There is evidence that young children learn and transfer specific scientific concepts from picture books, such as camouflage as early as 4 years of age (Ganea, Ma, & DeLoache, 2011) and natural selection beginning at 5 years of age (Emmons, Smith, & Kelemen, 2016; Kelemen, Emmons, Seston, Schillaci, & Ganea, 2014). Interventions that used picture books as a medium to communicate conceptually rich explanations about the nutritional benefits of healthy eating led to improved healthy-eating behaviors in children (Gripshover & Markman, 2013). In the current study, our goal was to use picture books to prompt 4- and 5-year-olds to revise a physical misconception by providing them with conceptually rich explanations about what makes objects fall. We selected a physical science misconception for two reasons: thus far, most research on young children's learning of science concepts from picture books has used biological content as the to-be-learned information, and according to teachers' reports, young children have more misconceptions about abstract physical concepts, such as forces and electricity, than about life science topics (Pine et al., 2001). Given the endurance of physical science concepts into adulthood, it is essential to find ways to address them early in development. In addition to using picture books to revise a physical misconception, in this study, we also manipulated the picture book genre by comparing learning from a realistic fiction text and an informational text.

The effect of genres: Narratives and informational books

Research has challenged the common assumption that children gain the ability to understand stories before expository texts (Donovan & Smolkin, 2001; Duke & Kays, 1998; Duke & Tower, 2004; Pappas, 1993). There has been a substantial increase in the publication of nonfiction titles, but only a small portion of these books are intended for children younger than those in Grade 3 (Duke & Tower, 2004). Kindergarten curricula requires the incorporation of both fiction and nonfiction texts into language and science lessons (Common Core State Standards Initiative, 2010; Ontario Ministry of Education, 2007). Despite this requirement, teachers tend to have a negative perception of informational texts (Donovan & Smolkin, 2002) and opt to select hybrid informational-narrative books such as the *Magic School Bus* over informational books (Donovan & Smolkin, 2001). The absence of informational texts has not been limited to reading books (Moss & Newton, 2002) and read-aloud books (Yopp & Yopp, 2006); it extends to classroom activities, displays, and school libraries, especially in lower socioeconomic-status communities (Duke, 2000; Duke, Bennett-Armistead, & Roberts, 2003). As a possible result of these factors, the ability to use and comprehend informational texts is a skill that remains underdeveloped in many children (Duke, 2000; Mantzicopoulos & Patrick, 2011). An effective method of combating these issues may involve exposing children to more nonfiction books. Research has shown nonfiction facilitates critical thinking and research skills crucial for building knowledge and understanding in content-area subjects (Palmer & Stewart, 2005; Pappas, 2006). Therefore, scholars have advocated for the use of nonfiction earlier to overcome this deficit and broaden reading experiences and skills (Donovan & Smolkin, 2001; Duke, 2000; Duke & Kays, 1998; Duke & Tower, 2004; Pappas, 1993).

Few researchers have created comparable texts while examining the effect genre has on learning science concepts (Donovan & Smolkin, 2002; Duke & Billman, 2009). The majority of research so far has included trade books when comparing genres. Trade books can differ in several features such as topic, length, or illustrations. Thus, it is difficult to draw strong conclusions about the effects of book genre. To our knowledge, only two studies have designed similar book pairs to examine whether genre affects science learning. However, these studies with older children produced inconsistent results. In one study, fourth graders recalled and comprehended more science concepts from informational books than narrative books (Cervetti, Bravo, Hiebert, Pearson, & Jaynes, 2009). In contrast, a study with seventh and eighth graders showed that children had greater recall and comprehension of science content after reading scientific discovery narratives compared with expository texts (Arya & Maul, 2012). Given these diverging outcomes, it is difficult to draw definitive conclusions about the effect of genre on science learning in older students.

Current study

In this study, we designed two identical picture books that differed only in the style of the text. Realistic fiction is a type of story that uses a narrative style and describes a situation that could possibly happen (Latrobe, Brodie, & White, 2002). Our realistic fiction depicted three examples of falling objects and an explanation of gravity in a story format that was character-driven. In contrast, informational books convey generic information about a topic and are identifiable by their style (i.e., labels, captions, and headings; Duke & Tower, 2004; Latrobe et al., 2002). The informational book presented the same three examples and explanation of gravity but lacked the conversational style and emphasis on characters.

We extended previous findings by examining learning from picture books when a physical science misconception was present and by asking whether providing correct explanations through two book genres mattered for children's learning. One possibility was that picture books operate similarly to refutation texts. Refutation texts state the misconception, directly refute it, and provide the correct explanation for the concept (McCrudden & Kendeou, 2014; Tippett, 2010). According to the coactivation hypothesis, the presence of these elements leads to cognitive conflict, which promotes conceptual change (McCrudden & Kendeou, 2014). Thus, as long as the books incorporated these steps to some extent and were similarly engaging to children, we expected that both books would be equally effective in promoting children's learning. Support for this hypothesis came from previous research suggesting kindergarteners can learn about informational language and learn from informational books (Duke et al., 2003; Duke & Kays, 1998; Pappas, 1993), and children as young as age 4 years can learn and transfer new biological facts from picture books, irrespective of the type of language format (narrative vs. factual; Ganea et al., 2011).

