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Representations of Astronomy in Children's Picture Books

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Abstract

This study examines how astronomy is portrayed in children's picture books, selected from notable book lists, published between 2001-2021. Selected books (N=32) were analyzed in terms of how they portray the practices of science, using the Next Generation Science Standards (NGSS) as a framework. We also analyzed the gender, age, and race of the main characters. Few books among the selection portrayed characters engaged in a scientific investigation, and many of the books had scientific inaccuracies in the story and/or illustrations. NGSS science practices appeared in less than half of the selected books, and this was primarily the practice of asking questions. The main characters were close to evenly split between male and female, and most main characters were children. When the selection of books from Diverse Book Finder was included, the racial background of human main characters was close to even between white and persons of color. However, without Diverse Book Finder, racial diversity in the sample was greatly reduced. Currently, astronomy picture books provide limited support for the Next Generation Science Standards in terms of how they convey science practices. In addition, teachers may have difficulty locating books that portray racially diverse characters engaged in astronomical phenomena.

Keywords: Early childhood, Picture books, Science practices

1 Introduction

Picture books are widely used with early learners at home, in schools, and in informal learning environments. A picture book combines words and pictures to tell a story. Young readers need to use both the illustrations and the words to create a full understanding of the story. A survey by Banilower et al. (2013) found that 22% of U.S. elementary teachers use a mix of textbooks and non-commercially published resources while 31% of U.S. elementary teachers use only non-commercially published resources. This suggests that more than half of U.S. elementary teachers are drawing on resources other than textbooks, such as picture books, to facilitate science instruction. Elementary teachers, in particular, rely on children's picture books as a way to bring science into the classroom (e.g., Oliveira, 2015). Teachers see picture books as an important resource to help children access science content when it is not practical for them to experience those phenomena in the classroom (Pringle and Lamme, 2005).

Further, children's books have been used as part of successful science and literacy curricular partnerships (e.g., Cervetti et al., 2012; Morrow et al., 1997; Varelas and Pappas, 2006; Varelas et al., 2014). However, questions have been raised by some early childhood educators as to whether narrative or expository texts are most beneficial to children's science learning. In a review of expository books for children, Pappas (2006) claimed "[c]hildren cannot truly learn science unless they also learn the distinctive language of science, and using only stories or hybrid books will not accomplish such a goal" (p. 246). However, Kelly (2018) and Brunner & Abd-El-Khalick (2017) found that biographies and

books containing human elements portrayed more aspects of the nature of science than expository books. Narrative books that tell stories of how and why scientists answer questions about natural phenomena have the opportunity to engage children in thinking about the practices of doing science in ways left unexplored in expository texts. Yet, questions remain as to whether children's science picture book authors choose to portray science in this way.

Educators rely on children's science picture books as a window into science for young children. Therefore, it is critical to consider how science is represented in picture books. The U.S. Next Generation Science Standards (NGSS)(NGSS Lead States, 2013) proposes that children learn science content through the use of science practices. NGSS science practices provide a detailed framework for understanding how children and adults should engage in scientific inquiry. Children make sense of the world through their application of science practices by answering questions about science phenomena, planning and carrying out investigations, interpreting and analyzing data, constructing explanations, engaging in scientific argumentation, and using models (among other practices). The important role science practices play in how we hope children will learn to do science should be reflected in their science picture books, if they are to serve as a useful tool within science education. Though the research in this area is limited, prior research with young children in the U.S. suggests that picture books can be used in science instruction to help children engage in science practices (Plummer and Cho, 2023).

Children's picture books should also depict the diversity of children and scientists, from around the world, who are engaging in science. An oft-used metaphor for children's picture books suggests that they can serve as windows, mirrors, and sliding doors (Bishop, 1990). Picture books can serve as mirrors by providing a positive representation of children's race, culture, and gender in science; doing so helps promote children's self-esteem and healthy development of identity with science (AACAP (American Academy of Child and Adolescent Psychiatry), 2016; Husband, 2019; Pew Research Center, 2015). Children's books can serve as windows by providing opportunities for children to see people and cultures different from their own. Research suggests that children who engage with diverse books that "feature the lived experiences of people with marginalized or underrepresented identities" can shape how children "perceive their own value and the significance of others who do and do not look like them" (Cahill et al., 2021, p. 269). Books featuring children of color are also important for white children, as these books "enable all readers to see children of color portrayed as fully realized characters" (Kliman, 2019, p.9). Considering illustrations as learning tools, these cultural products allow us to infer the conceptual outcomes for children as they engage with picture books (Dehghani et al., 2013). Finally, these mirrors and windows can become sliding doors when children engage within the picture book's world. Children begin to imagine themselves as participants in that world, and are changed by it (Martinez et al., 2016). In addition, children develop their capacity for social imagination, "the ability to think about the thoughts, feelings and intentions of others," through the process of reading fictional texts (Lysaker and Miller, 2013, p.148). In other words, it is the characters, cultures, and stories that children encounter when reading books that impacts their understanding of and empathy for others.

2 Science Representation in Picture Books

Picture books provide opportunities for children to engage with the nature of science, the people who do science, and to learn new science concepts. Yet, this relies on children having opportunities to engage with high quality picture books that portray a modern view of science, connect children with diverse scientists, and present the content of science accurately. Our review of prior research in these areas suggest that many children's picture books are limited in their portrayal of science across these areas.

