

Article

STEM Storytime: Integrating STEM and Literacy in Early Childhood

Kenyon Page * and Daryl B. Greenfield

Department of Psychology, College of Arts and Sciences, University of Miami, Miami, FL 33124, USA; dgreenfield@miami.edu

* Correspondence: kenyonpage@miami.edu

Abstract

This paper addresses the call for greater integration of science, technology, engineering, and mathematics (STEM) in the context of creating a foundational focus for STEM, beginning in early childhood. The work draws on a birth-to-five developmental framework that models and connects seamlessly with the U.S. Framework for K-12 Science Education). These 3D frameworks integrate STEM across a small set of big ideas in four disciplinary areas (including engineering and technology), acquired through active engagement in science, engineering, and mathematical practices, and connected through meaningful cross-cutting concepts. In addition, this project addresses the challenges and obstacles that teachers face in effective implementation by leveraging teachers' comfort and young students' enjoyment of storybooks as an additional level of integration, as recommended by the U.S. National Academies of Sciences, Engineering, and Medicine 2022 consensus volume on science and engineering from preschool through elementary grades. Finally, given the increase in young children in the U.S. who are learning more than one language as well as in other countries, the current study examined the instructional practices of preschool teachers during shared book reading sessions using a Spanish-English bilingual STEM storybook in an intentionally Spanish-English preschool setting. Findings support an increase in teacher use of three-dimensional (3D) STEM talk to provide information upon re-reading the storybook, regardless of the language(s) used to read. Interviews with the teachers revealed approval for the translational-equivalent structure of the bilingual storybook, and an appreciation of the STEM-embedded content format for introducing the content to these young students. This study extends findings on teacher practices and language use with a bilingual STEM-focused storybook in a bilingual preschool setting to support bilingual learners.

Keywords: dual-language learners; early childhood; preschool; STEM education; storybook reading; teacher practices

Academic Editor: Zhongfeng Tian

Received: 5 May 2026

Revised: 15 June 2026

Accepted: 17 June 2026

Published: 30 June 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

High-quality STEM instruction is often lacking, particularly in early childhood education classrooms, due to several factors, including the self-perception of a lack of ability and comfort for teachers to engage in this academic content area (Choi, 2016; Gerde et al., 2018; Greenfield et al., 2009; Torquati et al., 2013). The new U.S. Framework for K-12 Science Education (NRC, 2012) takes a three-dimensional (3D) integrative approach to STEM teaching and learning, which the Early Science Framework (Greenfield et al., 2017)

developmentally tailored to extend this powerful integrated approach to learning to younger children. Despite the integration of STEM domains with this age-appropriate approach, barriers in teacher preparedness to communicate STEM learning persist.

Repeated, shared storybook reading supports language, fluency, and comprehension and is a commonly used medium of instruction in early childhood education settings (Anderson et al., 1985; Harris & Sipay, 1990; NICHD, 2000; Routman & Routman, 1994). Science has been shown to benefit multiple school readiness domains (Bustamante et al., 2018; Halpin et al., 2023) and bilingual storybooks are a strong support for DLL students' growth in both of their languages (Naqvi et al., 2013; Read et al., 2021a). Though few studies focus on the integration of these powerful approaches to support learning in early childhood education, these benefits have been suggested to be complementary when engaged in together (NASEM, 2022). STEM-focused storybooks may, therefore, be an effective context for integrated learning to bring high-quality instruction into these early education settings in a way that supports teacher abilities and engages young students, including those learning more than one language.

In classrooms with students who speak other languages in addition to English, teachers have greater demands on instructional planning and content creation for accessible materials for their dual-language learner (DLL) students in the context of an English-dominant education system (Hoff, 2013; NASEM, 2023, 2024). Significant achievement gaps are seen for young Spanish-speaking DLLs in language and literacy (Aikens & Barbarin, 2008; Espinosa, 2013; López & Gonzalez-Barrera, 2015; NCES, 2024; Nores & Barnett, 2014; Reardon & Portilla, 2016; Thompson et al., 2019) as well as science ability (Betancur et al., 2018; Curran & Kellogg, 2016; Morgan et al., 2016). By creating a resource that can provide the benefits of STEM learning for a linguistically diverse population, this method becomes a more widely accessible support for teachers and early childhood students.

The current project leveraged the bilingual abilities of students and teachers to understand the frequency and function of the use of each language during the shared book reading of a STEM-focused storybook that included both Spanish and English translational equivalent text. This further integrates STEM with language and literacy in an attempt to address the barriers to high-quality STEM learning in early childhood. The goal was to examine practices that can improve the effectiveness of this medium in scaffolding high-quality STEM instruction in a way that concurrently supports children's language development.

