J Sci Teacher Educ (2013) 24:367–389
DOI 10.1007/s10972-012-9289-9

Teaching Science Through Pictorial Models During Read-Alouds

Alandeom W. Oliveira · Seema Rivera · Rory Glass · Michael Mastroianni · Francine Wizner · Vincent Amodeo

Published online: 4 April 2012

Abstract This study examines how three elementary teachers refer to pictorial models (photographs, drawings, and cartoons) during science read-alouds. While one teacher used realistic photographs for the purpose of visually verifying facts about crystals, another employed analytical diagrams as heuristic tools to help students visualize complex target systems (rainbow formation and human eye functioning). Another teacher used fictional cartoons to engage students in analogical storytelling, communicating animal camouflage as analogous to human "blending in." However, teachers did not always explicitly convey the representational nature of pictorial models (analog and target as separate entities). It is argued that teachers need to become more aware of how they refer to pictorial models in children's science books and how to promote student visual literacy.

Keywords Science read-aloud · Pictorial model · Children's science books · Elementary school · Pictures · Visual literacy

There is growing evidence that science can be effectively taught to students through the use of *pictorial models* (Pozzer and Roth 2003; Watkins et al. 2004). Pictorial models are defined as two dimensional, visual representations such as photographs, drawings, and cartoons with a high degree of similarity in physical appearance to their target concepts or systems (Gilbert and Ireton 2003). Moreover, pictorial models are concrete (made of tangible material), static (mimic unchanged physical attributes rather than dynamic system functioning), and share a certain degree of analogical correspondence in terms of physical resemblance with real objects

A. W. Oliveira (✉) · S. Rivera · R. Glass · M. Mastroianni · F. Wizner · V. Amodeo
Educational Theory and Practice Department, State University of New York, 1400 Washington Ave., ED 113B, Albany, NY 12222, USA
e-mail: aoliveira@albany.edu

(i.e., they look like/are analogous to real objects). As representations, pictorial models help us visualize and make sense of physical reality (Bass et al. 2009).

Pictorial models in science textbooks and trade books have been shown to promote student understanding of science content (Bean et al. 1990); enhance student recall and comprehension of target concepts (Vosinadou and Brewer 1987; Watkins et al. 2004); assist students in forming mental images of intended concepts (Bean et al. 1990); help students recognize and remember scientific information (Watkins et al. 2004); and engage elementary students in science (Ford 2006). Similarly, conceptual cartoons with fictional characters have been employed by teachers to engage children in non-threatening discussions and encourage them to share prior understandings, give opinions, defend positions, and critically analyze alternative perspectives (Cleveland and Fox 2008; Keogh and Naylor 1999).

On the other hand, research also shows that ineffective employment of pictorial models can lead to learning problems. Among problematic pictorial models are ambiguous evolution diagrams (Catley et al. 2010); pictorial models of energy that have a crowded layout, make ambiguous use of arrows, mix symbolic and real entities, combine abstract and naturalistic graphical features, and lack explicit information (Stylianidou et al. 2002); pictorial models of energy that integrate verbal elements (e.g., captions) and visual elements (e.g., arrows, triangles, rectangles vectors, and clip art images) (Ametller and Pinto 2002); pictorial models of the phases of the moon wherein visual illustrations are poorly linked to the written text (e.g., lack clear captions, labeling, and references) (Peacock and Weedon 2002); and, pictorial models of optical phenomena wherein light rays are unclearly represented by arrows (Colin et al. 2002). These studies underscore the potential for misunderstanding and confusion in picture-based science learning.

These findings suggest that further research is needed to guide the use of pictorial models as communicative tools for teaching science. Previous research has been conducted primarily at the middle- and high-school levels, leading to a dearth in knowledge on the precise pedagogical role of pictorial models in elementary science instruction. The present paper attends to this issue by examining elementary teachers' oral employment of pictorial models as communicative devices in the context of science read-alouds. Our research question is: How do elementary teachers teach science through pictorial models while reading children's science books aloud?

Theoretical Framework

Informed by previous theoretical work in the field of linguistics, we conceive of science read-alouds as referential speech events (Silverstein 1995, 2004). Central to this theoretical stance is the notion that science read-alouds encompass *pictorial reference*, a mode of signification or meaning-making wherein teachers and students resort to oral language mainly for the communicative purpose of referring to pictorially represented states of affairs in the physical world (i.e., to make pictorial references to physically absent objects or events). References to these publicly accessible pictorial models provides teachers and students with a shared cognitive space for interpretive work, enabling them to engage in shared cognition, articulate personal insight, and jointly construct conceptual knowledge.

As shown on Fig. 1, when teachers and students participate in science read-alouds, they usually make explicit references to pictorial models (symbolized by solid arrows) that implicitly represent or stand for a physically absent target or analog (symbolized by dotted arrow). Further, verbal reference can be made either to the pictorial model itself (e.g., "Here is the picture of a tree [point to the picture]") or to its target (e.g., "Here is a tree [pointing to the picture]"). In the former reference, a clear and explicit distinction is made between two entities in a representational relationship—a "picture" (the representing object or model) is clearly marked as a representation of a "tree" (the represented object or target). By contrast, in the second referential form, the representing and represented objects appear to merge together as if a reference was being made to an actual tree instead of its pictorial representation (the former replaces the latter). This second form is consistent with a *metonymy* (word substitution wherein an object, being or idea is referred to not by its actual name but by the naming of something near or closely related), a speech figure commonly used by elementary teachers to foster student engagement in science inquiry discussions (Oliveira 2010). These alternative referential forms are examined in this study in the context of science read-alouds.

Literature Review

This study is informed by previous research in model-based science teaching (drawn mainly from the field of science education) and read-alouds (primarily from language education).

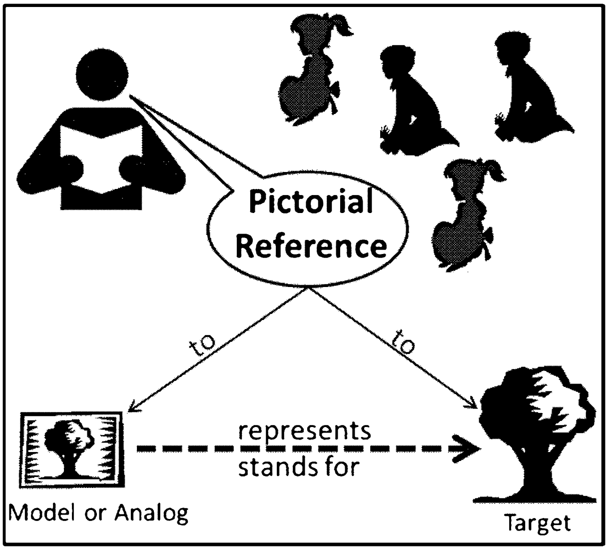


Fig. 1 Pictorial reference in read-alouds

Pictorial Reference as Scientific Modeling

Previous research on model-based approaches to science instruction emphasizes that scientific models can serve as effective tools for building conceptual bridges between the familiar and the unknown (Glynn 2008), teaching science meaningfully (Watkins et al. 2004), making present what is absent (Latour 1986), guiding and communicating with students, simplifying and explaining complex scientific phenomena, making scientific thinking accessible to students, making and testing predictions, and clarifying and illustrating scientific concepts (Gilbert and Ireton 2003). Also highlighted in this literature is that students need time in class to verbalize and discuss the models they are engaging with (Grosslight et al. 1991). When teaching through modeling, teachers must be explicit about what features they are explicating and in what ways the analog or model fails to represent the actual item or target (Gilbert and Ireton 2003; Harrison and Coll 2008); where the model breaks down (Glynn 2008). This systematic process of making important (un)shared aspects or attributes salient is referred to as mapping the analog to the target, and is critical if we are to avoid the creation of misconceptions (Harrison and Coll 2008).