2.1 Scientists in Picture Books

Current children's books do not provide adequate representations of the diversity of scientists (Kelly, 2018). Most children's science trade books–which include both fiction and nonfiction books and are produced geared towards public consumption rather than strictly academic settings–present scientists as majority male (61% - 70%; (Ford, 2006; Kelly, 2018; Rawson and McCool, 2014)). Kelly (2018) analyzed trade books, finding that representations of actual scientists are 77% male and fictional characters, including children, are 52% male. Rawson & McCool (2014) found that female scientists were more likely to be shown working alone than male scientists. Most scientists shown in science trade books are also white (78% - 89%; (Ford, 2006; Kelly, 2018; Rawson and McCool, 2014)). Rawson & McCool (2014) found that female scientists were more likely to be non-white, compared to the representations of male scientists. There are also limitations in the inclusion of characters with disabilities in children's books. A study of Caldecott Medal and Honor winners between 1938 and 2005 found that only 11 out of 276 books portrayed characters with disabilities (Dyches et al., 2006). Price et al. (2016) conducted a study of 102 children's books that included characters with disabilities. They found that 95% of the books provided "genuine insight into the lives of characters with disabilities" (p. 569), though limitations were found such as including characters with disabilities who did not have an active role in problem resolution. However, we were unable to find any reviews of the inclusion of disabilities in children's science trade books which raises questions as to the extent and role of how children with disabilities may see themselves reflected in the field of science. These findings suggest that children's science books do not mirror U.S. children in terms of racial background, gender, or disabilities. Children need opportunities to see themselves as capable of engaging with science, and to see underrepresented racial, ethnic, gender, and ability groups excelling within the scientific field.

2.2 The Nature of Science in Picture Books

Previous studies have also considered how children's picture books represent the nature of science, as well as the limitations of those representations. Ford (2006) investigated representations of the nature of science in 44 science trade books. Her investigation found that science trade books provide incomplete and inadequate representations of the nature of science, portraying "a range of representations of science and scientists, some of which are suitable for instruction on the nature of science, some which play a role as a component of inquiry, and some which distort or misrepresent aspects of scientific practice" (Ford, 2006, p.231)). Most books presented a limited or problematic representation of the nature of science with science presented as facts and scientists as knowers of facts (Ford, 2006). Brunner

and Abd-El-Khalick's (2017) analysis of 50 trade books found a similar theme: the majority of books "presented science as a listing of facts, with very little, or no representation of the processes underlying the development of scientific knowledge" (p. 144). Only two of the books in their sample represented the nature of science in an informed and explicit manner. Kelly's (2018) study of 28 science trade books mirrors these findings. Kelly found that biographies and other books describing the work of scientific teams included the most depth on the nature of science. Further, nature of science content was often hidden in peritextual materials (e.g., author's notes).

However, while previous studies have considered how science picture books represent the nature of science (Ford, 2006; Kelly, 2018), these did not consider how picture books might align with the NGSS vision for use of science practices in elementary classrooms. Understanding how and to what extent picture books engage readers in thinking about science practices will help us better advise elementary teachers in how to select books that support students' achievement in science. Schroeder et al. (2009) examined 116 children's science narrative, expository, and combination books, published between 1973 - 2003. Only 16% (n=18) of their sample presented science in such a way that the reader would understand how science progresses and evolves, including representations of asking systematic questions, making observations, and gathering data. Only 15% of the selected books presented science as involving claims, evidence, and conclusions. Schroeder et al. (2009) conclude "that a majority of trade books discussed the "what" of science but not the "how" and "why" of phenomena. The small amount of explanatory information compared to descriptive information in trade books was disappointing given that it is through discussions of "how" and "why" phenomena occur that individuals come to understand science processes" (p. 245). These findings suggest that we may find limited inclusion of science practices in children's picture books; but as this sample is more than 20 years old, a new study is needed to confirm this speculation.

2.3 Accuracy of Science in Picture Books

Finally, we raise the question of scientific accuracy in children's science picture books. Elementary teachers rely on science picture books, as well as nonfiction books to support their students' science education (Oliveira, 2015). Because elementary teachers are often not science majors, they have limited preparation in science topics (Banilower et al., 2013; Gess-Newsome, 1999; Jones and Edmunds, 2006), and often have limited science content knowledge (Akerson et al., 2006), they may encounter difficulties when teaching science and selecting high quality, scientifically accurate, teaching materials. This raises the stakes for the quality of materials, including picture books and other trade books, that are needed to support the elementary teacher's science lessons. Yet, many science trade books contain notable inaccuracies in science content knowledge (Rice, 2002). For example, Trundle et al. (2008) reviewed written and visual representations of the Moon across 80 children's books, where 20% of the representations of the Moon were scientifically inaccurate.

2.4 Research Questions

In the present study, we focus on how science is represented through an analysis of children's astronomy picture books. Kelly (2018) found that most current science trade books are in the life sciences (71% of her sample), with far fewer appearing in the physical sciences. This trend appears to be common across multiple studies (Brunner and Abd-El-Khalick, 2017; Ford, 2006; Rawson and McCool, 2014; Rearden and Broemmel, 2008). In fact, in a study of 116 trade books, only one book addressed astronomy content (changes in light/heat from the Sun) and a few other books related to changes in the Sun's energy to living organisms (Schroeder et al., 2009). Further, a previous study found that physical science trade books conveyed science through activity-based experiments while life science books were mostly conveyed through observations or facts (Ford, 2006). Therefore, we chose to take a narrow look into one physical science domain, to better understand how authors are communicating who does astronomy and how it is practiced. Given findings from previous studies concerning the limitations of how characters are represented, the nature of science, and the accuracy of content, we wondered whether the nature of astronomy, as an observational domain, would shape how children's picture book authors chose to represent astronomy. Our study was guided by the following research questions about astronomy picture books:

- To what extent is astronomy accurately conveyed?
- To what extent are characters portrayed as engaging in science practices?
- What is the range of gender, age, race, and disabilities of main characters?