1.1. STEM Integration in Early Childhood Education

There has been a long-term national effort to increase STEM education in early childhood education because of its ability to build foundational school readiness skills and domains for long-term achievement (Early Childhood STEM Working Group, 2017; NASEM, 2022; NRC, 2007, 2012). Broader learning behaviors, including executive function, approaches to learning, language, and mathematics, are strengthened through STEM education (Bustamante et al., 2018; Guo et al., 2016; Halpin et al., 2023; Kermani & Aldemir, 2015; NRC, 2007, 2012; Taboada & Rutherford, 2011). Research also shows lasting benefits of early exposure, with kindergarten science engagement predicting immediate and long-term science achievement through third grade (Saçkes et al., 2011).

Although the literature supports the many benefits of early science education, there is a lack of time being spent on its instruction in preschool classrooms. Young children's natural curiosity is often under supported in the classroom with minimal or isolated science engagement and no space for science activities, which are overshadowed by isolated literacy and mathematics instruction (Gerde et al., 2018; Gopnik, 2012; NASEM, 2022; Tu, 2006). While 99% of teachers engage in literacy instruction three to four times per week, only 42% engage in science instruction at that frequency (Gerde et al., 2018).

As a result, the U.S. Framework for K-12 Science Education (NRC, 2012) was developed to create connections across domains from an inquiry-based learning approach that is more conceptual in nature. This was done using 3D learning to simulate real-world science and engineering. Engineering was integrated within scientific investigation to focus on deeper foundational knowledge building in a way that is equitable and accessible to all students.

Many of the pieces of the K-12 framework are highly relevant to early childhood education classrooms, where the students are natural scientists engaging in curiosity, exploration, and problem-solving. To extend the vertical continuity of learning for this population, the Early Science Framework (Greenfield et al., 2017) integrates the STEM disciplines into a cohesive learning experience that is 3D in its approach. The framework was developed to mirror the paradigm shift of the new K-12 framework from fact memorization on an array of disconnected topics to an engaging and experimental format that connects across content areas. Each aspect of STEM learning is represented within this framework; Engineering and Technology is a core content area and embedded in multiple crosscutting concepts (i.e., systems and system models; structure and function), and Mathematics is included as both a practice (i.e., using math and computational skills) and embedded in crosscutting concepts (i.e., scale, proportion, and quantity; patterns). Practices reflect the hands-on activities students engage in to answer their questions using the principles of the scientific method, core ideas include the topics students are curious about, and crosscutting concepts embody what students are trying to understand and how these are meaningfully learned in a way that can be integrated across content areas. Through this 3D approach, not only are the STEM disciplines integrated in an engaging way, but they also have the potential to be integrated with other academic areas to allow for STEM learning to occur throughout the day and in all settings by providing rich academic language that can be used to support students in their natural scientific inquiry.

1.2. Literacy and 3-Dimensional Science Learning

Despite children's natural interest in making sense of the world around them through science exploration and investigation, they still need adults to support this learning (Early Childhood STEM Working Group, 2017). Adults are not providing this support for a number of reasons, including teachers' lack of comfort and self-perceived inability to teach science (Choi, 2016; Torquati et al., 2013). Even with STEM integration with the 3D science learning approach, there is still significant burden on teachers as a result of this self-perceived low efficacy and lack of confidence around teaching STEM content (Choi, 2016; Gerde et al., 2018; Greenfield et al., 2009; Torquati et al., 2013). This may also stem from a lack of teacher training, given the overemphasis on literacy and language in preparation for kindergarten entry where these skills become strong predictors of academic achievement through eighth grade (Halle et al., 2012; Han, 2012). Further, many classrooms lack the resources and materials to engage their students in high-quality science and engineering learning.

One potential solution to this is the further integration with literacy to foster interdisciplinary connections through a common and comfortable medium for teachers that is enjoyed by students—storybooks. Storybooks are consistent in the literature as effective tools to support early language development through vocabulary and concept learning communicated in shared book reading activities that use verbal and non-verbal interactions (Breitfeld et al., 2021; Bus et al., 1995; Dowdall et al., 2020; Duursma et al., 2007; Fitton et al., 2018; Flack et al., 2018). Storybooks have also commonly been used to introduce scientific concepts and natural phenomena to children in a way aligned with storybook-based pedagogy's view of shared reading as an interactive instructional context that allows teacher-guided scaffolding of learning through discussion, questioning, and

connections between text and children's experiences (Leech et al., 2020; Leung, 2008; Miller-Goldwater et al., 2023). Regular and repeated reading results in a larger vocabulary, particularly for younger children, and supports math and reading readiness beyond language alone (Barnes & Puccioni, 2017; Farrant & Zubrick, 2012; Noble et al., 2019; Sénéchal et al., 2008). Shared book reading allows teachers to scaffold learning through adaptive responses to child engagement through support around incorrect responses or extension of learning following correct responses, which provide significant support to child development despite being less frequently used (Barnes & Dickinson, 2017; Blewitt & Langan, 2016; Deshmukh et al., 2019, 2022). Higher interaction quality and intentional reading strategies through open-ended questions and responsiveness to child engagement promotes expressive and receptive language development to benefit child outcomes (Flack et al., 2018; Noble et al., 2019; Sénéchal et al., 2008).