Method

Participants

One hundred and fifty-six children aged 4 and 5 years old (range = 4;0–5;11; 79 girls, 77 boys) were tested in one of three conditions: realistic fiction (n = 52, M_{age} = 4;11; 27 girls, 25 boys), informational (n = 52, M_{age} = 5;0; 27 girls, 25 boys), and control (n = 52, M_{age} = 5;0; 25 girls, 27 boys). Twenty-six additional children were excluded because they had a perfect score on the pretest (n = 11), failed comprehension questions about the story content (n = 10), had a receptive language score 2 standard deviations below the mean (n = 1), received feedback by dropping the test objects (n = 2), or experienced experimenter error (n = 2).

Participants were recruited either from a database of families who expressed interest in participating in research (n = 74) or at a science museum (n = 82). Children's responses did not differ as a function of location (p = .13) and were grouped in the following analyses. The majority of children were White (52%), and the remaining children were South Asian (11%), Chinese (9%), Black (2%), Filipino (1%), Latin American (1%), Arab (1%), Southeast Asian (1%), or from Mixed Ethnicities (15%). An additional 7% of families did not disclose ethnicity. Almost all parents had earned a high school degree (99%). Most parents completed postsecondary education: bachelor's degree (33%), master's degree (26%), diploma (13%), or doctoral degree (9%). An additional 12% of the sample did not report education.

Materials

Test phase stimuli

We created eight pairs of objects so that four pairs had the same weight and four pairs had different weights. Of the eight pairs of objects, half the pairs were composed of identical objects and half consisted of objects that looked different (nonidentical). There were two pairs of visually identical and two pairs of visually nonidentical objects for both same-weight and different-weight object types. Table 1 displays information about the objects' weight and dimensions. Note that nonidentical objects varied from one another only in their color or pattern, but not in shape or size. The objects were organized into two groups (A and B) that were counterbalanced between test phases (pretest and posttest).

Picture books

The realistic fiction and informational books (both 23 cm × 29 cm when closed) had identical illustrations and were similar in length (14 pages each), word count (419 and 407 words, respectively), and scores on the Flesch-Kincaid Reading Ease test (range = 0–100, with higher scores indicating easier reading; scores of 98 and 92, respectively). See Figure 1 for excerpts from the books (and supplementary materials for complete picture book texts). A graduate student earning a Ph.D. in engineering read the experimental books for scientific accuracy. The control book (23 cm × 29 cm) was adapted from the children's book *Plants Feed Me* by Lizzy Rockwell (2014). The control book was similar to the experimental books in length (14 pages), word count (416 words), and the Flesch-Kincaid Reading Ease test (93).

Table 1. Weight and dimensions of objects used in the pretest and posttest.

Object Pairs	Group A Object Weight and Dimensions		Group B Object Weight and Dimensions	
Identical Same Weight	0.5 g 3.50 cm diameter × 11.40 cm		1.2 g 6.00 cm diameter	
Nonidentical Different Weight	1.2 g and 5.5 g 3.60 cm diameter × 16.7 cm		1.4 g and 8.9 g 6.00 cm × 6.00 cm × 9.00 cm	
Nonidentical Same Weight	0.8 g 7.00 cm × 7.00 cm × 4.50 cm		1.2 g 6.50 cm diameter × 11.0 cm	
Identical Different Weight	1.8 g and 9.4 g 6.30 cm diameter × 10.1 cm		1.0 g and 4.9 g 4.50 cm diameter × 8.60 cm	

Procedure

There were four phases in this study: a weight test, pretest, picture book reading, and a posttest. The entire session was video-recorded, lasted approximately 20 min to 30 min, and was conducted by the same experimenter. Children were randomly assigned to one of three book conditions: realistic fiction, informational, or control.

Weight-test phase

To ensure that children had a fundamental concept of weight, they were asked to compare the weights of two object pairs. One pair had identical weights, and the other pair had different weights. Children were asked, “Do these objects have the same weight or different weight?” followed by, “How do you know?” Children who correctly answered proceeded directly to the next phase. Children who used color or material to distinguish objects (n = 102) were taught to use weight instead. The experimenter taught children to use the distinction of heavier and lighter to compare weight by asking, “Which object is

Realistic fiction text	Informational text
Luke and Alice climbed to the top of the jungle gym. “I wonder what happens if you drop two things at the exact same time?” Alice asked. Luke said, “Our buckets are the same size. But my bucket is full of toys and your bucket’s empty. I think my bucket’s going to reach the ground first. “No way!”Alice exclaimed.	What happens if you drop two things at the exact same time? Let’s find out how two different objects fall when they are dropped together. First, look at these buckets.These two buckets are the same size. But one bucket is full of toys and the other bucket is empty.

Figure 1. Excerpt from the realistic fiction and informational picture books.

heavier? Which is lighter? When one object is heavier than another, we say that the objects have different weights.” Then children were again asked to compare the object pairs. After the training, all children demonstrated an understanding of weight and continued to the pretest.