3 Methodology

Using a qualitative methodological approach, we conducted a content analysis of astronomy picture books for early elementary students. Content analysis describes the systematic investigation of texts, images, media, and/or material culture for both overt and subtextual meaning (Bengtsson, 2016; Saldaña, 2011).

3.1 Sample selection

We began by gathering all astronomy-related books with potential to be narrative texts for young readers from the following sources: 1) two lists featuring noteworthy children's trade books (National Science Teaching Association Outstanding Trade Book winners (n=13); Association for Library Service to Children Notable Children's books (n=5)); 2) two lists targeting or adjacent to astronomy (Astronomical Society of the Pacific Storytime (n=19); Storytime from Space (n=2)); and, 3) books from the Diverse Book Finder in order to ensure our selected books included published books featuring characters who are Black, Indigenous, and people of color (n=19). In addition, we used WorldCat to select the 10 books held by the most libraries worldwide so that we could include those most likely to be read by children or used in classrooms.

Next, we applied selection criteria outlined in Table 1 to our initial list of books. We selected books featuring astronomy content—the study of objects we can see beyond the Earth, such as Sun, Moon, planets, stars, galaxies, and the Universe. We also included books about astronomers, those that study astronomical phenomena. We excluded astronauts and space travel; though many people associate this with astronomy, astronauts work does not typical engage in inquiry about astronomical objects and phenomena. The sample of books selected for this study were limited to those written at a reading level for ages 3-8 years old. In addition, we limited our selection to books published between 2001 - 2021. The books selected were written in English, as this is the language read by the authors. Finally, as we are interested in how the narrative text within the books may inform readers about science practices, we excluded expository texts.

All books found through the application of our search criteria on these lists were included in our final sample. There was overlap between the books found on each of the lists. Thus, the final list was a selection of 32 astronomy picture books that met our criteria.

Table 1. Selection criteria

Lists and catalogs	• National Science Teaching Association Outstanding Trade Books winners • Association for Library Service to Children Notable Children's books • Astronomical Society of the Pacific Storytime • Storytime from Space • Diverse Book Finder - Science, Technology, Engineering, and Mathematics collection • WorldCat (limited to the 10 books meeting all other criteria held by the most libraries worldwide)
Book style	Narratives and biographies; expository texts were excluded
Publishing dates	2001 - 2021
Content	All astronomy content (i.e., study of objects and phenomena beyond the Earth) and books about astronomers (i.e., those who study astronomical phenomena); excludes astronauts and space travel
Reading level	Ages 3-8 years old
Language	English (though other languages may be included if the story could be read in English)

3.2 Analysis

We began by developing a codebook to analyze the picture books towards answering our three research questions (see Appendix). Categories were developed related to each research question, described further below. After an initial round of shared coding of three books to develop and clarify the codebook, both authors separately coded one-third of the sample (10 books) then compared and resolved any discrepancies. Most codes achieved at least 80% agreement and any disagreements were discussed and resolved. Codes with less than 80% agreement led to further discussion to improve the clarity of the codebook and re-coding of previously coded picture books. The remaining books in the sample were coded by both authors to improve reliability.

Research Question 1: Scientific Content and Accuracy

We began by assigning descriptive words for the primary astronomy content of each book. Each author did this separately for all books. These topics were then compared and discussed to reach a final 'main content' descriptor or descriptors for each book (some books had more than one main topic). For example, a book might have been primarily about the Solar System but more briefly include information about the Milky Way. In this case, we coded for Solar System as the main content.

Given the broad range of astronomy topics covered by the books, the authors used their own knowledge of astronomy to evaluate the accuracy of the written text and illustrations; the first author has a Ph.D. in astronomy and education and the second author is an experienced science educator. Because of the range of topics in the books, we did not create specific codes that described accuracy; rather, we evaluated each book using the breadth of our knowledge. While it is possible that we missed some inaccuracies in the books, our process of separately reviewing and then discussing potential errors was helpful to find the major issues with each book.

Research Question 2: Science Practices

To realize the vision of the NGSS requires school science curricula to engage children in science and engineering practices in ways that help them make sense of science phenomena or to solve problems they have identified (Penuel and Reiser, 2018). Codes were developed using a deductive approach. We began by asking whether the picture books depict characters investigating a scientific phenomenon. Based on this, we developed five codes that represent the range of ways scientific investigations are or are not represented in the books: a) characters investigated a phenomenon (main focus of the narrative); b) characters partially investigated a phenomenon (minor focus of the narrative); c) narrative included an astronomical phenomenon, but this is not investigated; d) narrative only presents astronomy facts, without investigation; e) no astronomy phenomena or facts are presented or discussed by characters. Next, we coded for science practices; our codebook for science practices is based on Appendix F of the Next Generation Science Standards (NGSS Lead States, 2013), which describes each of the eight practices for grades K-2 (children age 5 – 8 years).