Alongside teacher comfort with storybooks, young students often eagerly engage with storybooks, making them a potentially powerful yet underutilized resource for supporting science content development without interfering with instructional time spent on language and literacy (Alatalo & Westlund, 2021; Leung, 2008; Miller-Goldwater et al., 2023). Teachers regularly use shared book reading as a method for engaging their students and the inclusion of rich science language and content within this medium can help to bridge the gap in science education with a method teachers are confident in implementing (Alatalo & Westlund, 2021). There is emerging evidence of a relationship between literacy and science that explores the unidirectional influence (Hopkins & Weisberg, 2021; Leech et al., 2020; Mantzicopoulos & Patrick, 2010; Neuman et al., 2011; Neuman & Danielson, 2021; Wright & Gotwals, 2017). It is likely that these relationships are actually bidirectional, with reading comprehension, vocabulary development, and scientific inquiry naturally being interconnected; strong language and literacy skills are foundational to scientific achievement (Jang et al., 2024). An entire chapter of the National Academies consensus volume (NASEM, 2022) explored the integration of science with other domains, including literacy, in the identification of these bidirectional benefits as preliminarily supported by commissioned papers (e.g., NASEM, 2020).

1.3. Accessibility for Bilingual Students

To promote academic success, determining effective instructional practices for students who speak more than one language is critical. It is projected that 40% of children in U.S. schools will have a home language other than English by the 2030s, most commonly Spanish (American Speech-Language-Hearing Association, 2015; Magruder et al., 2013; U.S. Census Bureau, 2022). About 4 million Spanish-speaking DLLs are enrolled in K-3, with Spanish-English DLLs being the fastest growing group (NCES, 2013, 2024; Passel et al., 2011). Early language experiences are essential to learning, with teacher language use (English, Spanish, or both) identified as a support for bilingual students (Burchinal et al., 2012; Raikes et al., 2019).

Children with a home language other than English often have limited exposure to English until formal schooling, an imbalance exacerbated by the English-dominant U.S. education system with limited access to non-English materials (Eilers et al., 2006; A. Hurtado & Vega, 2004; Welsh & Hoff, 2021; Worthington et al., 2011). As a result, DLLs tend to enter formal schooling at an academic disadvantage while being expected to obtain proficiency at the same rate as monolingual English peers (Evans & Hornberger, 2005; NCES, 2013; Oller & Eilers, 2002).

One strategy that supports bilingual development is the inclusion of the home language in instruction. Spanish-English bilingual instruction supports Spanish development without interfering with English growth across the school year (Barnett et al., 2007; Raikes et al., 2019). Although bilingual experiences vary, early language and literacy skills

predict academic success through eighth grade (Halle et al., 2012; Han, 2012). Because these skills are well established by school entry (Brown, 2014; Scarborough et al., 2009; Wilson et al., 2013), preschool is a critical period for strengthening school readiness for DLLs.

Storybooks provide a medium to connect both languages for DLL students, potentially offering more benefit than single-language literacy activities by building connections across languages (Brouillard et al., 2022; Domke, 2018; N. Hurtado et al., 2014; Méndez et al., 2015; Read et al., 2021b; Restrepo et al., 2013). Using both languages in instruction facilitates cognitive and language development (N. Hurtado et al., 2014), and bilingual children adapt to varied language formats in texts (Brouillard et al., 2022). Bilingual books also increase motivation by providing comfort and familiarity, while supporting motivation, comprehension, vocabulary growth, and metalinguistic awareness (Domke, 2018; Naqvi et al., 2013; Read et al., 2021b; Semingson et al., 2015). Parents value bilingual books for enabling use of their full linguistic repertoire, and teachers report them as effective tools to support comprehension and scaffold instruction (Domke, 2018; Noguerón-Liu & Driscoll, 2021).

1.4. The Current Study

Drawing from theory on modeling, scaffolding, and culture as key components of child learning, this study provides a developmentally appropriate and culturally relevant approach to closing the achievement gaps that are so prevalent upon kindergarten entry. Bronfenbrenner explains that models can exist in various levels of an interconnected system that makes up an individual's environment, which Bandura and Vygotsky posit can serve as experts to interact with the child and model a social learning process (Bandura, 1971; Bronfenbrenner, 2000; Vygotsky, 1978). A cultural revision of Bronfenbrenner's theory adds that culture is a dynamic and interacting component of these environments and social interactions, rather than a macro-level and distant force, where the learning is mediated through cultural tools or language and shared activity as explained by the Zone of Proximal Development (Vélez-Agosto et al., 2017; Vygotsky, 1978). Thus, development occurs through culturally situated activities that are co-constructed in daily contexts and inseparable in nature. These co-constructions often include guided participation in culturally meaningful activities such as storytelling and caregiving, particularly for young children (Rogoff, 2003). Active, participatory roles in learning that are informed by one's lived experience with their culture is practiced at the micro-level in everyday contexts, not as abstract macro-level indicators.