It should be noted that these arguments and points are made in instructional contexts other than science read-alouds. What these researchers refer to as *modeling* is actually model-building, a type of instructional activity in which students construct, test, validate, and revise scale models, diagrams, and maps based on empirical data collection and analysis. Nonetheless, we believe that these points and arguments also apply to science read-alouds wherein pictorial reference can be said to constitute a form of scientific modeling. Though not student-generated or empirically-based, pictorial models in children's science book provide students with simplified and analogous representations of complex relations and systems in the natural world, thus serving similar explanatory, interpretive, and communicative functions. As Michaels et al. (2008) write, "[pictorial] representation is a predecessor to full-fledged [data] modeling (p. 109)." Similarly, we conceive of pictorial reference in science read-alouds as a less developed representational practice consistent with scientific modeling.

Pictorial Models and Written Texts

In children's science books, pictorial models are usually accompanied by texts, a source of verbal models (Harrison and Coll). This integration of pictorial models and verbal models has been shown to lead to improved learning in computer mediated environments (Carroll and Mack 1999) and to provide clarity and authenticity by visually foregrounding important aspects of written scientific texts (Pozzer and Roth 2003). Nonetheless, Watkins et al. (2004) warns that pictorial models can also detract from, conflict with, or even contradict accompanying text rather than reinforce it. Such possibility underscores the importance of giving careful and critical consideration to the level of consistency between pictorial and verbal models in children's books selected for science read-alouds.

Teaching Science through Read-Alouds

Language educators have urged elementary teachers to incorporate science read-alouds into their classroom practices. Kletzien and Dreher (2004) advocate frequent aloud reading of science books by teachers as a way of increasing primary students' achievement and motivation. Similarly, Albright (2002) describes how reading picture books aloud allows for students to engage in and respond to literature and content knowledge, enhances learning, fosters deeper understanding of content, and improves students' communication skills. The National Commission on Reading considers the practice of reading aloud to younger children as "the single most important activity for building knowledge required for eventual success in reading" (Anderson et al. 1985). Reading picture books aloud is an idyllic way to teach to young students, because of the short layout, visual appeal and directness to the topic at hand (Alvermann and Phelps 1998; Farris and Fuhler 1994; Neal and Moore 1991).

This call for an increased use of science read-alouds by teachers has been driven mainly by research suggesting that such instructional practice can improve students' vocabulary (Elley 1992), encourage students to develop a love for science (Lake 1993), enhance primary students' abilities to decode, comprehend, and tell stories (Rosenhouse et al. 1997), draw students into topics of study (McClure and Zitlow 1991), provide scaffolding for struggling readers (Fielding and Roller 1992), and help students learn the language of different genres such as expository texts and storybooks (Duke and Kays 1998; Pappas 1993). However, due to their focus on issues related to literacy, these researchers have yet to give systematic analytical consideration to pictorial representation and modeling in science read-alouds.

Text Genre and Teacher Performance

Previous research has focused mainly on the types of texts that teachers select for science read-alouds. Donovan and Smolkin (2001) points out that a variety of text genres are currently available for teachers to use as read-alouds, including informational books (factual or informative texts written in the present tense that describe a procedure or natural phenomenon), imaginary storybooks (entertaining texts usually focused on the action of a main character and/or a series of fictional events), and dual-purpose information books (hybrid texts that present factual information in a story format, e.g., Magic School Bus series). Despite researchers' recommendation of a balance between fiction and fact (Saul and Dieckman 2005), evidence shows that most science read-alouds are fictional stories (Hoffman et al. 1993; Jacobs et al. 2000). This preference for fictional over factual texts has been shown to be commonly driven by teachers' assumptions that science is boring, informational books are too difficult to read, and stories add feelings to science (Donovan and Smolkin 2001; Hoffman et al. 1993; Jacobs et al. 2000).

Considerably less attention has been given to how teachers actually perform or deliver their science read-alouds, that is, to the nature and effectiveness of oral strategies employed by teachers while reading science books aloud to their students. The scarce existing research suggests an overall effectiveness of encouraging students to make intertextual connections to books previously read (Oyler and Barry 1996) as well as dialogic links to students' previous experiences inside and outside the classroom, movies, poems, charts, etc. (Pappas et al. 2004); and, interrupting aloud text reading to provide textual information (explanations about the meanings of words), contextual information (about the context in which the book was originally written), and recontextualizing information (parallels between the original and local contexts) (Oliveira et al. 2009). The present study addresses this limitation in the scholarly literature by identifying oral strategies that teachers can adopt to make effective use of pictorial models in children's science books during read-alouds.

Methodology

The present study adopts a qualitative research approach (Bogdan and Biklen 2003; Creswell 2003) and has a micro-ethnographic design (Erickson 1996), being part of a larger exploratory research project on elementary teachers' oral performance of science read-alouds in the capital region of New York State. This exploration relies mainly on descriptive data systematically collected through open-ended research methods (surveys, interviews, and video-recorded observations) and analyzed inductively to build a naturalistic (Lincoln and Guba 1985) and phenomenological (Merriam 1998) account of one specific aspect of teachers' science read-aloud performance, namely their teaching of science through pictorial models in children's science books. This methodological choice allowed us to conduct an in-depth exploration without interfering with teachers' model-based, oral literacy practices.

Participants

Using an Albany-area listserv, a survey of science read-aloud practices was sent to elementary teachers in upstate New York. The survey was composed of a series of open-ended questions that asked for demographic information such as years of teaching experience, teacher preparation, school and classroom settings, as well as pedagogical information concerning teachers' read-aloud practices including frequency of their science read-alouds, book selection criteria, books commonly read aloud, strategies used to incorporate read-alouds into science instruction, and strategies adopted to ensure science learning during read-alouds. From the pool of respondents, 10 elementary teachers who regularly performed science read-alouds were recruited to be video-recorded while facilitating a science read-aloud session in their classroom, and then invited to participate in interviews about their oral performances. While participation in the project was voluntary, we sought to select teachers that had a wide range of teaching experiences (novices and veterans) and taught in a variety of instructional settings (urban, suburban, and rural areas) and grade levels (1 through 6).

Initial inspection of the resulting corpus of video-recorded data revealed a salient and recurrent trend among fourth-grade teachers, namely the instructional practice of reading pictures aloud. More specifically, these teachers repeatedly interrupted their aloud reading of the text for short periods of time to facilitate whole-class discussions about photographs, drawings, and cartoons in the children's books being read aloud. This instructional practice became the central focal point of our analysis, being adopted by three-fourth-grade teachers—Melissa, Morgan, and Dave (all pseudonyms)—from different elementary schools.