Pretest phase

Participants were given one of the four pairs of objects to inspect. To avoid differences in response patterns within the sample, the pairs were presented in the same order to each participant (identical same weight, nonidentical different weight, nonidentical same weight, and identical different weight). If children were asked about different weight objects first, they would likely score higher than the children who received the same weight objects first because the comparison of weight could provide insight into the task. For each pair, children were asked about the size (“Do you think these objects have the same size?”) and weight (“Do you think these objects have the same weight?”). When children said that the objects had different weight, they were asked, “Which one is heavier?” The order of the size and weight questions was counterbalanced across the test phases, and no feedback was given to the children regardless of accuracy. Children were at ceiling in assessing whether the objects were equal in size (88.8%), in assessing whether they had the same or different weights (97.3%), and in identifying the heavier object (98.9%). Because only a small minority of children answered incorrectly, none of them were excluded. Finally, children were asked the test question, adapted from Hast (2012): "If you hold the objects out like this and let them drop, do you think one of the two will fall faster, or do you think they will both fall at the same time?" The sequence of the question was counterbalanced so that half the time, children heard "both fall at the same time" first followed by "one of the two will fall faster," and vice versa. Children received neutral feedback ("Thank you") after answering the test question. If children answered all four test questions correctly at pretest, they were excluded from the study (n = 11).

Picture book reading

The experimenter read one of the three books to each child. Children were asked five open-ended comprehension questions following the reading of the realistic fiction or informational books (Appendix). Six children from the informational condition and four from the narrative condition were excluded because they scored less than 3 out of 5 on the comprehension questions. The small number of exclusions indicated that children paid attention to both picture book genres. The experimenter read each book twice to all children except one child. This child declined to reread the book but passed the comprehension questions and was included in the analysis. Following the comprehension questions, children's enjoyment of the book was assessed. Children were asked, "How much did you like the book?" and "How much would you like to read the book again?" For each question, children selected a response from a 5-point scale (a lot, a little, cannot decide, not really, or not at all). We averaged the two responses to create a composite book enjoyment variable ranging from 0 to 5.

Posttest phase

The posttest was identical to the pretest but employed the remaining group of objects not used at pretest. In this study, learning was measured as the ability to transfer information from picture books to actual pairs of objects. To keep task demands age-appropriate, we relied on children's ability to generalize their understanding to similar situations rather than relying on their ability to recall or verbalize what they learned.

Receptive language

The National Institutes of Health Toolbox Picture Vocabulary Test (TPVT) is a computer-adaptive, standardized measure of receptive language. The TPVT controlled for language ability to ensure that children's receptive language fell within the age-appropriate range, suggesting that they would be unlikely to encounter difficulties in understanding the language used in the picture books. One child scored 70 (2 standard deviations below the mean of 100), which is in a range that indicated significant language impairments (Slotkin et al., 2012). This child was excluded from the analysis. Four children did not complete the TPVT but demonstrated an adequate understanding of English as measured by correct answers to the comprehension questions and through parental reports indicating no language problems.

Coding and reliability

Children's responses were coded as either 0 (one object will fall faster) or 1 (both objects will fall at the same time). The four test questions were split into two categories: responses to same- and different-weight objects. Scores ranged from 0 to 2 for both same- and different-weight objects for each test phase (pretest and posttest). If children had the misconception that heavier objects fall faster than light objects, there should have been two distinct response patterns: Children should have predicted that the pairs of same-weight objects would fall at the same rate but the pairs of different weight objects would fall at different rates. Two research assistants coded 96% of the children's responses from video. The coders were blind to the hypotheses of the study. Due to the nature of the data, the coders were not blind to the condition or test phase but were instructed to only watch the beginning and end of the videos. There was high interrater reliability determined by Cohen's $\kappa = .98$, $p < .001$, a 98.10% agreement rate. The coders resolved two disagreements through discussion. Seven videos were not recorded successfully, and in this case, the live coding of children's responses was used. There was a high interrater reliability overall between the live coder and research assistants determined by Fleiss' $\kappa = .96$, $p < .001$, a 97.39% agreement rate.

Results

First, we examined differences in children's book comprehension scores, rating of book enjoyment, and receptive language scores between picture book conditions. A preliminary independent *t* test analysis revealed book comprehension scores for the realistic fiction book ($M = 3.98$, $SD = 0.76$) were not significantly different from the scores for the informational book ($M = 4.17$, $SD = 0.76$), $t(101) = -1.29$, $p = .20$, $d = 0.25$, 95% CI [−0.49, 0.11]. Similarly, children enjoyed the realistic book ($M = 3.70$, $SD = 1.26$) and informational book ($M = 3.64$, $SD = 1.43$) equally, $t(102) = 0.21$, $p = .83$, $d = 0.05$, 95% CI [−0.47, 0.58]. The Likert ratings out of 5 indicated a high enjoyment of the books. A one-way between-subjects analysis of variance revealed that TPVT scores were similar in the realistic fiction ($M = 107.99$, $SD = 11.08$), informational ($M = 110.61$, $SD = 11.07$), and control ($M = 112.15$, $SD = 10.83$) book conditions, $F(2, 149) = 1.87$, $p = .16$, $\eta 2 = .02$.