This project advantages the overemphasis placed on language and literacy instruction by meaningfully integrating 3D science into shared book reading to increase access to these rich and engaging learning experiences to help narrow the gaps in science knowledge in a way that simultaneously supports language development and conceptual understanding (Morgan et al., 2016). Teacher comfort with storybooks strengthened the choice of this medium for integration, a strategy that is especially promising for young DLL students by creating a bridge between their two languages. More transferable learning and deeper content knowledge occur as a result of strategic and responsive teacher talk in Spanish and English, particularly for Spanish-dominant students (Halpin et al., 2023; Rumper, 2019). The storybook was created to purposefully include relevant, everyday activities to the daily context of the students to provide opportunities for meaningful concept development and enhance the feasibility of engagement. Integration with a storybook that has high relevance and easy adaptation to the students aimed to foster interdisciplinary connections as well, built to reflect the students' natural curiosity using high-quality STEM and rich academic vocabulary to support their outcomes in language, literacy, and STEM.

Building on prior work, this study provides qualitative insight into the translational equivalent approach of incorporating both languages and STEM learning within a single storybook. The field lacks information around teacher practices with bilingual storybooks for a bilingual student audience, particularly for preschool children as the focus tends to be on kindergarten through third grade (Goldenberg, 2013). A DLL population can use a single language, though they naturally have access to both of their languages, so the inclusion of both within the same storybook facilitates the natural access these students have to both of their languages and supports connection of the two languages through a single medium for the teachers. By leveraging teacher comfort and student enjoyment of shared book reading, this project introduces a bilingual STEM-focused storybook to extend teachers' instructional repertoire with a strategy to build knowledge and support bilingual language development while fostering engagement and promoting equitable access to early STEM learning in a culturally and linguistically responsive way. It further extends the use of extratextual talk, known to be highly beneficial, to scaffold STEM learning which in turn improves multiple aspects of school readiness. Specifically, the study investigated:

(1) What STEM-related and language practices do teachers use across the full shared book reading session with a bilingual science book, including interactions immediately before and after reading the book? Do these vary based on language usage (e.g., English, Spanish, both) and across repeated readings?

(2) What supplemental behavioral practices, if any, do teachers engage in across the full shared book reading session with a bilingual science book, including interactions immediately before and after reading the book, to reinforce STEM learning? Do these vary based on language usage (e.g., English, Spanish, both) and across repeated readings?

(3) What benefits and challenges do teachers perceive when using a bilingual storybook to promote STEM learning in bilingual classrooms?

2. Materials and Methods

This was an exploratory, qualitative multiple-case study supplemented by descriptive quantitative analyses of coded teacher language practices and instructional behaviors. The data for this study were collected in the 2024–2025 school year at Miami Educare, one of the 25 birth-to-five early childhood centers in the Educare Learning Network (Educare Network|Advancing Excellence for Every Child, <https://educarenationalnetwork.org/> (accessed on 26 January 2026)). Miami Educare includes four preschool classrooms that were all part of the study. All classrooms are bilingual, with both Spanish and English used intentionally. Miami Educare is also a mixed-SES model where a subset of the infants, toddlers, preschoolers, and their families enroll with Early Head Start and Head Start funding.

2.1. Participants

Teachers

All eight teachers from the Miami Educare preschool classrooms were recruited for this study, four lead and four co-teachers. It is typical for each classroom to have one teacher assigned to Spanish instruction, and the other assigned to English instruction. Despite the designation as lead or co-teacher, there is much collaboration such that each teacher acts as lead for their assigned language of instruction. The teachers in Classroom 1 of the classrooms in this study were both the lead teacher at the time of their reading session, with one teacher hired as the lead teacher later in the school year, where the other teacher had been acting as lead teacher. Between the four lead teachers, there was an average of 16 years of education, an average of 16 years with children birth to eight, and 2.3 years spent teaching at Miami Educare. Three lead teachers were assigned to English

instruction, and one lead teacher was assigned to Spanish instruction. The four co-teachers had an average of 14 years of education, with an average of 18 years with children birth to eight, and 3.3 years at the Miami Educare site. Three co-teachers were assigned to Spanish instruction, and one was assigned to a mix of English and Spanish (in Classroom 1, one teacher was assigned to English when she was acting as the lead teacher, then Spanish once the other was hired as lead and assigned to English instruction). Seven of the eight teachers were Spanish-English bilingual, five of which identified as Spanish-dominant. The non-bilingual teacher spoke English. The racial/ethnic composition of the teachers included six Hispanic/Latine teachers, one Black teacher, and one Asian teacher. A table summarizing the demographics of the teachers can be found below in Table 1.

Table 1. Teacher demographics for the eight preschool teachers.