Research Question 3: Gender, Age, Race, and Disabilities of Main Characters

Gender, race, age, and disabilities were coded primarily using contextual clues provided through illustrations and text. We focused exclusively on human main characters for our analysis. Codes were developed using a deductive approach. For gender, we considered the author's use of pronouns (e.g., she, her) to assign binary gender designations (male, female) and neutral when gender was unclear. Drawing on previous studies' methods and codebooks (Emmerson et al., 2014; Koss, 2015), we also examined the text and illustrations for any reference to the main character having a disability (e.g., Deaf character or a character with a learning disability), including wearing glasses. Characters' race was determined using illustrated appearance, contextual clues in the story, and information about the author. Some illustrations appeared to depict people of color but we were not able to provide more specific racial identification. Initially, we also coded for whether the book was written or illustrated by an 'own voices author.' Own voices, a term coined by Corinne Duyvis in 2015, describes books featuring characters from underrepresented and/or marginalized groups in which the author shares the same identity. However, recently some have questioned the use of this label as it has the potential to marginalize authors; the term is unclear and can interfere with an author's privacy (LaPointe, 2022).

4 Findings

Our sampling process was open to finding books that covered any aspect of the study of astronomy. After reviewing the selec-

tion and determining the main content for each book, we found that children's books cover a wide range of astronomy topics, with books about the Moon (n=6), stars & galaxies (n=6), current & historical astronomers (n=6), and the night sky (n=5) being the most frequently represented (see Table 2).

Table 2. Picture book content
[a] *Some books had multiple key concepts resulting in more than 32 entries in the table*

Key words describing primary content	Frequency [a]
Moon and lunar phases	6
Stars and galaxies	6
Astronomers (Maria Mitchell; Caroline Hershel; Carl Sagan; two books on Neil DeGrasse Tyson; Zhang Heng)	6
The night sky (including constellations, meteor showers, and the North Star)	5
Telescopes	4
Solar System	4
The Earth	2
The Sun	2
Space exploration	2
Life in the universe	2
Light pollution	2
Comets	2
Other: Supernova; extrasolar planets	2

4.1 Research Question 1: Scientific Accuracy

The sample included: 23 books with accurate text; 3 books with partially accurate text; and 6 books where the premise of the book was evaluated to not portray accurate science (see Table 3). An example of partially accurate text appears in *Monkeys and the Universe* by Kate Banks which included multiple instances of inaccurate text, such as "Stars can be blue, yellow, green, or red"; there are no stars that appear to be green because stars that emit the most light in the green part of the spectrum also submit substantial amounts of red and blue light, which together combine to appear as white. An example of the premise of the book not portraying accurate science was from *Nick and Nack See the Stars* by Brandon Budzi; throughout the text, the characters make a telescope out of a paper towel roll and other found materials but do not use this to make sense of any astronomy concepts nor do they demonstrate accurate construction or use of a telescope. In terms of illustrations, 17 picture books were accurate, 10 were partially accurate, and 5 were evaluated to have a premise that was not scientifically accurate. Three of the partially accurate books and one book where the premise was not scientifically accurate related to representations of the Moon's appearance or location in the sky. The most problematic illustration of astronomy concepts occurred in *Moon: A Peek-Through Picture Book* by Britta Teckentrup. The book shows: a) what may be intended to be a Gibbous Moon but shown in a shape never observed in the sky; b) depicts the New Moon as a dark circle in the night sky (the New Moon is in the sky at the same time as the Sun); and skips from Full Moon to New Moon rather than showing an accurate representation of the pattern of phases of the Moon.

Table 3. Accuracy in Astronomy Picture Books (N=32)

	Accurate	Partially accurate	Inaccurate
Text	23	3	6
Illustrations	17	10	5

4.2 Research Question 2: Investigations and science practices

We explored the extent to which our sample represented characters investigating astronomical phenomena (see Table 4). Few books either focused on characters investigating an astronomical phenomenon as the main narrative (n=3) or as part of the narrative (n=4). For example, *Luna luminosa, ¿dónde estás?/ Luminous Moon, Where Are You?* by Aracely De Alvarado featured an investigation as the main focus of the narrative. The story begins with Juanito wondering where the Moon has gone, asking "Where, oh where, is the Moon?" He checks under his bed, and wonders if the coyote took it to his lair. Eventually, the Moon reappears the next night as a thin crescent Moon, which Juanito observes through his telescope. Juanito asks a question and makes observations of the natural world as part of his investigation.

Table 4. Investigating astronomical phenomenon in children's picture books (N=32)

Category	Frequency
Investigation or problem solving	3
Partially engaged in investigation or problem solving	4
Phenomenon is discussed / explanation provided, without an investigation	10
Includes astronomy facts without an investigation/astronomy phenomenon	12
No astronomy facts or phenomena discussed	3

Most books either presented a phenomenon without an investigation (n=10) or conveyed astronomy as a collection of facts (n=12). An example of a phenomenon without investigation appeared in *Rocket Says Look Up* by Nathan Bryon. The narrative focuses on a young, Black girl named Rocket who wants to watch an upcoming meteor shower and invites many of her neighbors to watch with her. The story concludes with Rocket, her brother Jamaal, and many of her neighbors watching the meteor shower. However, no questions were asked about the meteor shower, nor are there any attempts to explain the event based on the observations. Other books in our sample conveyed astronomy facts throughout the narrative but lacked a focus on astronomical phenomena (i.e., characters observing an astronomical event). For example, our sample included two biographies about Dr. Neil DeGrasse Tyson, a noted astronomer and science communicator, which conveyed factual astronomy information related to Dr. Tyson's life and research.