Our selection of three-fourth-grade teachers for the present study was purposeful and data-driven. The main motivation behind such selection was availability of data. First, the majority of teachers who agreed to participate in this study (by returning their surveys) taught at the fourth-grade level, hence enabling same-grade analytical comparisons and examination of trends. Furthermore, the unavailability of data on some grade levels (kindergarten and third) and small amount of data on others (first, second, fourth, fifth, and sixth) limited our ability to conduct more systematic comparisons across grade levels. As a result, focusing only on fourth-grade teachers allowed us to reduce variability due to age differences and enabled us to avoid conducting cross-grade comparisons with an unbalanced or biased focus on fourth-grade.

With 15 years of teaching experience, Melissa taught at a suburban elementary school in a large district and conducted one to two read-alouds for each science topic studied. She used science read-alouds to give students "background knowledge and to build a shared vocabulary for science study, as well as to generate interest in the topic" and was video-recorded while reading a book entitled *Snowflakes, Sugar and Salt: Crystals Up Close* (Maki and Sekido 1993). A more detailed description of the contents, genre and stylistic features of this book can be found on Table 1. At the time of this video-recording, Melissa and her students were learning about crystals in the classroom, and the read-aloud was performed as part of an inquiry lesson aimed at enhancing students' understanding of the topic. Students had already participated in a hands-on activity examining different forms of crystals (sugar, salt, baking soda, and alum) with a pocket scope prior to the read-aloud.

Among the three participants, Morgan was the teacher with the most teaching experience—19 years. She taught at a rural elementary school in a medium-sized district and conducted science read-alouds in her classroom about once per week to "enhance instruction in science concepts." While being video-recorded, Morgan read Olien's (2003) book *Light* (see Table 1). This particular read-aloud activity was designed to provide students with background information necessary for future in-classroom experiments. During the read-aloud, Morgan had students complete an accompanying activity sheet that they were given at the start of the activity. At the conclusion of the read aloud, with student participation, Morgan summarized the read-aloud's contents on a large flipchart displayed in the front of the classroom.

Dave had the least teaching experience—only 2 years. He taught in an urban elementary school in a very large district and performed science read-alouds once every 2 months only "if they illustrate a skill in ELA [English Language Arts] (such as identifying character traits)… occasionally we read short, non-fiction articles about the science are covering… animals, electricity, floating and sinking, and simple machines." For his video-recording, Dave read *Almost Invisible Irene*

Table 1 Video-recorded science read-alouds

Teacher	Science read-aloud
Melissa	*Duration*: 27 min
	Book Title: Snowflakes, Sugar and Salt: Crystals Up Close (Maki and Sekido 1993)
	Book Genre and Stylistic Features: Nonfictional, expository picture book that provides a factual account of crystal formation and properties, leading the reader from one form of crystal to another (snowflakes, ice, sugar, salt, baking soda, alum). Its several probing questions (e.g., "can you think of other crystals or solutions of crystals that are in the world around you?") encourage the reader to inquire more and initiate discussion about crystals. The book guides readers in how to examine crystals and what properties to look for, providing many points of entry for readers; a feature commonly found in "narrative informational books" (Donovan and Smolkin 2001) which are composed of multiple sections that can be read and understood independently. At the end of the book, there is a page with hands-on activities for children to further investigate crystals; a feature consistent with Pappas' (2006) category of books with "experimental ideas"
Morgan	*Duration*: 60 min
	Book Title: Light (Olien 2003)
	Book Genre and Stylistic Features: Non-fictional picture book that provides an expository description of light and its qualities. It describes light as a form of energy that originates from the Sun, travels through transparent but not opaque objects, reflects off of objects that are shiny or white, and can be refracted/bent by objects such as magnifying lenses, prisms and raindrops. It also describes the formation of rainbows, plant use of light to make food, Thomas Edison's invention of the light bulb, technological uses of light (lasers, solar electricity, scans, CDs, etc.), and the structure and function of the human eye. Like other "narrative informational books" (Donovan and Smolkin 2001), it is composed of multiple sections that can be read and understood independently of others (i.e., provides readers with multiple points of entry). Its layout follows a traditional textbook format, with a table of contents, glossary, and resources for further reading. At the end of the book there is a page with a hands-on activity for children to investigate shadows, that is, an "experimental idea" (Pappas 2006)
Dave	*Duration*: 17 min
	Book Title: Almost Invisible Irene (Skinner and Smath 2003)
	Book Genre and Stylistic Features: Hybrid storybook with two simultaneous lines of text. The first one is a fictional narrative telling the story of a little girl called Irene who, upon learning about animal camouflage in her science class, goes through an emotional journey as she attempts to confront her shyness by blending herself into the background in the course of various social events (e.g., a sleepover birthday party). The second line of text is a non-fictional exposition conveyed through small factual text boxes with scientific information about animal camouflage; these boxes are located on the lower, right-hand corner of several pages of the book. This simultaneous and parallel presentation of a story (with characters and dialogues) and scientific information is characteristic of "atypical or hybrid information books" (Pappas 2006) or "dual-purpose books" (Donovan and Smolkin 2001)

(Skinner and Smath 2003), a science read-aloud not directly related to any other immediate classroom activities (Table 1).

Data Collection

Our data set was comprised of three main components: (1) a digitally captured corpus of video-recordings of classroom observations (main data source) supplemented by (2) pre-observation teacher surveys, and (3) post-observation, audio-recorded, semi-structured teacher interviews (Bernard 2002; Robson 2002) that lasted about 30 min, were open-ended, and followed a flexible protocol. The video-recordings, which took place during the 2009–2010 school year, were captured with a digital camcorder focused mainly on the teacher. All video- and audio-recordings were transcribed in full (see "Appendix" for transcription conventions). Our transcription included verbatim reproduction of audio-recorded spoken words into writing as well as lexicalization of nonverbal forms of communication such as gestures (e.g., pointing to pictorial models with index finger) and body movement (e.g., nodding head) captured in video. The contents of these transcripts were then examined to determine how teachers used pictorial models from their literature selections to aid in the teaching of science.

Data Analysis

We conducted a *micro-ethnographic discourse analysis*, that is, a study of video-recorded social interaction in minute detail through an up-close and exhaustive examination of how people use language to realize the social work of their daily lives (Erickson 1996). Our analytical approach involved systematic examination of transcribed recordings and sequential analysis and playback of video-recorded interaction.

Our analysis focused on the referential functional mode of discourse (Silverstein 1995) being conducted at the level of *episodes* or *key cultural scenes* (Erickson 1996); short stretches of naturally occurring discursive interactions with variable numbers of utterances, including teacher monologues and teacher-student exchanges. More specifically, we conducted an in-depth and up-close analysis of *pictorial reference*—the oral language used by elementary teachers in reference to pictorial models in children's science books, focusing on (1) the referential meanings being explicitly and implicitly conveyed to students with regard to the representational nature of pictorial models, and (2) the pedagogical or instructional functions of teachers' oral references to pictorial models (i.e., the educational purposes of these oral references in the context of science read-alouds).

Multiple peer debriefing sessions were held as we worked to triangulate our interpretations of the data. In these sessions, discursive records of particular key cultural scenes were examined collectively, individual analyses were shared, and interpretations were discussed extensively. The emergent account was gradually adjusted to include any variation that surfaced from this reflective group interpretation of the data. This collaborative analytical approach contributed to guarding against individual researcher biases (Robson 2002).