Variable	Value
Classroom Role	4 Lead Teachers; 4 Co-Teachers
Years of Education, M	16 years for Lead Teachers, 14 years for Co-Teachers
Years of Teaching Experience, M	16 years for Lead Teachers, 18 years for Co-Teachers
Race/Ethnicity	1 Black; 6 Hispanic/Latine; 1 Asian
Dominant Language ¹	3 English; 5 Spanish
Assigned Language of Instruction	3 Spanish; 4 English; 1 mix of Spanish and English

¹ All but 1 teacher are bilingual.

2.2. Measures

Qualitative Post-Interview

Following the recorded reading sessions, all teachers completed an interview on their strategies before, during, and after their storybook reading session. This included questions on their motivation behind the language they read in, and their perceived advantages and disadvantages to the format and structure of the storybook. These were conducted in the language most comfortable for the teacher, and the complete list of questions in both English and Spanish can be found in Appendix A.

2.3. Procedure

2.3.1. Creation of the Storybook

There are two dominant formats of Spanish-English bilingual books in the U.S.: code-switching books and translational equivalent books (Chaudhri and Torres, 2022; Gonzalez-Barrero et al., 2021). Code-switching books involve the interchangeable use of the two languages, often as intrasentential mixed language sentences. Translational equivalent books use two separate sentences to communicate the same content in each language (see Figure 1 for an example of each).

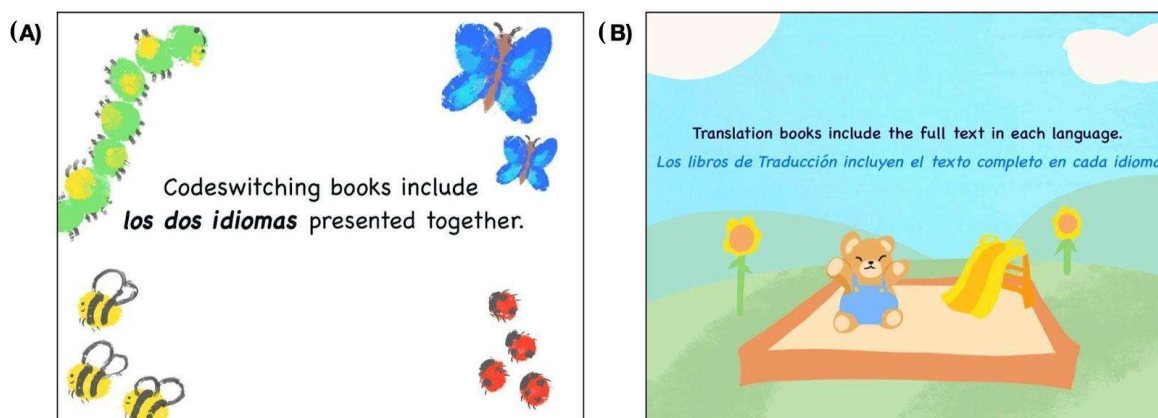


Figure 1. Illustrations of pages from Codeswitching and Translation books. Examples of how English and Spanish text tended to appear in (A) Codeswitching and (B) Translation books. Reproduced from (Potter et al., 2024).

The book in this study is a translational equivalent that combined two monolingual books (“Science is Everywhere” and “La Ciencia Está en Todas Partes”) into a single storybook. These were created in conjunction with the Early Science Framework (Greenfield et al., 2017) that includes a small set of big ideas in the core disciplinary science areas, science and engineering practices, and crosscutting concepts. The storybook uses rich STEM language, bolded for emphasis, in the context of daily routines (e.g., clothes engineered for hot versus cold weather; the technology of an ice pack for keeping ESI’s lunch cold as opposed to ice cubes that would melt and make the lunch wet; the size and shape of car wheels for driving to school; see Appendix B for the science talk coded). Three crosscutting concepts are highlighted: cause and effect (e.g., milk caused cereal to become soggy), stability and change (e.g., the sky changes from day to night), and structure and function (e.g., the hat is designed to cover the head and block sun from the eyes). Open-ended questions are embedded in the story to support interaction and critical thinking about the applicability of the story concepts to real life, foregrounding the STEM in daily routines (e.g., asking students to predict what caused the cereal to change from crunchy to soggy; asking students to construct an explanation of why the wheels are good for rolling to help a car move). In this way, the storybook is not solely about content, but active engagement in practices and concepts. Thus, the book itself is a 3D STEM education tool as it provides the rich academic language that allows teachers to support STEM learning. The main character of the story is ESI, a robot, engaging for young students, who is completing everyday activities that are commonly part of children’s daily routines (e.g., getting dressed for the day, packing lunch). This approach maps what the children are doing and experiencing onto vocabulary of attributes of concepts and content areas from the framework.

The book was created by developmental researchers and science experts, including those who developed the Early Science Framework (Greenfield et al., 2017), a developmental version of the revised Framework for K-12 Science Education (NRC, 2012). The concept of the book stemmed from identifying opportunities in preschool children’s daily routines to foreground 3D STEM learning, focusing on aspects of morning routines that are relatively universal (i.e., waking up, getting dressed, eating something, traveling to school). From a cognitive development perspective, children easily learn patterns through routines that have a sequence to them and repeat, with small variations in how they occur (Selman & Dilworth-Bart, 2023). While the activities may occur in different orders in different children’s routines, they all occur within the routine. These variations also invite real-life connections and engaging discussions with and among students.