Nonparametric tests were used to analyze the test responses because of the ordinal nature of the data. A Kruskal-Wallis *H* test examined pretest scores to determine if any differences existed between picture book conditions at baseline. The pretest scores for same-weight objects were similar across all three picture book conditions, $\chi^2(2) = 1.72$, $p = .42$, with a mean rank pretest score of 82.88 for the realistic fiction condition, 80.12 for the informational condition, and 72.5 for the control condition. Similarly, the pretest scores for different-weight objects were comparable across picture book conditions, χ^2 $(2) = 1.56$, $p = .46$, with a mean rank pretest score of 82.10 for the realistic fiction condition, 79.32 for the informational condition, and 74.09 for the control condition. A Wilcoxon signed-rank test revealed that at pretest children answered more same-weight test questions correctly compared with different-weight test questions across all conditions ($Z = -7.90$, $p < .001$). Children's poorer performance on the different-weight pretest questions indicated that they held the misconception that heavy objects fall faster than light objects. Table 2 displays the proportion of correct responses for same-weight and different-weight objects across the three conditions.

Table 2: The proportion of children's correct responses for the same and different weight pre- and post-test questions as a function of picture book condition.

	Realistic Fiction			Informational			Control		
Test Phase	0/2	1/2	2/2	0/2	1/2	2/2	0/2	1/2	2/2
Same Weight Objects									
Pre-test	17% (9)	33% (17)	50% (26)	10% (5)	50% (26)	40% (21)	27% (14)	33% (17)	40% (21)
Post-test	8% (4)	15% (8)	77% (40)	8% (4)	13% (7)	79% (41)	23% (12)	15% (8)	62% (32)
Different Weight Objects									
Pre-test	73% (38)	15% (8)	12% (6)	75% (39)	21% (11)	4% (2)	83% (43)	12% (6)	6% (3)
Post-test	35% (18)	13% (7)	52% (27)	42% (22)	12% (6)	46% (24)	85% (44)	8% (4)	8% (4)

Notes. The actual number of responses are in parentheses with 52 total responses for each picture book condition per test phase.

Two generalized estimating equation (GEE) analyses with multinomial distributions and cumulative logit-log link functions were conducted to investigate whether children revised the misconception that heavier objects fall faster than lighter objects after the reading of picture books. This type of analysis was selected to accommodate the ordinal nature of the dependent variables and the presence of a within-subject factor (pretest and posttest scores) in the data. Preliminary analyses determined that age (p = .16), gender (p = .16), and receptive language (p = .93) did not predict children's responses, and they were not considered further in the subsequent analyses. The scores for the same- and different-weight objects were analyzed separately. The dependent variables for the first and second GEE analyses were children's responses for same-weight objects and different-weight objects, respectively. The predictors were test phase (pretest and posttest), condition (narrative, informational, and control), and the interaction between test phase and condition. The reference categories were the pretest phase, the control condition, and the interaction between the two.

For same-weight objects, the GEE analysis showed a main effect of test phase, Wald $\chi^2(1) = 5.27$, $p = .02$, $b = 0.72$, $SE = .26$. At the posttest, all children were 2 times more likely to respond correctly compared with the pretest, Exp(B) = 2.05, 95% CI = [1.11, 3.78]. However, there was no main effect of picture book condition. Children were not more likely to answer correctly after reading the realistic fiction (p = .22) or informational (p = .35) books compared with the control book. Similarly, there was no interaction between test phase and condition. From pretest to posttest, children were not more likely to answer more test questions correctly in the realistic fiction (p = .34) or informational (p = .15) book conditions in comparison with the control condition. Learning about how gravity affects same-weight objects was a function of test phase only and not of picture book condition or the interaction term. This finding suggests that children from all three conditions determined that same-weight objects fall at the same rate.

For the critical comparison of different-weight objects, the GEE analysis showed no main effect of test phase (p = .82) or picture book condition (realistic fiction, p = .23; informational, p = .42). However, there was a significant interaction between test phase and picture book condition. From pretest to posttest, children were more likely to answer more test questions correctly after reading the realistic fiction book, Wald $\chi^2(1) = 10.05$, $p = .002$, $b = 1.94$, $SE = .62$, and informational book, Wald $\chi^2(1) = 8.08$, $p = .004$, $b = 1.82$, $SE = .64$, compared with the control book. Children in the realistic fiction book condition,