Findings

In this section, we report trends in Melissa, Morgan, and Dave's pictorial references.

Melissa

The book *Snowflakes, Sugar, and Salt* contained highly realistic or naturalistic pictorial models—colored photographs (e.g., several photographs of powders and magnified crystals without any human presence). During her science read-aloud, Melissa discussed these photographs, focusing specifically on sets of crystals of the same kind and similarly looking powders. Table 2 provides a descriptions as well as sketches of the visual layout of the five models discussed by Melissa.

Pictorial Models as Real Substances

Throughout the read-aloud, Melissa repeatedly referred to pictorial models as if they were the actual targets. This referential practice was evident when Melissa made statements such as: "*To me these* [crystals on pictorial model 1] *don't even look real, they look like they are manmade plastic, they're perfectly formed, so interesting*", "*as you can see here* [on pictorial model 3] *all five powders look pretty much alike*," and "*here they are, those same substances* [on pictorial model 4]." In all these utterances, Melissa makes reference to "real" crystals and powders as if the discussion was about actual substances rather than photographed ones, thus systematically replacing pictorial models with their targets.

Verifying Factual Information

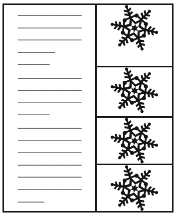
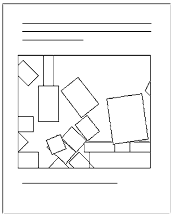
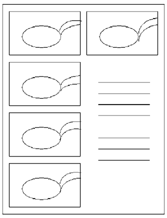
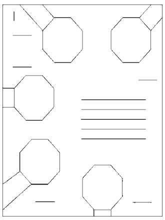
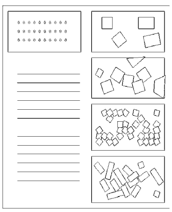
Treating photographs as actual substances enabled Melissa to "verify" the factual information being read aloud. For instance, the text on pictorial model 1 states that "snowflakes always have six sides." After reading this particular statement aloud, Melissa immediately stopped reading from the book and uttered the following "*Do you want to count?* [in unison with students while pointing to top picture] *one, two, three, four, five, six* [pointing to second picture from top] *one, two, three, four, five, six. This is a little different pattern but you can still see the tips* [pointing to third picture from top] *one, two, three, four, five, six. Pretty amazing, even this one which really kind of looks like one solid object, you can actually see those points* [pointing to bottom picture] *one, two, three, four, five, six*." As can be seen, Melissa treats the statement "snowflakes always have six sides" as a hypothesis that can be tested or empirically verified by means of direct observation (i.e., simply counting the number of sides on the four different snowflake crystals on the photographs). In doing so, Melissa transforms her science read-aloud into an activity wherein students are provided with factual information about crystals that is actively verified though visual inspection of pictorial evidence.

Similarly, Melissa used pictorial models 3, 4 and 5 to prompt students to visually determine which of five similarly looking white powders (flours, sugar, alum, salt, and baking soda) was not made of crystals. For instance, while referring to pictorial model 4, Melissa temporarily interrupted the oral delivery of the text to pose the following research question:

Melissa: Which one of <u>these powders</u> is not crystals? Can you see? Which one does not form, can you see? [leaning forward waving at the picture in the book] which one would you say does not form that regular [pattern]?

Student: flour

Table 2 Pictorial models discussed by Melissa

Pictorial model[a]		Description
1		Pictorial model wherein four photographs of different snowflakes are placed along the right side of a page to illustrate the fact that snowflakes look lacy when the outside air is drier (top picture) and resemble solid plates of ice when humidity levels are higher (bottom picture); this factual information is presented in the 3 paragraphs on the left side of the same page
2		Pictorial model wherein a single large photograph of sugar crystals (shaped like cubes) is placed in the center of a page, taking most of its space. The short text (a few lines above and below the picture) informs readers that these crystals are edible and have been magnified 100 times
3		Pictorial model wherein photographs of five spoons full of different white powders (flour, sugar, alum, salt, and baking soda) are placed along the left side and top of a page to highlight the fact these substances look alike. Two paragraphs on the right side of the page inform student that close inspection will reveal that these similar looking powders are actually different
4		Pictorial model wherein magnified photographs of the same white powders (showing crystalline forms for all powders except flour) are placed over drawings of magnifying lenses to create the impression that readers are looking at the powders through magnifying lenses. The paragraph at the center poses the question "which powder is not made of crystals?"
5		Pictorial model wherein photographs of the same five powders with a much higher magnification are provided at the top and right side of the page. Two paragraphs on the left side inform readers that the powders have been magnified 50 times and that crystals are made of nonliving things and have different shapes

[a] Due to copyright restrictions, sketches of the overall layout of pictorial models are provided in lieu of actual reproductions

It should be noted that Melissa makes reference to "actual" powders (as opposed to pictures of powders), hence replacing pictorial model 4 with its targets. In doing so, Melissa once again encourages her students to engage in visual observation as a means to determine the answer to a scientific question. More specifically, she asks students to look closely at the powders (as if students were looking at real powder samples) to identify the one lacking a regular pattern (described in the text as an indication of the presence of crystalline forms).

Unshared Attributes of Pictorial Models

Prior to the read-aloud, Melissa's students had already made direct observations of real sugar crystals using pocket scopes. Discrepancies in appearance between the real sugar crystals previously examined and the photographed sugar crystals being looked at led Melissa to communicate pictorial model 2 as an imperfect representation:

Melissa: Do they [crystals on pictorial model 2] look like the sugar crystals you looked at?
Students: No
Melissa: No, we're gonna have to do a little comparison aren't we? With these pictures of the sugar crystals and the ones that we have, THESE ARE SUGAR CRYSTALS MAGNIFIED 100 TIMES, who remembers, raise your hands if you can remember the magnification that we used in our pocket scopes
Student: Thirty times
Melissa: 30 times [nodding]. So it makes sense that they may look a little bit different. And the color of the background paper is also a little bit different. So that could change it too

To account for the fact the photographed crystals appear somewhat different, Melissa acknowledges that pictorial model 2 (this time referred to as "*these pictures of the sugar crystals*") is in fact a scale model, that is, a pictorial model wherein the relative dimensions of sugar crystals have been considerably amplified with some loss of similarity in appearance due to differences in scale and background (compared to the crystals students observed using pocket scopes). In doing so, Melissa implicitly communicates to students that both size and color are unshared attributes or features of pictorial model 2 (i.e., she implicitly identifies where pictorial model 2 breaks down).

Similarly, toward the end of the read-aloud, Melissa drew students' attention to the dimensionality of pictorial model 5:

Melissa: I heard a lot of you using the word three-dimensional
Students: Yeah
Melissa: Well, are these pieces of flour [on model 5] three-dimensional?
Student: [overlapping mixed replies]
Melissa: They actually are [nods positively], but it's hard to see, isn't it?

Melissa first questions whether the grains of flour shown on model 5 (the grains and crystals on this model look particularly large due to a very high magnification) can be considered "three-dimensional." When her students respond positively, Melissa replies with the comment "*they actually are, but it's hard to see, isn't it*?"