2.3.2. Data Collection

The week before their first shared book reading session, the teachers were given the book to look over and familiarize themselves with, as is typical practice for any book being introduced in their classroom and instructed not to share the book with the class until their scheduled session. Recorded reading sessions took place over the Spring semester (January–April), during which time each teacher was video and audio recorded while reading the book twice for a total of four recorded reading sessions per classroom, as repetition and rereading have been shown to help children learn new vocabulary and language (Horst et al., 2011). The lead and co-teacher in each classroom alternated such that there were seven days between each teacher’s reading within a classroom, and about a month between an individual teacher’s two reading sessions. Following their reading

sessions, the book was removed from the children's reach to ensure their only exposure occurred during the recorded shared book reading sessions. For the shared book reading sessions, teachers were instructed to share the book as they normally would for observation of their typical practices and language use patterns. Once the study was completed, the book was given to the classroom to be freely accessible to the students.

While reading the storybook, the teacher wore a DJI Mic 2 wireless lavalier microphone clipped to their clothing to capture high-quality audio data with a range up to 250 m to allow for easy and uninterrupted recording. Video data were simultaneously collected from a window outside the classroom with an unobstructed view of the teacher and students. This setup facilitated the naturalistic observation of the session with minimal disruption to the classroom during data collection.

Each teacher completed a post-interview once all reading sessions were recorded, in which only audio data were collected using the same DJI Mic 2 wireless microphones, one for the teacher and one for the interviewer. The teacher chose the language they felt most comfortable completing the interview. Interviews lasted approximately 15 min and began with a reminder that there were no right or wrong answers as the goal was to understand their perspective and motivations for their practices sharing the storybook. These were transcribed similarly to the book reading sessions.

3. Results

3.1. Aim 1: What STEM-Related and Language Practices Do Teachers Use Across The Full Shared Book Reading Session With a Bilingual Science Book? Do These Vary Based on Language Usage (e.g., English, Spanish, Both) and Across Repeated Readings?

The following results integrate findings from coded observations of audio-recorded storybook reading sessions with teachers' perceptions and reported practices collected during post-interviews. Audio data were transcribed with (ATLAS.ti Scientific Software Development GmbH, 2023) (Version 23.2.1) auto transcription and checked for accuracy before segmenting at the utterance level in (ELAN, 2026) (Version 7.1) using CHAT conventions to systematically define utterance boundaries. Two different team members completed and checked segmentation to ensure accuracy prior to coding. An adapted language coding scheme from prior work on interactional patterns and language input (e.g., Dickinson & Smith, 1994; Melzi & Caspe, 2005; Schick et al., 2021) was modified to include the 3D STEM language from the Early Science Framework (Greenfield et al., 2017) and any themes that emerged from the data that were not already accounted for (see Appendix B for the science talk portion of the coding scheme). Measures used for analysis include the amount of Spanish and English used when reading the storybook text, measured as the proportion of the total reading in each language. The amount of Spanish and English extratextual talk that included STEM language during the book reading session was measured as a proportion of the total extratextual talk in each language. Within that, analyses were done on the functions of the extratextual talk (e.g., providing information, requesting information) which were measured as proportions of the total extratextual talk.

3.1.1. Storybook Reading

Results describe how teachers supported language, literacy, and STEM learning across classrooms, using within-teacher proportions and conditional comparisons to avoid conflating language absence with instructional choice as a result of teacher variation in use of English, Spanish, or both while reading. Overall, teachers produced an average of 75% of the utterances in a given reading session, about 27% of which included at least one of the three dimensions of STEM coded for based on the Early Science Framework (Greenfield et al., 2017).

When reading the storybook text, teachers read exclusively in their school-assigned language of instruction, with a single utterance of language mixing during the reading of the storybook text observed in the entire dataset. In three of the classrooms, one teacher read the storybook only in English and one only in Spanish. In the fourth classroom both teachers read storybook text in English, the assigned language of instruction for each of those teachers at the time of their reading sessions. STEM language was not coded for direct reading of the storybook text due to the nature of the storybook being written specifically to include this language, based on the Early Science Framework.

3.1.2. Extratextual Talk

While teachers exclusively used a single language while reading the storybook text, extratextual talk showed greater use of both languages and combination utterances, suggesting greater linguistic flexibility in interactions that extend beyond the printed text, even when both languages are available in printed text. The amount of STEM talk used outside of direct reading of the storybook text while remaining related in content was examined to understand not only the proportion of STEM extratextual talk as compared to the total extratextual talk, but also at what points during the shared reading sessions this occurred and what functions of language were used when incorporating STEM talk. The first versus second shared book reading sessions were compared within and between teachers within the same classroom, and across teachers and classrooms to identify consistencies and differences in practices.