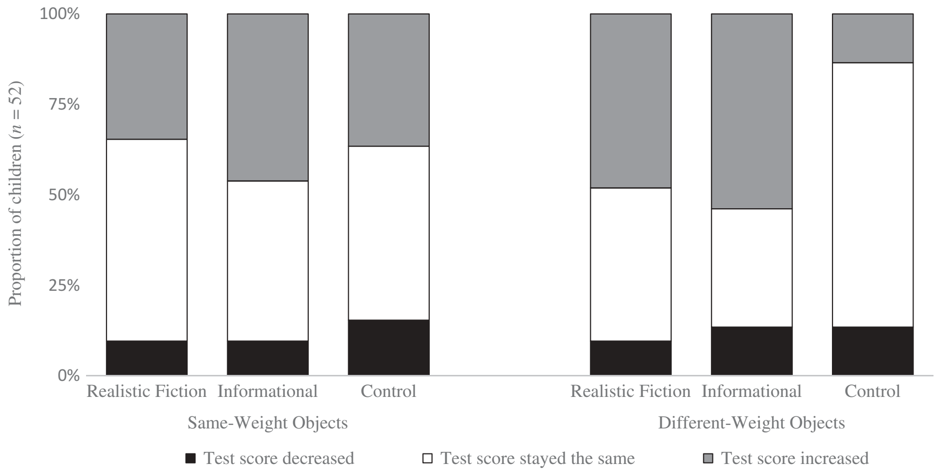

Figure 2. The proportion of children's test scores that decreased, stayed the same, or increased from pretest to posttest contrasting responses for same-weight and different-weight objects.

Exp(B) = 6.95, 95% CI = [2.10, 23.04], and informational book condition, Exp(B) = 6.17, 95% CI = [1.76, 21.61], were approximately 6 times more likely to answer the test questions correctly for the different-weight objects after the picture book intervention in comparison with children in the control book condition. Therefore, only after reading the realistic fiction and informational books did children revise their misconception about how different-weight objects fall. Figure 2 shows the proportion of children's responses that decreased, stayed the same, or increased from pretest to posttest for same- and different-weight objects across the three picture book conditions. For a detailed break down of children's posttest responses as a function of pretest response for the same-weight and different-weight objects for each picture book condition, see the supplementary Table S1. Children's response patterns for the same-weight objects were similar across all three groups. However, with respect to different-weight objects, only children in the experimental conditions answered more questions correctly after the picture book intervention. As expected, children's responses to different-weight objects in the control book condition stayed relatively the same before and after the picture book reading.

Discussion

We examined whether young children can revise a physical science misconception from picture books and whether book genre has an impact on their learning. Kindergarten children were exposed to the concept of free fall with the explanation of gravity in either a realistic fiction book or an informational picture book. A group of children read a control book about plants. At pretest, children in the three picture book conditions had the misconception that heavy objects fall at a faster rate than lighter objects. This finding replicates those of previous studies on the prevalence of this misconception even in older children and adults (Hast, 2014; Hast & Howe, 2012; Kavanagh & Sneider, 2007). In the current study, when children were asked to predict whether different-weight objects would fall at the same rate, their answers from pretest to posttest improved significantly after they were exposed to both a realistic fiction book and an informational book, but not after being exposed to a control book. Approximately half the children in the experimental groups answered both different-weight objects questions correctly compared with children in the control book condition. This finding shows that children as young as 4-years-old can learn about an abstract concept from picture books and that both informational and fictional books can be used effectively to expose young children to accurate conceptual information.

Previous research established that young children are capable of learning life science concepts from picture books (Emmons et al., 2016; Ganea et al., 2011; Gripshover & Markman, 2013; Kelemen et al., 2014). The current findings add to existing research by demonstrating that picture books can also be used to expose young children to knowledge about physical science. This study also provides new evidence regarding the effect of genre. Most research comparing narratives and expository texts has relied on trade books making it difficult to control for potentially confounding factors. The picture books in this study were created with identical illustrations and were matched in content, length, and difficulty. Because both the realistic fiction and informational picture books were effective in addressing this science misconception, these findings suggest that these two book genres are not a determining factor in young children's science learning as long as the book is engaging and provides accurate information.

In this study, we could not establish whether conceptual change occurred because learning was measured once and the books provided children with a subset of a conceptual theory but not the entire category of force. However, children in this study did revise their misconceptions after reading a single book twice. The mechanism of learning from a picture book may be similar to the revision that takes place with refutation texts, which addresses, confronts, and resolves misconceptions (McCrudden & Kendeou, 2014; Tippett, 2010). Both the realistic fiction book (e.g., "I thought heavier things reach the ground before light ones") and informational book (e.g., "Some people think that heavier things reach the ground before light ones") specified the misconception. However, instead of directly refuting the statement, the books had a "let's find out" sentence followed by a final third counterexample and then an explanation about gravity. The picture books in this study did not directly refute the target misconception (by using a "this is not true" statement) and thus would not be considered genuine refutation texts. Nevertheless, it is possible that the coactivation of the target misconception and explanation led to cognitive conflict prompting revision, similar to learning from refutational texts (McCrudden & Kendeou, 2014; Tippett, 2010). Our findings suggest that picture books are an effective means of highlighting erroneous beliefs and providing correct theoretical information to children that can be incorporated into their current beliefs. Over time and combined with other relevant evidence and experiences, conceptual change may occur. Revision of incorrect beliefs is a gradual process, and conceptual change requires prolonged and diverse experiences with the concept in question (Vosniadou, 2013).