It should be noted that the pronoun “they” refers to the target (i.e., actual pieces of flour), whereas her pronoun “it” refers to the analog (i.e., pictorial model 5). Through these pronominal choices, Melissa implicitly communicates pictorial model 5 as an imperfect visual representation and its two-dimensional nature as an unshared attribute. Once again, her communication of the imperfect representational nature of the pictorial model is implicit.

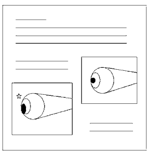
Morgan

The book *Light*, selected by Morgan for her science read-aloud, contained two abstract colored drawings and several naturalistic colored pictures (e.g., a picture of a house with metal rectangles on its roof labeled “solar panels” and a picture of an eye doctor examining a boy’s glasses). However, unlike Melissa, Morgan did not discuss any of the photographs, choosing instead to focus on the meanings of the two colored drawings (schematic diagrams). These are described on Table 3 below.

Referring to Pictures of Objects

Morgan invariably communicated the representational nature of the pictorial models under discussion. For instance, while drawing students’ attention to pictorial model 1, she uttered “*ok, you have a picture there* [on students’ handouts] *that looks very similar to this one* [pictorial model 1].” Similarly, while showing students the page where pictorial model 2 was located, Morgan stated “*I’m going to come closer with this picture* [pictorial model 2].” In both instances, Melissa refers to models as pictures of objects rather than actual objects (e.g., “this prism” and “this eye”), thus explicitly communicating the representational nature of these drawings.

Table 3 Pictorial models discussed by Morgan

Pictorial model[a]		Description
1		Pictorial model wherein light diffraction is represented in drawing as a series of three successive stages (labeled as white light → prism → visible spectrum), starting at the upper left-hand corner and ending at the lower right-corner of the picture. The short text at the top of the page identifies a prism as an agent of refraction and defines the terms “white light” as light from the sun and “visible spectrum” as separate colors
2		Pictorial model wherein the human eye is presented as a whole made up of multiple parts all shown with topological accuracy (interconnected accurately but not to scale). Two nearly identical drawings are provided side-by-side: a human eye looking at a dark sky with stars and a moon, and a second one staring at a clear sky with a bright sun. The pupil (the only labeled part of the drawing) appears much larger in the former. The text on the top of the page defines pupil as “a hole that lets light into the eye” and warns that excessive light can be harmful. The two drawings also have titles explaining that the pupil changes its size to allow more or less light to enter the eye

[a] Due to copyright restrictions, sketches of the overall layout of pictorial models are provided in lieu of actual reproductions

Pictorial Models as Visual Heuristic Tools

Morgan used both pictorial models as visual heuristic tools, that is, as instructional devices for guiding and helping students visualize or understand real-world phenomena and situations (complex target systems), namely how rainbows are formed and why people experience discomfort subsequent to having their pupils dilated during an eye examination. Her instructional approach consisted of two sequential phases: (1) explaining the pictorial model, and (2) applying the pictorial model (i.e., using it to explain a target system). These are described and illustrated below.

While explaining each pictorial model, Morgan defined the scientific terms used as labels ("*light from the sun is white light*" and "*the prism turns it* [white light] *into colors which is the visible spectrum*"), identified both verbally and physically the specific model parts being referred to ("*here you have a prism*" and "*the center black part of your eye* [pointing with index finger] *is the pupil*"), asked students to label model parts on handouts ("*on your sheet I want you to label that white light*"); and, provided temporal readings of the pictorial models, that is, read each drawing aloud as a series of sequential stages from left to right ("*this* [label on left of model 1] *is the white light… then you have a line that goes to the prism* [in the center]… *the visible spectrum is broken up into different colors* [on the right]" and "*the center black part of your eye is the pupil* [on the left of model 2], *that allows light through to your retina* [in the center] *and allows your brain, it sends a signal to your brain* [on the right] *to let you see*"). Through the combined used of these oral strategies, Morgan communicated lexical meanings (i.e., word definitions) as well as topological meanings (i.e., logical relations between model parts) to her students.

Subsequent to explaining each pictorial model, Morgan communicated to students how it could be applied to real-world situations. For instance, immediately after explaining pictorial model 1 to students, Morgan uttered "*raindrops* [also] *bend sunlight, that's how we get a rainbow, when sunlight comes through raindrops it makes the rainbow because the raindrop is refracting the light, and that's what causes a rainbow to happen*." Morgan highlights that, like the prism on pictorial model 1, raindrops also refract or bend sunlight, hence producing a rainbow. By doing so, Morgan encourages students to visualize the formation of rainbows as a three part system (light input/refraction agent/light output) analogous to pictorial model 1. Put differently, Morgan utilizes pictorial model 1 as a heuristic tool to guide students' emergent understanding or visualization of the formation of rainbows.

Similarly, after explaining pictorial model 2, Morgan applied it to a real-world scenario: "*I don't know if you've ever had an eye exam, but if your pupil gets dilated when you've had an eye exam, and then you're like this* [covering her eyes] *when you come outside because it's really hard to see, it's because your pupils are letting too much light in while it's bright out*." Having just discussed with students how human pupils adapt to the two luminosity conditions (a dark night and a bright day) visually depicted on pictorial model 2, Morgan now poses and explains a third condition (a person experiencing discomfort after an eye exam). Her comparative explanation encourages students to visualize the eye exam situation in terms of the same two-part system conveyed by pictorial model 2: outside condition/pupil size. In other words, she employs pictorial model 2 as heuristic device to guide students' development of a scientific understanding of the sensation of discomfort produced by eye exams.

Dave

For his read-aloud, Dave selected *Almost Invisible Irene*, a fictional book with very colorful and large drawings that resemble cartoon strips wherein thought and dialogue balloons are used to represent the speech and thought of characters (Irene, her teachers, and/or classmates). All of its pictorial models focus on unfolding action and events and no naturalistic photographs are provided. Although Dave commented on most pictures in the book, he paid relatively more attention to representations wherein the main character Irene, while blending into the background, looks back at or reacts to other characters in the foreground (meant to illustrate the concept of animal camouflage. Table 4 provides a description of these pictorial models.

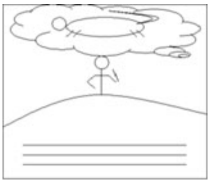
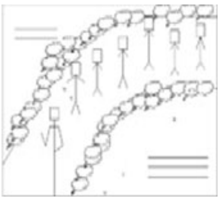
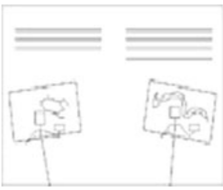
Pictorial Models as Realistic Fiction

Throughout the read-aloud, Dave underscored the representational nature of the pictorial models under discussion by making statements such as "*take a look at the picture* [pictorial model 1]," "*and you can see the picture* [pictorial model 4] *in here as well showing her blending in with the outdoors*", "*and take a look at those pictures* [pictorial model 5]." In all these instances, Dave refers to pictorial models, thus communicating to students that the discussion is about pictorial representations rather than actual events or action. Moreover, Dave repeatedly described the pictorial models as a form of realistic fiction ("*just like when we've been doing our realistic fiction*"), frequently distinguishing between fictional and non-fictional visual elements. For instance, while commenting on pictorial model 2, he uttered "*notice this book is kind of like blend of fiction, this is a made up story, and non-fiction with these little boxes down here that tell us some facts about what we're learning about, some science facts.*" Similarly, when one of his students made the comment "*this* [pictorial model 6] *is definitely not real because of the cat chasing the dog*," Dave replied "*there are parts of this that are not a realistic depiction.*" As a result, Dave communicates the pictorial models under deliberation as fictional yet partially realistic visual representations.