Reading phase-level (prereading, reading, post-reading) proportions across all teachers compared the amount of science talk in each phase in the first and second reading sessions. The amount of STEM talk during the reading phase remained relatively stable, on average across all teachers, while the pre- and post-reading phases showed an average increase from the first to the second reading session (see Figure 2). With this, the question arose of how consistent across reading sessions STEM talk is when it tends to happen, both within and across teachers.

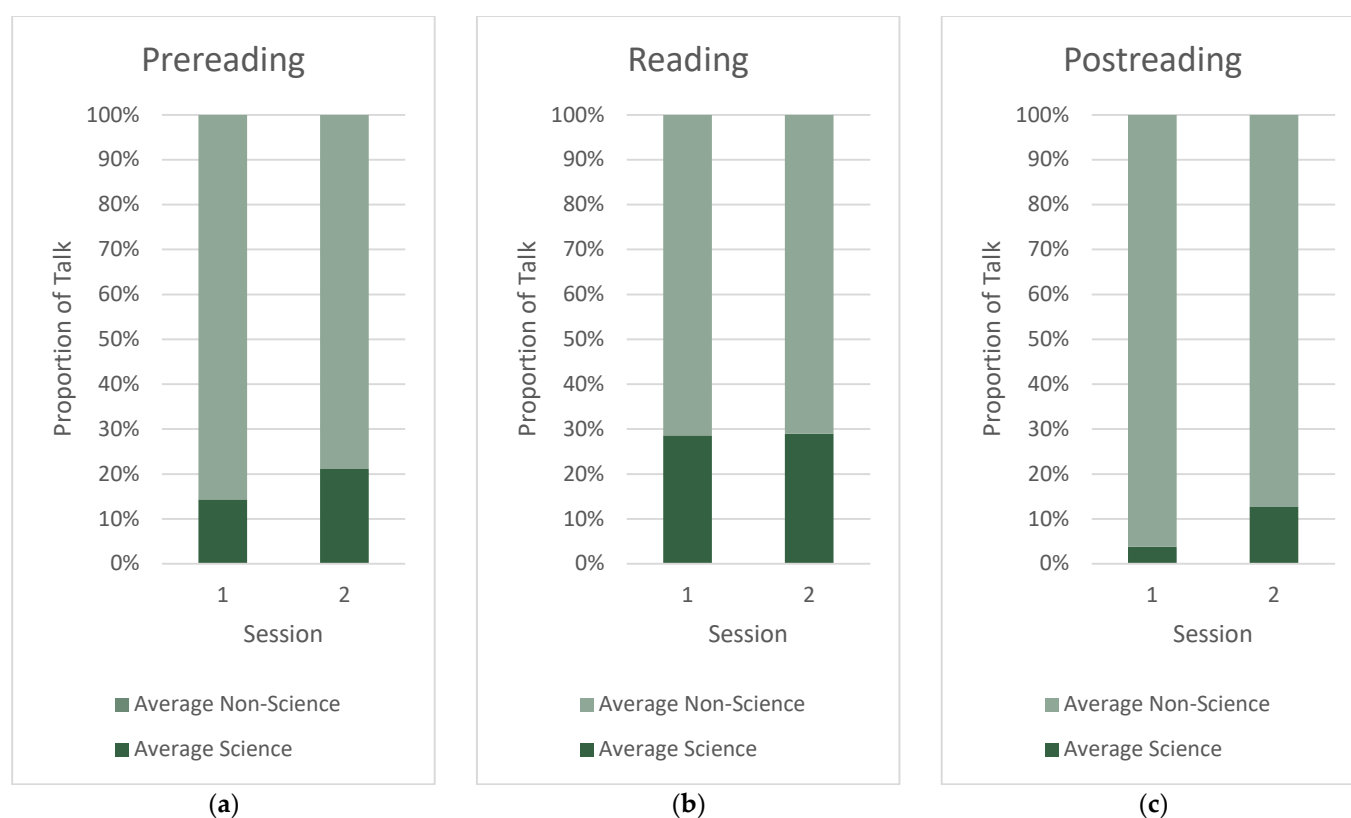


Figure 2. Proportion of teacher talk coded for science during (a) prereading, (b) reading, and (c) post-reading phases across two shared book-reading sessions. Values reflect averages computed within teacher and then across teachers.

Within individual teachers, the distribution of extratextual talk (both STEM and non-STEM) was generally stable from the first to second reading, with teachers engaging in about the same number of total utterances across each of the reading phases and the reading phase typically having significantly more utterances than pre- or post-reading. There were some variations from a teacher's first to second reading session, particularly in pre- or post-reading utterances and amount of STEM talk within each of those reading phases.