Finally, three books were coded as containing no investigations, astronomical phenomena, or presentation of facts. For example, in the book *Hello, Moon!* by Francesca Simon, a young boy asks the Moon (who doesn't reply) a series of questions about the Moon's life, focusing on topics that would be of interest to a small child. Typical text includes "Do you like chocolate ice cream? That's my favorite food" and "Can you see the whole wide world? Oh show me, show me!" This has the potential to allow educators to introduce a discussion of astronomical perspectives but, as with the rest of the text, does not convey facts or particular astronomical phenomena.

We also coded for the eight NGSS science practices (NGSS Lead States, 2013). Fourteen books included at least one science practice while the remaining 18 books included no depictions or text describing science practices (see Table 5 for a full list of practices and frequency of appearance in the books). The most frequently observed practice was asking questions (when a character posed a question that could be answered through observation) (n=13) followed by planning and carrying out investigations (n=6). Some of the books coded as asking questions featured only a minimal level of engagement with this practice. For example, on one page of *The Moon is Going to Addy's House* by Ida Pearle, Addy asks "Where did it [the Moon] go?", she looked out the car window and then found the Moon. No other examples of science practices were coded in the book. The book with the most science practices depicted was *The Dreamer of Stars* by Jillian Lin which featured five practices. This biography features Zhang Heng, a 1st Century scientist of the Eastern Han Dynasty. The narrative describes his inventions and investigations; for example, using observations and inferences, he concluded that the Earth was round, and used this insight to build a model of the sky, which he used to make new discoveries.

Table 5. Use of science practices in astronomy picture books (N=32)

Science Practices	Frequency
Asking questions and defining problems	13
Developing and using models	1
Planning and carrying out investigations	6
Analyzing and interpreting data	1
Using mathematics and computational thinking	0
Constructing explanations and designing solutions	2
Engaging in argument from evidence	1
Obtaining, evaluating, and communicating information	0
Total books with one more science practice represented	14
Total books with no use of science practices	18

4.3 Research Question 3: Characteristics of main characters

We evaluated the main character(s) for each picture book, beginning with identifying whether those characters were human (n=23), animal (n=3), other (n=4), or no main character (n=5) (total is 35 as a few books had more than one main character). Gender distribution was 13 male, 16 female, and 4 neutral. Characters were primarily children (n=25). The only disability we identified in a main character was in *Caroline's Comets* by Emily Arnold McCully. The story is based on the historical astronomer Caroline Herschel; in the book, she is described as contracting typhus and smallpox as a child which stunted her growth and left her face disfigured. We also noted only one character in a wheelchair; this was a background character appearing on one page of *Look Up with Me, Neil deGrasse Tyson: A Life Among the Stars* by Jennifer Berne. Finally, six books included main characters wearing glasses.

We identified the race of human characters based on appearance, contextual clues in the story, and author information. Table 6 includes racial background of 1) the full sample and 2) a subsample, after removing books selected from Diverse Book Finder (DBF), a comprehensive collection of children's picture books featuring Black and Indigenous people and People of Color (BIPOC). Without the inclusion of the DBF selections, the remaining sample of books include a majority of white characters compared to characters who are people of color. More concerning is that, when considering the 10 astronomy books held by the most libraries worldwide (using WorldCat), only three books feature characters who are people of color, and only *Bright Sky, Starry City* by Uma Krishnaswami features main characters who we identified race (characters are Asian). Two other books on that list feature animals as main characters and one has no main character.

5 Discussion

Our findings raise questions about the extent to which elementary teachers are able to use existing astronomy picture books to support NGSS-based science instruction and to provide culturally sustaining lessons through the inclusion of picture books featuring BIPOC children and children with disabilities. First, we questioned the extent to which science is accurately portrayed in the books. We found that 28% of books in the sample had textual inaccuracies or lack of science content and 53% of books had illustrations with inaccuracies or lack of scientific content. Trundle and colleagues (2008) conducted a study on the accuracy of children's books featuring the phases of the Moon. Out of 80 children's books analyzed, including both narrative and expository texts, 20% of the illustrations were non-scientific. Science picture books, both narrative and expository, are used by elementary teachers as part of instruction. Erroneous illustrations and inaccurate scientific illustrations may reinforce existing non-normative preconceptions and may confuse both children and educators.

Second, we questioned the extent to which characters were portrayed engaging in science practices. The picture books in our sample provided limited representation of characters engaged in scientific investigation or modeling of the NGSS science practices. Only 22% of the sample includes characters engaged in a scientific investigation. And, while the science practice of asking questions is reasonably well represented (41%), the use of questions was often limited in scope and failed to demonstrate how questions lead to an investigation that could be carried out further by children. Narrative-based picture books have the potential to introduce characters engaged in doing science through the science practices in ways that will help teachers facilitate their students' understanding of the practices or further discussion about their own investigations that are conducted in the classroom. This will require science picture book authors to weave more science practices into their narratives. However, as Ford (2006) points out, science trade books can "play an important role in learning about the nature of science, if chosen and used carefully, but they cannot by themselves adequately

Table 6. Representation of books with human main characters by racial background.
[a] *Race not identifiable with contextual clues.*
[b] *Two books had animals as main characters; one book had no main character.*

	White	Black	Asian	Latine	Person of Color[a]	Unclear
Full sample (n=23)	9	5	3	2	3	3
Sample without Diverse Book Finder selections (n=16)	9	3	1	0	2	2
Astronomy books held by the most libraries (n=7) [b]	5	0	1	0	2	0

represent the complexities of science" (p. 231). Picture books can initiate investigations or model aspects of doing science, but educators need to provide children with opportunities to engage in their own investigations.