Analogical Storytelling

Dave used the narrative pictorial models to engage students in analogical storytelling, that is, to tell the story of a fictional character (a timid little girl) who sets out to physically simulate animal camouflage by dressing up and positioning herself in ways that would allow her to blend into the background while participating in a variety of social events (a sleepover birthday party, a classroom discussion, an outdoor hiking trip, and a school lunch). In this story, Irene's

Table 4 Pictorial representations engaged by Dave and his students

Pictorial representation[a]		Description
1		Pictorial model wherein Irene, upon arriving home from school, is pinched on the cheek by her grandmother. This cartoon occupies the top half of the page, being placed above a short dialogue
2		Pictorial model of a teacher showing her students a large drawing of two white foxes in a snowy forest, several students looking at the drawing with puzzled expressions, and another student thinking about polar bears, snowshoe hares, and snowy owls on snowy landscapes (side-by-side inside a thought balloon). This cartoon occupies two pages, being placed underneath short dialogues
3		Pictorial model of Irene imagining herself as a chameleon while lying in bed; a drawing of a "creature" that has Irene's head on the body of a chameleon is provided inside a thought balloon. This cartoon occupies most of the page, being placed above a short paragraph
4		Pictorial model wherein Irene observes the reactions of her classmates and teacher while simulating animal camouflage by dressing herself in green during a hiking field trip. The teacher leads the group, being followed by Irene who is blended in with the green trees and bushes behind her, and several classmates walking in a line formation. This cartoon occupies two pages with two statements on the upper left-hand corner, and a small factual box on the lower right-hand corner providing readers with several examples of animals that blend into their surroundings
5		Pictorial model wherein Irene is giving her oral report on animal camouflage (i.e., sharing with her peers how she simulated a frog and a rattle snake by dressing herself in green and tan, respectively). This cartoon occupies two pages, showing two drawings of Irene side-by-side: one holding a small picture of a green frog and another holding a picture of a rattle snake; blown up copies of each animal picture blending into their surroundings are also placed in the background. On the top of each page are short dialogues
6		Pictorial model wherein Irene talks to two classmates while walking home. They are shown walking on the sidewalk of a residential street, being preceded by a cat that is running after a dog. This cartoon occupies the top half of the page, being placed above a short dialogue

[a] Due to copyright restrictions, sketches of the overall layout of pictorial representations are provided in lieu of actual reproductions

simulation not only allowed her to physically explore the concept of animal camouflage but also provided her with a means to cope with her shyness in social events. In other words, animal camouflage (color adaptations that allow certain animals to protect themselves from predators) was communicated as being analogous to human "blending in" (interactional strategies used by humans to cope with social life).

Dave first communicated the analogical nature of the story to his students while commenting on pictorial model 3 ("*look at it*, *she* [Irene] *imagines herself blending in just like a chameleon*"). Later, while discussing pictorial model 5, he elaborated upon Irene's analogical reasoning:

Dave: She [Irene] is now showing the animals she was dressed up like, or at least the colors she was matching
Student: She [Irene] was dressed up like animals. What was she dressed like?
Dave: The colors that she [Irene] was wearing that were like those animals

Dave begins by identifying the two animals—a tree frog and a desert rattlesnake—on pictorial model 5 as the targets of Irene's physical simulation ("*the animals she was dressed up like*"). He also identifies color as an attribute shared by the analog (Irene's dresses) and its target (animals). However, Dave's reference to the analog is vague and imprecise as Irene did not actually dressed herself up in a frog or snake costume, but simply put on green and tan clothes. This apparent inconsistency in Dave's statement is sensed by his student who in turn requests further elaboration ("*what was she dressed like*?"). In response, Dave restates his analogy, this time identifying "the colors worn by Irene" as the analog and "those animals" as the target. His communication of the imperfect representational nature of the pictorial models under discussion is implicit, that is, where the "dress" analogy breaks down is implicitly conveyed to students; only shared attributes are explicitly identified by Dave.

Discussion

In this section, we discuss empirical and theoretical connections to the existing literature.

Highlighting Key Visual Attributes

As described above, our research revealed that the three elementary teachers relied on both texts and pictorial models in the teaching of science through read-alouds. Melissa discussed conceptual photographs with students consistently highlighting explicit characteristics of the photographs as described in the book (e.g., number of sides in snowflakes). Melissa's read-aloud featured naturalistic photographs that served as a source of factual content verification. In contrast, the pictorial models selected by Morgan for collective deliberation were two diagrams that depicted analytical representations of specific phenomena related to light (refraction and human vision). Like Melissa, Morgan discussed with students key characteristics of these pictorial models. However, the analytical diagrams discussed by Morgan served as visual heuristic tools—pictorial models meant to help students' visualize the complex target system as a sequence of events. Lastly, Dave used cartoons to engage students in the story's narrative, which was analogous to the science topic of his fictional read-aloud, namely animal camouflage. In sum, all three teachers highlighted (i.e., drew students' attention to) specific attributes of the pictorial models that were most relevant to the discussion regardless of the specific type of pictorial model or science topic under consideration.

Previous cognitive research has stressed the centrality of the practice of highlighting in the development of "shared vision," that is, a shared and socially organized ability to "see" or notice significant phenomena and interpret meaningful events in complex perceptual landscapes (Goodwin 1994, 1995, 1996, 1997). By making relevant features that are difficult to see more visible and prominent discussants are able to organize, shape and structure a complicated perceptual field into a salient figure and a background, shape human perception and guide others' ways of seeing and understanding events. Consistent with this literature, the three teachers in our study also selectively highlighted (through their oral references) pictorial models and their visual features as a means to shape the complicated perceptual field visible on the pictures of children's science books. Through these highlighting practices the teachers promoted a socially organized "vision," that is, a particular way of seeing or understanding significant visual features in the complex perceptual fields of photos, drawings and cartoons.

Another practice central to the shaping of human perception and creation of collective vision is the use of *coding* (Cicourel 1968; Goodwin 1994). Like highlighting, coding provides a practical way of developing student's ability to gain information from pictorial models through selective attention focusing on relevant visual information. This practice was evident in Morgan's use of the diagrammatic models wherein, in addition to her oral highlighting, written labels (i.e., codes) provided further guidance encouraging students to see only the features of the system relevant to their topic.

Referential Fusion

While all three teachers used pictures to communicate science, they were not consistent in their communication of the representational nature of pictorial models under deliberation; they did not always help students clearly identify the pictorial models as being separate from their targets. Morgan and Dave explicitly referred to each model as a *picture of* an object or scene (e.g., "*this picture*" and "*this diagram*"), hence making the representational nature of analytical diagrams and (re)actional cartoons explicit to students. On the other hand, Melissa consistently referred to pictorial models as the actual targets (e.g., "*this snowflake*" and "*these crystals*"). In doing so, she was able to use photographs as a visual resource for verifying the factual information conveyed in the book. Such referential practice is consistent with the notion of *fusion* which Nemirovsky and Monk (2000) define as "acting, talking, and gesturing without distinguishing between symbols and referents (p. 182)." When there is fusion, the model or analog is communicated as if it were the target (i.e., speakers make no explicit reference to the model itself, choosing instead to refer directly to its target). Similarly, by identifying pictures as real objects, Melissa repeatedly fused the pictorial model and its target together.