The current findings have two broad implications: the importance of early science education and the use of picture books in teaching science. First, this study supports the viewpoint that science concepts should be introduced early in development (Eshach & Fried, 2005). Participating in a science inquiry and literacy intervention increases kindergarteners' motivation toward science, eliminates gender differences, and most importantly increases science competence compared with a typical kindergarten science classroom (Patrick, Mantzicopoulos, & Samarapungavan, 2009). Early science interventions can potentially have longstanding effects on science education. A recent longitudinal study revealed that science knowledge in kindergarten was the strongest predictor of science knowledge in Grade 1, which was the strongest predictor of science achievement from Grade 3 through Grade 8 (Morgan et al., 2016). Because knowledge in kindergarten predicts later achievement, targeting robust misconceptions at an early age facilitates greater learning than teaching without addressing misconceptions (Morrison & Lederman, 2003; Pine et al., 2001; Tippett, 2010), thereby preventing misconceptions from being held with a high degree of confidence and reducing the interference in science learning in later grades. Therefore, early science education is not only essential in fostering science interest during childhood (Patrick et al., 2009) but also for later academic success (Morgan et al., 2016) and career trajectories (DeJarnette, 2012; Mantzicopoulos & Patrick, 2011).

Second, this study illustrates the view that picture books are an effective way to provide children with conceptually rich explanations and, especially in the face of misconceptions, the provision of alternate explanations is beneficial (Gripshover & Markman, 2013; Kelemen et al., 2014). Children have difficulty making correct observations when the evidence conflicts with their own belief system (Chinn & Malhotra, 2002), making some science misconceptions difficult to overcome with hands-on activities alone (Pine et al., 2001). Providing children with a solid and viable alternate conceptual framework will make it more likely that they will achieve the specific conceptual changes that educators seek to promote (Weisman & Markman, 2017). Furthermore, the current findings support the growing body of research that questions the assumption that children learn more from stories compared with expository books. Both 4- and 5-year-olds learned from both a fictional text and an informational text. Despite research showing that exposure to nonfiction books promotes critical thinking and research skills (Palmer & Stewart, 2005; Pappas, 2006), children in primary grades do not receive adequate exposure to different book genres (Duke & Tower, 2004). Thus, it is essential for adults to provide a breadth of genres and evaluate their appropriateness as well as highlight the differences between genres so that children can learn to use all types of genres effectively (Calo, 2011; Duke, 2000). When selecting trade books for educational purposes, realistic illustrations and accurate information are critical characteristics to consider (Pringle & Lamme, 2005; Sackes, Trundle, & Flevares, 2009) because many children's science books contain misconceptions, anthropomorphism, and inaccurate illustrations (Atkinson, Matusevich, & Huber, 2009; Sackes et al., 2009; Smolkin, McTigue, Donovan, & Coleman, 2009).

In this study, children immediately revised their misconceptions about falling objects after being read a picture book. Nevertheless, not all children answered both different-weight test questions correctly, and we did not test children after a delay to assess the robustness of their learning. Future investigation is needed to examine whether the short-term revisions observed in the current study will be retained. Here, learning was defined as the ability to transfer and apply information from a picture book to novel objects. Future studies could also examine how children transfer knowledge to objects with which children are already familiar. Also, to make task demands age-appropriate, children were never asked to recall or explain the concept they learned from the picture book.

Researchers can ask children to verbally explain both their predictions and the concept taught in the picture books. The explanations would provide more insight into children's misconceptions and would determine further ways to design appropriate interventions. Finally, it would be important to investigate whether other genres such as hybrid narrative-informational or fantasy stories affect learning of a physical science concept.

To summarize, this study showed that kindergarteners can correct the misconception that heavy objects fall faster than light objects after a picture book intervention using both realistic fiction and informational books. Both picture book genres were effective in promoting children's learning, indicating that picture books are effective tools in helping young children learn about abstract science concepts. Providing children with a variety of science picture book genres as early as kindergarten may increase their science literacy.

Acknowledgments

We are grateful to the children and parents in the Greater Toronto Area who participated in this research and the Ontario Science Centre for allowing us to conduct part of this study at their location. We thank Shelley He for her lovely picture book illustrations. We also thank Angela Nyhout, Ruth Lee and Begüm Özdemir for helpful feedback on an earlier version of this article.

Funding

This research was supported by an Insight grant from the Social Sciences and Humanities Research Council of Canada (SSHRC 435-2017-0631) and the Early Researcher Award (ER13-09-151)) from the Ontario Ministry of Research, Innovation and Science to P. Ganea.

References

Arya, D. J., & Maul, A. (2012). The role of the scientific discovery narrative in middle school science education: An experimental study. *Journal of Educational Psychology*, *104*, 1022–1032. doi:10.1037/a0028108

Atkinson, T. S., Matusevich, M. N., & Huber, L. (2009). Making science trade book choices for elementary classrooms. *The Reading Teacher*, *62*, 484–497. doi:10.1598/RT.62.6.3

Baillargeon, R. (2002). The acquisition of physical knowledge in infancy: A summary in eight lessons. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 46–83). Malden, MA: Blackwell Publishers Ltd. doi:10.1002/9780470996652.ch3

Calo, K. M. (2011). Incorporating informational texts in the primary grades: A research-based rationale, practical strategies, and two teachers' experiences. *Early Childhood Education Journal*, *39*, 291–295. doi:10.1007/s10643-011-0470-0

Cervetti, G. N., Bravo, M. A., Hiebert, E. H., Pearson, P. D., & Jaynes, C. A. (2009). Text genre and science content: Ease of reading, comprehension, and reader preference. *Reading Psychology*, *30*, 487–511.