Third, we investigated the range of gender, age, race, and disabilities of main characters in the picture books. The distribution of human main character(s) in the sample without DBF books (56% white, 38% person of color; 13% unclear) includes more diverse characters than the previous studies of children's books, as does our full sample's gender distribution (39% male, 48% female, and 12% neutral). Previous studies with children's science trade books found that scientists were mostly white (78% - 89%) and male (61% - 70%) (Ford, 2006; Kelly, 2018; Rawson and McCool, 2014). However, we coded for "main characters" rather than "scientists"; we would not describe all of the characters in our sample as enacting the role of a scientist in their stories. While having nonfiction accounts of scientists in books for children is important, we argue that the ways fictional stories of child protagonists doing science are also important as these may provide additional avenues for children to identify with science at a more personal level. Picture books have the potential to play an important role in culturally relevant science education in the early years of learning. "[M]ulticultural picture books can serve as an important tool in [the] process of stereotype reduction, as they provide children with opportunities to see and learn about various racial groups in the world in non-stereotypical ways" (Husband, 2019, p.1067). The books in our sample suggest that teachers have opportunities to include astronomy picture books which feature main characters who are people of color. However, many of these are not books found most frequently in libraries which may mean that educators have limited access to astronomy picture books representing BIPOC characters.

We also note some additional, significant limitations in terms of how main characters in these picture books represent the diversity of children in the U.S. Notably, none of the books uncovered in our sampling effort were by Indigenous authors or about Indigenous astronomy knowledge. The lack of picture books by Indigenous authors suggests we are missing an important perspective on astronomy. For example, Dehghani and colleagues (2013) reviewed children's books by Native American and European American authors. They found that Native books were more likely to include greater depth about the natural world, describe the relationship between humans and nature, and discuss the cause for natural processes. We are aware of a few astronomy picture books by Indigenous authors, including *Great the Dawn: The Lakota Way (2003)* and *The Star People: A Lakota Story (2012)* by S.D. Nelson of the Standing Rock Sioux. Greet the Dawn explores the Lakota Way of living in balance and celebrating each new morning, through a modern view of the Lakota people. *The Star People* introduces traditional Sioux knowledge, including traditional ways of referencing the clouds (Cloud People) and stars (Star People), communicating that they have living energy like people. *The Star People* is included in the Diverse Book Finder archive but is not categorized in the STEM section, and thus was not included in our sampling efforts. By not choosing to label the book as relevant to STEM, educators may not see how this can be a way to bring indigenous knowledge to their classroom.

We also considered how the picture books portrayed characters with disabilities in our analysis. In 2010, 95% of students aged 8-21 years with disabilities were included in general education classrooms in the U.S. (Snyder and Dillow, 2013). Thus, it is important to consider how classroom materials, including picture books, portray this diversity so that children with disabilities are able to see themselves reflected in classroom literature (Price et al., 2016). None of the main characters exhibited visible disabilities (e.g., character with an amputation), nor did the text refer to any invisible disabilities (e.g., dyslexia). This is consistent with other studies of children's picture books. Koss (2015) analyzed picture books published in 2012. Koss found that only 36 out of 455 books (8%) contained characters with disabilities (not including characters wearing glasses) and in only 13 books (3%) were main characters with disabilities. A few astronomy picture books, not picked up in our sampling methods, include characters with disabilities. For example, Annie Jump Cannon, Astronomer (2011) by Carole Gerber and Christine Wald tells the story of the American astronomer who, at age 30, became profoundly deaf after contracting scarlet fever. However, she continued to work as an astronomer, publishing the stellar classification system we still use today.

Finally, we consider how the picture books represented diverse gender identities. More main characters were female than male. However, we recognize that these designations are potentially problematic because gender is not solely a binary construction (Koss, 2015). The neutral characters included two children and one robot with appearances that did not include stereotypical references to gender and the text did not include any pronouns. While the inclusion of neutral characters is promising, more books are needed that include characters that identify as non-binary. One limitation of our study was that we did not examine whether characters were depicted in stereotypical gender roles. Koss (2015) found that female presenting characters were more likely to be depicted in stereotypical gender roles compared to male presenting characters in children's picture books.

5.1 Limitations and future research

The number of books reviewed appears small – only 32 picture books were included in our study. However, given our work to identify published books across multiple sources, this small number is likely to reflect a relatively small pool of narrative-based astronomy books published for children in the last 20 years. While including expository texts would greatly expand the num-

ber of books available for review, our goal was to understand how these issues arise when children engage with stories about astronomy. Many of the choices we made in selecting our analysis frameworks and picture book selections focus our findings on U.S.-centric issues. We are interested in how books support the implementation of science practices by drawing on the U.S. national science standards (i.e., NGSS). Our interpretation of diversity in children's books is interpreted from a standpoint of racial diversity in U.S. children. Our book selection was also limited to books with English text as this is our first language and the language spoken/read by the majority of U.S. children. We recommend that readers interpret our findings and analyses with this perspective in mind, while also considering how these findings may be reflected in the children's picture books in their own context.