Limitations and Significance

Our findings underscore the need for elementary teachers to become more aware of how pictorial models in children's science books constitute an important instructional tool for teaching science in the context of read-alouds. For instance, across the three science read-alouds examined in this study there was an utter lack of explicit mapping of the pictorial models to the targets they represented. As emphasized by Harrison and Coll (2008), utilizing models without emphasizing their limitations and unshared attributes can potentially bring about unwelcomed results such as misconceptions. However, because no data was collected with regard to the student content learning (e.g., student conceptual understandings) that resulted from the science read-alouds, we are unable to assess whether such lack of explicit mapping indeed had a negative impact on instructional outcomes.

Despite the above limitations, we believe that our study has important implications for elementary science educators. Its significance stems mainly from recent education reform efforts emphasizing literacy across subject areas in the elementary grades. In an attempt to qualify for President Obama's Race to the Top incentives, several states have adopted the Common Core State Standards (NGA Center CCSSO 2010) which include a non-fictional reading and writing component for science in elementary education. These new science literacy standards are positioned as an addition to the existing content knowledge standards. With the adoption of the CCSS by the states, elementary teachers are increasingly faced with the challenging task of integrating non-fictional literacy skills into their science teaching practices. The present study, we believe, has the potential to help elementary teachers cope with this new challenge by identifying a set of oral strategies that can improve their use of pictorial models in children's science books during read-alouds, thus placing them in a better position to meet the CCSS science literacy requirements.

Generally speaking, our examination of the three teachers' performance of science read-alouds revealed several oral practices that clearly supported students' development of visual literacy skills, including highlighting key visual attributes of pictorial models, helping students scan and navigate pictorial models, etc. However, the teachers did not always adopt pedagogical strategies aimed specifically at addressing the unique challenges posed by each different type of pictorial model. For example, Morgan did not discuss with students the illustrative techniques used in the analytical diagrams (the use of arrows to represent incoming light, the use of arrows to label specific parts of the human eye, the cutaway views of the human eye, etc.). As emphasized by Vasquez et al. (2010), rather than assuming that visual messages are self-explanatory and that children will automatically be able to interpret the characteristics of visuals, K-8 teachers should provide students with explicit instructions in how to "read" specific types of visuals. For instance, when looking at photographs, teachers should heighten their students' awareness of viewer's position and missing visual components by encouraging them to make careful observations, draw inferences, and ask questions about when and where the photographs were taken and how the information visually conveyed relates back to previously studied science content. On the other hand, analytical diagrams are usually more complex and challenging for children to interpret due to discrepancies in scale, improper positioning, and unclear use of illustrative techniques such as labels, arrows, insets (circles with a magnified view of portions of an image) and cutaway views (images that reveal "hidden" things that cannot usually be seen such as organs inside the human body, plant roots beneath the soil, etc.). To prevent students from developing misconceptions, Vasquez et al. (2010) recommend that teachers explicitly comment on these illustrative techniques and discuss the visual features of analytical diagrams using questions such as: "How does the diagram [help] organize or categorize information?"; "Does the diagram [show] something that a person would not usually be able to see?"; and "Does the diagram depict the actual size of the object or relative size of its features?" Future research will need to examine how the absence of these more explicit discussions and teacher guidance during the science read-alouds can affect children's development of visual literacy (i.e., the ability to critically interpret pictorial models) and whether it can foster misconceptions.

Researchers can further examine the impact of elementary teachers' aloud reading of pictorial models on students' science (mis)conceptions by asking students to retell information books (Donovan and Smolkin 2001), (re)draw pictorial models previously encountered, or retrieve information from pictures (Peacock and Weedon 2002). Researchers can also systematically explore the effects of teacher oral references to pictorial models on students' general understanding of models through one-on-one interviews based on previously developed protocols (Grosslight et al. 1991; Golbert and Pallant 2004) and questionnaires such as VOMMS (Treagust et al. 2004). This research is likely to offer elementary science educators valuable insights on how to effectively teach science through pictorial models while orally performing science read-alouds.

Appendix: Transcription Conventions

The following notation is adopted in all transcripts excerpts included in the present manuscript:

?	indicates rising intonations
.	indicates falling intonations
[]	indicates observer comments
<u>Underscore</u>	indicates key linguistic features of the provided excerpts

References

Albright, L. K. (2002). Bringing the ice maiden to life: Engaging adolescents in learning through picture book read-alouds in content areas. *Journal of Adolescent and Adult Literacy, 45*, 418–428.

Alvermann, D. E., & Phelps, S. F. (1998). *Content reading and literacy* (2nd ed.). Boston, MA: Allyn and Bacon.
Ametller, J., & Pinto, R. (2002). Students' reading of innovative images of energy at secondary school level. *International Journal of Science Education, 24*, 285–312.
Anderson, R. C., Hiebert, E. H., Scott, J. A., & Wilkinson, I. A. (1985). *Becoming a nation of readers*. Washington, DC: National Institute of Education.
Bass, J. E., Contant, T. L., & Carin, A. A. (2009). *Methods for teaching science as inquiry* (10th ed.). Boston, MA: Allyn & Bacon.
Bean, T. W., Searles, D., Singer, H., & Cowen, S. (1990). Learning concepts from biology text through pictorial analogies and analogical study guide. *Journal of Educational Research, 83*, 233–237.
Bernard, H. R. (2002). *Research methods in anthropology: Qualitative and quantitative approaches* (5th ed., pp. 443–449). Walnut Creek, CA: AltaMira Press.
Bogdan, R. C., & Biklen, S. K. (2003). *Qualitative research for education: An introduction to theory and methods* (4th ed.). Boston, MA: Allyn and Bacon.
Carroll, J. M., & Mack, R. L. (1999). Metaphor, computing systems, and active learning. *International Journal of Human-Computer Studies, 51*, 385–403.
Catley, K. F., Novick, L. R., & Shade, C. K. (2010). Interpreting evolutionary diagrams: When topology and process conflict. *Journal of Research in Science Teaching, 47*, 861–882.
Cicourel, A. (1968). *The social organization of juvenile justice*. New York: Wiley Publishing.
Cleveland, H., & Fox, S. (2008). Cartoon-initiated conversations. *Science Scope, 31*, 50–52.
Colin, P., Chauvet, F., & Vinnot, L. (2002). Reading images in optics: Students' difficulties and teachers' views. *International Journal of Science Education, 24*, 313–332.
Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications.
Donovan, C. A., & Smolkin, L. B. (2001). Genre and other factors influencing teachers' book selections for science instruction. *Reading Research Quarterly, 36*, 412–440.
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.
Elley, W. B. (1992). *How in the world do students read?*. Hamburg: International Association for the Evaluation of Educational Achievement.
Erickson, F. (1996). Ethnographic microanalysis. In S. L. McKay & N. H. Hornberger (Eds.), *Sociolinguistics and language teaching* (pp. 283–306). New York: Cambridge University Press.
Farris, P. J., & Fuhler, C. J. (1994). Developing social studies concepts through picture books. *The Reading Teacher, 47*, 380–386.
Fielding, L., & Roller, C. (1992). Making difficult books accessible and easy books acceptable. *The Reading Teacher, 45*, 678–685.
Ford, D. J. (2006). Representations of science within children's trade books. *Journal of Research in Science Teaching, 43*, 214–235.
Gilbert, S. W., & Ireton, S. W. (2003). *Understanding models in earth and space science*. Arlington, VA: NSTA Press.
Glynn, S. M. (2008). Making science concepts meaningful to students: Teaching with analogies. In S. Mikelskis-Seifert, U. Ringelband, & M. Bruckmann (Eds.), *Four decades of research in science education: From curriculum development to quality improvement* (pp. 112–125). Munster: Waxmann.
Golbert, J. D., & Pallant, A. (2004). Fostering students' epistemologies of models via authentic model-based tasks. *Journal of Science Education and Technology, 13*, 7–22.
Goodwin, C. (1994). Professional vision. *American Anthropologist, 96*, 606–633.
Goodwin, C. (1995). Seeing in depth. *Social Studies of Science, 25*, 237–274.
Goodwin, C. (1996). Transparent vision. In E. Ochs, E. A. Schegloff, & S. Thompson (Eds.), *Interaction and grammar* (pp. 370–404). Cambridge: Cambridge University Press.
Goodwin, C. (1997). The blackness of black: Color categories as situated practice. In L. B. Resnick, R. Säljö, C. Pontecorvo, & B. Burge (Eds.), *Discourse, tools and reasoning: Essays on situated cognition* (pp. 111–140). Berlin, Heidelberg: Springer.
Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching, 28*, 799–822.
Harrison, A. G., & Coll, R. K. (2008). *Using analogies in middle and secondary science classrooms: The FAR guide—an interesting way to teach with analogies*. Thousand Oaks, CA: Corwin Press.