Chinn, C. A., & Malhotra, B. A. (2002). Children's responses to anomalous scientific data: How is conceptual change impeded? *Journal of Educational Psychology*, *94*, 327–500. doi:10.1037/0022-0663.94.2.327

Common Core State Standards Initiative. (2010). *Common Core State Standards for English language arts & literacy in history/social studies, science, and technical subjects*. Washington, DC: National Governors Association Center for Best Practices, Council of Chief State School Officers. Retrieved from http://www.corestandards.org/wp-content/uploads/ELA_Standards1.pdf

DeJarnette, N. (2012). America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives. *Education*, *133*(1), 77–84. Retrieved from https://eric.ed.gov/?id=EJ996974

Donovan, C. A., & Smolkin, L. B. (2001). Genre and other factors influencing teachers' book selections for science instruction. *Reading Research Quarterly*, *36*, 412–440. doi:10.1598/RRQ.36.4.4

Donovan, C. A., & Smolkin, L. B. (2002). Considering genre, content, and visual features in the selection of trade books for science instruction. *The Reading Teacher*, *55*, 502–520.

Duke, N. K. (2000). 3.6 minutes per day: The scarcity of informational texts in first grade. *Reading Research Quarterly*, *35*, 202–224. doi:10.1598/RRQ.35.2.1

Duke, N. K., Bennett-Armistead, V. S., & Roberts, E. M. (2003). Bridging the gap between learning to read and reading to learn. In D. M. Barone & L. M. Morrow (Eds.), *Literacy and young children: Research-based practices* (pp. 226–242). New York, NY: Guilford.

Duke, N. K., & Billman, A. (2009). Informational text difficulty for beginning readers. In E. Hiebert & M. Sailors (Eds.), *Finding the right texts: What works for beginning and struggling readers* (pp. 109–128). New York, NY: Guilford.

Duke, N. K., & Kays, J. (1998). 'Can I say "once upon a time"?': Kindergarten children developing knowledge of information book language. *Early Childhood Research Quarterly*, *13*, 295–318. doi:10.1016/S0885-2006(99)80041-6

Duke, N. K., & Tower, C. (2004). Nonfiction texts for young readers. In J. Hoffman & D. Schallert (Eds.), *The texts in elementary classrooms* (pp. 111–128). Mahwah, NJ: Erlbaum.

Emmons, N., Smith, H., & Kelemen, D. (2016). Changing minds with the story of adaptation: Strategies for teaching young children about natural selection. *Early Education and Development*, *27*, 1205–1221. doi:10.1080/10409289.2016.1169823

Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, *14*, 315–336. doi:10.1007/s10956-005-7198-9

Ganea, P. A., Ma, L., & DeLoache, J. S. (2011). Young children's learning and transfer of biological information from picture books to real animals. *Child Development*, *82*, 1421–1433. doi:10.1111/j.1467-8624.2011.01612.x

Gripshover, S. J., & Markman, E. M. (2013). Teaching young children a theory of nutrition: Conceptual change and the potential for increased vegetable consumption. *Psychological Science*, *24*, 1541–1553. doi:10.1177/0956797612474827

Hast, M. (2014). Exploring the shift in children's incline motion predictions: Fragmentation and integration of knowledge as possible contributors. *Journal of Educational and Developmental Psychology*, *4*, 74–81. doi:10.5539/jedp.v4n2p74

Hast, M., & Howe, C. (2012). Understanding the beliefs informing children's commonsense theories of motion: The role of everyday object variables in dynamic event predictions. *Research in Science & Technological Education*, *30*, 3–15. doi:10.1080/02635143.2011.653876

Hespos, S. J., & vanMarle, K. (2012). Physics for infants: Characterizing the origins of knowledge about objects, substances, and number. *Wiley Interdisciplinary Reviews: Cognitive Science*, *3*, 19–27. doi:10.1002/wcs.157

Hood, B. M. (1995). Gravity rules for 2- to 4-year-olds? *Cognitive Development*, *10*, 577–598. doi:10.1016/0885-2014(95)90027-6

Kambouri, M. (2016). Investigating early years teachers' understanding and response to children's preconceptions. *European Early Childhood Education Research Journal*, *24*, 907–927. doi:10.1080/1350293X.2014.970857

Kavanagh, C., & Sneider, C. (2007). Learning about gravity: I. Free fall: A guide for teachers and curriculum developers. *Astronomy Education Review*, *5*(2), 21–52. doi:10.3847/AER2006018

Kelemen, D., Emmons, N. A., Schillaci, R. S., & Ganea, P. A. (2014). Young children can be taught basic natural selection using a picture-storybook intervention. *Psychological Science*, *25*, 893–902. doi:10.1177/0956797613516009

Kim, I. K., & Spelke, E. S. (1999). Perception and understanding of effects of gravity and inertia on object motion. *Developmental Science*, *2*, 339–362. doi:10.1111/1467-7687.00080

Latrobe, K. H., Brodie, C. S., & White, M. (2002). *The children's literature dictionary: Definitions, resources, and learning activities*. New York, NY: Neal-Schuman.