We recommend that future research compare how science practices are portrayed in other picture books in other domains of science, such as physics, biology, or chemistry. This may reveal strengths or weaknesses in how science is portrayed across children's picture books when considering all domains. While we were interested in investigating the extent to which astronomy picture books may support students' and teachers' work towards achieving the goals of the NGSS-aligned science practices, there were limitations in the extent to which we carried out this analysis. NGSS proposes that, in order to deepen children's understanding of science, they engage in the integration of disciplinary core ideas (DCIs), science practices, and cross-cutting concepts. We only coded for how characters engaged in science practices and did not examine how the characters engaged with cross-cutting concepts; nor did we explicitly identify DCIs addressed in the picture books. Based on the limited inclusion of science practices, we suggest that had we looked for this integration of DCIs, practices, and concepts we would have found even more limited support for NGSS's vision. Finally, our sampling method identified primarily children's books from English-speaking authors and Western cultures. Cross-cultural studies of how children's books portray who does science and how science is practiced may yield new insights into how we might put further effort into producing high quality books for children and educators.

5.2 Recommendations

We recommend publishers work with authors to include narratives featuring characters that represent the range of diversity found in U.S. classrooms. In particular, more picture books that communicate how children from underrepresented and marginalized backgrounds are engaged in scientific inquiry about astronomical phenomena are needed to provide windows, mirrors, and sliding glass doors for children (Cahill et al., 2021). In particular, publishers should seek out the work of own voice authors, as has been done in the Storytelling Math series which shows how all children can be mathematical thinkers by featuring stories children of color written by authors from the same background (TERC, Inc., with Charlesbridge Publishing). Publishers and authors should also consider the range of children with disabilities and gender identities in classrooms today and consider how their stories can be told, normalizing those children's experiences with science. Many of the books found in WorldCat, representing those books found in the most libraries worldwide, were limited in their representation of racial diversity and included scientific inaccuracies. Thus, we also suggest that librarians consider applying our evaluation criteria as they select picture books for their collections. Finally, we recommend teachers to be critical consumers of children's picture books by considering how the books they select will help students in their classroom see themselves in books but also to see others as capable in doing science (Bishop, 1990; Cahill et al., 2021).

6 Declarations

6.1 Competing Interests

The authors declare that they have no competing interests.

6.2 Ethical Considerations

No approval for this research was required as this study only used document analysis.

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7 Appendix - Codebook for Picture Book Analysis

7.1 Appendix A - Codebook - Storybook Analysis

Table 7. Scientific Accuracy of Text

Code	Definition	Example
Scientifically accurate	The entire premise of the book is scientifically accurate.	Text accurately portrays that an observer would experience the new Moon over 2 days by showing that the main character would not be able to see the Moon in the sky over that period, followed by observing the waxing crescent. *Luminous Moon, Where Are You? By Aracely De Alvarado*
Partially accurate	Individual inaccuracies appear on one or a few pages.	Glossary includes definition of the Solar System that inaccurately states that all stars orbit the Sun. *Caroline's Comets by Emily Arnold McCully*
Premise not accurate	Overall premise/narrative of the book is not scientifically accurate. It can have a few accurate facts, but overall the storyline is not accurate or does not contain any science to evaluate.	Premise of the story inaccurately depicts that there is Earth-like life on the planet Mars. A large alien is shown throughout the story, observing the main character. The main character finds an Earth-like flower blooming on Mars. *Life on Mars by Jon Agee*

Table 8. Scientific Accuracy of Text

Code	Definition	Example
Scientifically accurate	The entire premise of the illustrations is scientifically accurate.	The main characters look at images of galaxies. The images of galaxies are actual photos taken by research telescopes. Illustrations of the characters are layered on top of the real galaxy images. *Ada and the Galaxies by Alan Lightman and Olga Pastuchiv*
Partially accurate	Individual inaccuracies appear on one or a few pages of illustrations.	Crescent Moon images are shown in a stylized appearance. The illuminated portion stretches across what should be the terminator line. *Luminous Moon, Where Are You? By Aracely De Alvarado*
Premise not accurate	Overall illustrations in the book are not scientifically accurate.	Each page of the book shows a different phase of the Moon. The order of the phases does not follow the accurate pattern; instead, it jumps from Full to New Moon. The New Moon is shown as a dark circle in the nighttime sky. The images of the Gibbous Moon appear as a "bite" out of one side of a full Moon. *Moon: A Peek-Through Picture Book by Britta Teckentrup*

Table 9. Investigating a science phenomenon / solving a problem with a science phenomenon