Hoffman, J., Roser, N., & Battle, J. (1993). Reading aloud in classrooms: From the modal towards a "model". *The Reading Teacher, 46*, 496–502.

Jacobs, J. S., Morrison, T. G., & Swinyard, W. R. (2000). Reading aloud to students: A national probability study of classroom reading practices of elementary school teachers. *Reading Psychology, 21*, 171–193.

Keogh, B., & Naylor, S. (1999). Concept cartoons, teaching and learning in science: An evaluation. *International Journal of Science Education, 21*, 431–446.

Kletzien, S. B., & Dreher, M. J. (2004). *Informational text in K-3 classrooms: Helping Children read and write* (pp. 45–54). Newark, DE: International Reading Association.

Lake, J. (1993). *Imagine: A literature-based approach to science*. Bothell, WA: The Wright Group.

Latour, B. (1986). Visualization and cognition: Thinking with eyes and hands. *Knowledge and Society: Studies in the Sociology of Culture Past and Present, 6*, 1–40.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage Publications.

Maki, C., & Sekido, I. (1993). *Snowflakes, sugar and salt: Crystals up close*. Minneapolis, MN: Lerner Publications Company.

McClure, A. A., & Zitlow, C. S. (1991). Not just the facts: Aesthetic response in elementary content area studies. *Language Arts, 68*, 27–33.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science! Putting research to work in K-8 science classrooms*. Washington, DC: The National Academies Press.

National Governors Association Center for Best Practices, Council of Chief State School Officers (NGA Center CCSSO) (2010). *Common core state standards*. Retrieved on March 13th from http://www.corestandards.org/the-standards.

Neal, J. C., & Moore, K. (1991). The Very Hungry Caterpillar meets Beowulf in secondary classrooms. *Journal of Reading, 35*, 290–296.

Nemirovsky, R., & Monk, S. (2000). "If you look at it the other way…" An exploration into the nature of symbolizing. In P. Cobb, E. Yackel, & K. McClain (Eds.), *Symbolizing and communicating in mathematics classrooms: Perspectives on discourse, tools and instructional design*. Hillsdale, NJ: Lawrence Earlbaum Associates.

Olien, B. (2003). *Light*. Mankato, MN: Bridgestone Books.

Oliveira, A. W. (2010). Engaging students in guided science inquiry discussions; elementary teachers' oral strategies. *Journal of Science Teacher Education*, *21*, 747–765.

Oliveira, A. W., Colak, H., & Akerson, V. L. (2009). "Who polluted the Potomac?" The translation and implementation of a US environmental story in Brazilian and Turkish classrooms. *Cultural Studies of Science Education*, *4*, 89–132.

Oyler, C., & Barry, A. (1996). Intertextual connections in read-alouds of information books. *Language Arts, 73*, 324–329.

Pappas, C. C. (1993). Is narrative "primary"? Some insights from kindergartners' pretend readings of stories and information books. *Journal of Reading Behavior, 25*, 97–129.

Pappas, C. C. (2006). The Information book genre: Its goal in integrated science literacy research and practice. *Reading Research Quarterly, 41*, 226–250.

Pappas, C. C., Varelas, M., Barry, A., & Rife, A. (2004). Promoting dialogic inquiry in information book read-alouds: Young urban children's ways of making sense. In E. W. Saul (Ed.), *Crossing borders in literacy and science instruction* (pp. 161–189). Arlington, VA: NSTA Press.

Peacock, A., & Weedon, H. (2002). Children working with text in science: Disparities with 'literacy hour' practice. *Research in Science and Technological Education, 20*, 185–197.

Pozzer, L. L., & Roth, W. M. (2003). Prevalence, function, and structure of photographs in high school biology textbooks. *Journal of Research in Science Teaching, 40*, 1089–1114.

Robson, C. (2002). *Real world research* (2nd ed.). United Kingdom: Blackwell Publishing.

Rosenhouse, J., Feitelson, D., Kita, B., & Goldstein, Z. (1997). Interactive reading aloud to Israeli first graders: Its contribution to literacy development. *Reading Research Quarterly, 32*, 168–183.

Saul, E. W., & Dieckman, D. (2005). Choosing and using information trade books. *Reading Research Quarterly, 40*, 502–513.

Silverstein, M. (1995). Shifters, linguistic categories and cultural description. In B. G. Blount (Ed.), *Language, culture and society*. Prospect Heights IL: Waveland Press Inc.

Silverstein, M. (2004). "Cultural" concepts and the language-culture nexus. *Current Anthropology, 45*, 621–652.

Skinner, D., & Smath, J. (2003). *Almost invisible Irene*. New York: Kane Press.
Stylianidou, F., Ormerod, F., & Ogborn, J. (2002). Analysis of science textbook pictures about energy and pupils' reading of them. *International Journal of Science Education, 24*, 257–283.
Treagust, D. F., Chittleborough, G. D., & Mamiala, T. L. (2004). Students' understanding of the descriptive and predictive nature of teaching models in organic chemistry. *Research in Science Education, 34*, 1–20.
Vasquez, J., Comer, M., & Troutman, F. (2010). *Developing visual literacy in science, K-8*. Arlington, VA: NSTA Press.
Vosinadou, S., & Brewer, W. F. (1987). Theories of knowledge restructuring in development. *Review of Educational Research, 57*, 51–67.
Watkins, J. K., Miller, E., & Brubaker, D. (2004). The role of visual image: What are students really learning from pictorial representations? *Journal of Visual Literacy, 24*, 23–40.