Lewandowsky, S., Ecker, U. K., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and its correction: Continued influence and successful debiasing. *Psychological Science in the Public Interest*, *13*, 106–131. doi:10.1177/1529100612451018

Mantzicopoulos, P., & Patrick, H. (2011). Reading picture books and learning science: Engaging young children with informational text. *Theory Into Practice*, *50*, 269–276. doi:10.1080/00405841.2011.607372

McCrudden, M. T., & Kendeou, P. (2014). Exploring the link between processes and learning from refutational text. *Journal of Research in Reading*, *37*(S1), S116–S140. doi:10.1111/j.1467-9817.2011.01527.x

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher*, *45*, 18–35. doi:10.3102/0013189X16633182

Morrison, J. A., & Lederman, N. G. (2003). Science teachers' diagnosis and understanding of students' preconceptions. *Science Education*, *87*, 849–867. doi:10.1002/(ISSN)1098-237X

Moss, B., & Newton, E. (2002). An examination of the informational text genre in basal readers. *Reading Psychology*, *23*, 1–13. doi:10.1080/027027102317345376

Needham, A., & Baillargeon, R. (1993). Intuitions about support in 4.5-month-old infants. *Cognition*, *47*, 121–148. doi:10.1016/0010-0277(93)90002-D

Next Generation Science Standards Lead States. (2013). *Next Generation Science Standards: For states, by states: Topic arrangements of the Next Generation Science Standards*. Washington, DC: National Academies Press. Retrieved from http://nstahosted.org/pdfs/ngss/20130509/CombinedTopicArrangementBookmarked5.1.13.pdf

Ontario Ministry of Education. (2007). *The Ontario Curriculum, Grades 1–8: Science and Technology*. Retrieved from http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec18currb.pdf

Palmer, R. G., & Stewart, R. A. (2005). Models for using nonfiction in the primary grades. *The Reading Teacher*, *58*, 426–434. doi:10.1598/RT.58.5.2

Pappas, C. C. (1993). Is narrative 'primary'? Some insights from kindergarteners' pretend readings of stories and information books. *Journal of Literacy Research*, *25*, 97–129. doi:10.1080/10862969309547803

Pappas, C. C. (2006). The information book genre: Its role in integrated science literacy research and practice. *Reading Research Quarterly*, *41*, 226–250. doi:10.1598/RRQ.41.2.4

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference? *Journal of Research in Science Teaching*, *46*, 166–191. doi:10.1002/tea.v46:2

Pine, K., Messer, D., & St. John, K. (2001). Children's misconceptions in primary science: A survey of teachers' views. *Research in Science & Technological Education*, *19*, 79–96. doi:10.1080/02635140120046240

Pringle, R. M., Lamme, L. L. (2005). Using picture storybooks to support young children's science learning. *Reading Horizons*, *46*(1). Retrieved from http://scholarworks.wmich.edu/reading_horizons/vol46/iss1/2

Rockwell, L. (2014). *Plants feed me*. New York, NY: Holiday House.

Sackes, M., Trundle, K. C., & Flevares, L. M. (2009). Using children's literature to teach standard-based science concepts in early years. *Early Childhood Education Journal*, *36*, 415–422. doi:10.1007/s10643-009-0304-5

Slotkin, J., Nowinski, C., Hays, R., Beaumont, J., Griffith, J., Magasi, S., … Gershon, R., (2012). NIH Toolbox scoring and interpretation guide [Computer software]. Retrieved from https://nihtoolbox.desk.com/customer/en/portal/articles/2437205-nih-toolbox-scoring-and-interpretation-guide

Smolkin, L. B., McTigue, E. M., Donovan, C. A., & Coleman, J. M. (2009). Explanation in science trade books recommended for use with elementary students. *Science Education*, *93*, 587–610. doi:10.1002/sce.v93:4

Stein, M., Larrabee, T. G., & Barman, C. R. (2008). A study of common beliefs and misconceptions in physical science. *Journal of Elementary Science Education*, *20*(2), 1–11. doi:10.1007/BF03173666
Tippett, C. D. (2010). Refutation text in science education: A review of two decades of research. *International Journal of Science and Mathematics Education*, *8*, 951–970. doi:10.1007/s10763-010-9203-x
Vosniadou, S. (2013). Conceptual change in learning and instruction: The framework theory approach. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (2nd ed., pp. 11–30). New York, NY: Routledge.
Weisman, K., & Markman, E. M. (2017). Theory-based explanation as intervention. *Psychonomic Bulletin & Review*, *24*(5), 1555–1562. doi:10.3758/s13423-016-1207-2
Yopp, R. H., & Yopp, H. K. (2006). Informational texts as read-alouds at school and home. *Journal of Literacy Research*, *38*, 37–51. doi:10.1207/s15548430jlr3801_2

Appendix

Comprehension questions for the realistic fiction and informational book

(1) What was in the bucket that made it heavier?
(2) What was dropped from the top of the playground?
(3) What was put into the shoe to make it heavier?
(4) What was dropped from the jungle gym?
(5) What was dropped from the top of the seesaw?