Code	Definition	Example
Investigation/ problem solving	Main narrative includes character(s) investigating a science phenomenon or engaged with a problem related to a science phenomenon. This implies that the characters are engaged in some form of data collection or working with previously collected data.	Sisters Usha and Aarti look up at the stars. Aarti sees the Big Dipper while Usha sees the Big Digger. The sisters discuss their observations as they investigate how perspective plays a role in their understanding of the appearance of patterns in the sky. *Usha and the Big Digger by Amitha Jagannath Knight*
Partially engaged in investigation/ problem solving	A portion of the storybook includes character(s) investigating a science phenomenon or engaged with a problem related to a science phenomenon, but this is not the main focus of the narrative.	During one part of the book, Chinese astronomer Zhang Heng (born in 78 AD) studied how stars move in the sky. He determined that the Earth is round, and not a square like he was taught. He created a model of the celestial sphere with the Earth at the center, and the Sun, Moon, and stars moving around it. He used this model to further investigate the sky. *The Dreamer of Stars by Jillian Lin*
Phenomenon is presented or discussed, without an investigation	Phenomenon is presented or discussed, without an investigation. This can be with or without characters.	Narrative shows Miss Mitchell randomly searching the sky with her telescope. She eventually spots a comet in the sky. Observing the appearance of a comet in the sky constitutes a phenomenon, but the characters do not investigate its appearance or attempt to generate explanations or deeper understanding based on their observations. *What Miss Mitchell Saw by Hayley Barrett*
Includes astronomy facts, without an investigation, or focus on engagement with a phenomenon	Narrative includes scientific facts but does not engage readers with a science phenomenon. This can be with or without characters.	Throughout the book, the main characters state facts about astronomical objects. For example, Max says “Did you know the Sun is really a star?” and “Did you say Neptune was the farthest planet from the Sun?” *Monkeys and the Universe by Kate Banks*
None	No investigation or phenomenon.	Throughout the book, the main character asks the Moon if it enjoys some if its favorite activities. The boy asks questions throughout the story such as, Can the moon see the city? Can the moon see the whole wide world? What are the Moon’s friends like? *Hello, Moon! By Francesca Simon*

Table 10. Science Practices

Code	Definition	Example
Asking questions and defining problems	To ask and refine questions that lead to descriptions and explanations of the natural and designated worlds work and which can be empirically tested.	1) Ask question based on observations. 2) Ask or identify questions that can be answered by an investigation. The main character is searching for life on Mars. They ask, "I'm starting to wonder – could anything possibly live here?" *on Mars by Jon Agee*
Developing and using models	To use and construct models as helpful tools for representing ideas and explanations. Tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.	1) Develop models based on evidence. 2) Develop and use a model to represent natural world and/or patterns. 3) Drawings and representations. 4) Use the model to generate data Chinese astronomer Zhang Heng built a model of the Earth, Sun, Moon, and stars based on his observations of these objects' movement in the skies. *The Dreamer of Star by Jillian Lin*
Planning and carrying out investigations	Scientists and engineers plan and carry out investigations in the field or lab, working collaboratively as well as individually.	After wondering where the Moon has gone, the main character makes repeated observations of the sky until he observes the Moon again. *Luminous Moon, Where are you? By Aracely De Alvarado*
Analyzing and Interpreting data	Produce data that must be analyzed in order to derive meaning. Patterns, trends, tabulation, graphical representation, visualization, statistical analysis to identify features and patterns.	Chinese astronomer Zhang Heng made observations of the stars for years. He analyzed his observations to determine the patterns in how stars appear to move. *The Dreamer of Star by Jillian Lin*
Using mathematics and computational thinking	Representing physical variables and their relationships.	No examples found in the books analyzed.
Constructing explanations and designing solutions	The products of science are explanations, and the projects of engineering are solutions.	A child travels to Mars to look for life. He walked around on Mars looking for evidence and eventually finds a flower. He uses this evidence to conclude that there is life on Mars. *Life on Mars by Jon Agee*
Engaging in argument from evidence	Process by which explanations and solutions are reached.	Chinese astronomer Zhang Heng built a device to detect earthquakes. After his device indicated that a serious earthquake occurred west of the city, Zhang presented his findings to the emperor. The emperor did not believe him until a messenger brought observations of a big earthquake west of the palace. *The Dreamer of Star by Jillian Lin*
Obtaining, Evaluating, and communicating information	Able to communicate and persuasively the ideas and methods they generate.	No examples found in the books analyzed.

Table 11. Main Character

Code	Sub-code	Definition	Examples
Human/animal	Human		
	Animal		
	Other		E.g., aliens, robots, supernova
	None		E.g., invisible narrator
Gender	Male	Use of he/him pronouns	
	Female	Use of she/her pronouns	
	Unclear	No use of pronouns or other gender references	
	None		
Race	White	Use contextual clues	E.g., Drawing appears to be a brown-haired, white boy.
	Black	Use at least two contextual clues to draw conclusions about characters race	Character is a historical figure known to be African American, and the character is drawn with dark skin.
	Asian	Use at least two contextual clues to draw conclusions about characters race	Character is a historical figure known to be Chinese; and, multiple elements of historic Chinese culture are represented in the book.
	Latinx	Use at least two contextual clues to draw conclusions about characters race	E.g., Author is from Mexico and the character uses Spanish words and phrases.
	Other non-White but not specified in the text	Use contextual clues	E.g., Characters were drawn with multiple non-white skin tones and had names reflecting many different ethnic backgrounds.
	Other unknown	Not clear from contextual clues	
Age	Child		
	Adolescent		
	Adult		
	Other		
Disabilities	Character with disabilities	Main character with visible or invisible disabilities	E.g., Text describes the main character as having a visual impairment.
	Other		

Table 12. Own Voice Authors / Illustrators

Code	
Own Voice Author	# OwnVoices is a term that was coined by YA author, Corinne Duyvis. The term refers to books about characters from underrepresented/ marginalized groups in which the author shares the same identity. The writing is inspired by the author's own experiences and written from their own perspective.
Own Voice Illustrator	The illustrator shares the same identity as characters from underrepresented / marginalized groups.
Unknown	Not enough information is available about the author / illustrator.
Unclear	Information about the author is unclear or the main character's identity is unclear.
Other	E.g., any white author