Across all teachers, a majority of the extratextual talk took place in the reading phase and there was meaningful variation in the pre- and post-reading phases between teachers, with some omitting those phases entirely in one of their two shared book reading sessions. Four teachers spent more time in pre-reading introducing the book and its contents in the first reading session, while the four others spent more time pre-reading in the second reading session. This split was such that one teacher from each classroom was in either group, making the total amount of time spent in pre-reading between the two teachers within the same classroom about equal.

Despite there being three classrooms where each teacher read the storybook in a different language, the two teachers within each classroom showed a similar trend in number of utterances. Most of the STEM talk occurred in the reading phase, and teachers had similar numbers of total utterances across reading phases.

Finally, across classrooms, there was substantial variation in the amount of extratextual talk and the proportion of that talk that included STEM. While Classroom 3 had the highest total amount of extratextual talk across reading phases and sessions, they did not have the highest proportion of STEM talk, which instead occurred in Classroom 1. Thus, more utterances during a reading session did not necessarily translate into more STEM talk. Classroom 3 also tended to spend more time in the prereading phase than other classrooms, though the second reading session of one teacher from Classroom 1 was similarly high, suggesting that the increased utterances in that classroom were spent introducing the book without necessarily focusing on its STEM content. All classrooms tended to have most of the extratextual talk and STEM talk in the reading phase, with all but one reading session having a very low amount of talk occur in the post-reading phase across all reading sessions such that teachers did not seem to extend the STEM talk immediately after finishing the storybook reading to the same degree with which they used STEM talk to introduce the book or while reading the text.

Every teacher had utterances of STEM talk during the reading phase of each of their reading sessions. Most commonly, STEM talk only occurred in two of the three reading phases, or only in the reading phase. Five reading sessions (of the 16 total) included STEM talk in each of the three reading phases. Nine of the shared book readings included no STEM talk in the post-reading phase, and six lacked any STEM talk in the prereading phase. Variations were visible between teachers and within teachers across sessions. For example, one teacher engaged in more STEM talk in S2 than in S1, in each of the phases. Another showed less STEM talk in prereading in S2 than in S1, and her co-teacher had the opposite trend with more STEM talk in prereading in S2 than in S1. Between teachers, some engaged in much more STEM outside of the reading phase (e.g., two co-teachers in S2 prereading). Additionally, three teachers engaged in a much higher proportion of STEM talk during the first reading whereas one teacher had a higher proportion in the second reading.

Within-teacher comparisons of the first and second shared book reading sessions showed some changes in instructional practices. For each teacher, proportions of STEM

talk and language function categories were separately calculated for reading session one and reading session two, followed by computing change scores, treating each teacher as their own comparison to capture stability and change across readings while controlling for variability in language use between teachers. A ± 2 percentage points stability band was used to reflect minimal session variation within a teacher.

There was an increase in overall STEM talk from reading session one to reading session two for half of the teachers, two of whom read in Spanish and two who read in English. Two teachers remained relatively stable in their STEM talk across reading sessions, one who read in Spanish and one who read in English, and two teachers who read in English showed an overall decrease in STEM talk (see Table 2).

Table 2. Change in Science-Coded Teacher Utterances from reading session 1 to reading session 2.

Reading Language	Overall STEM Talk S1	Overall STEM Talk S2	Change in Overall STEM Talk	Extratextual STEM Provisions of Information S1	Extratextual STEM Provisions of Information S2	Change in Extratextual STEM Provisions of Information	Extratextual STEM Requests for Information S1	Extratextual STEM Requests for Information S2	Change in Extratextual STEM Requests for Information
EN	39%	49%	10%	21%	33%	11%	37%	35%	−2%
EN	38%	30%	−8%	38%	37%	−1%	25%	23%	−2%
EN	15%	18%	4%	22%	30%	8%	15%	14%	−1%
EN	31%	27%	−3%	35%	26%	−8%	26%	15%	−11%
EN	20%	22%	2%	19%	26%	7%	32%	16%	−16%
SP	16%	24%	8%	13%	26%	13%	19%	23%	4%
SP	22%	24%	2%	14%	16%	1%	22%	26%	3%
SP	26%	30%	5%	22%	28%	6%	28%	26%	−2%

Proportions represent the amount of STEM talk as compared to the total amount of that function of talk (e.g., 21% of the total extratextual talk provisions of information included a STEM code); EN = English, SP = Spanish. Green indicates an increase, red indicates a decrease, no color indicates stability.

Follow-up analyses were conducted to examine the pragmatic functions of teacher talk and the changes in STEM talk within the most frequent functions. Follow-up analyses were conducted to examine the pragmatic functions of teacher talk and the changes in STEM talk within the most frequent functions. The primary functions of extratextual talk across all teachers were provisions of information (i.e., statements of information in a “telling” form) and requests for information (i.e., eliciting information from another individual or group of individuals as direct or indirect questions), and these functions typically included significant portions of a teacher’s STEM talk. Five teachers, regardless of the language they read in, increased the amount of information they provided related to the story that included STEM talk in their second reading session as compared to their first. Two teachers, one who read in Spanish and one who read in English, remained relatively stable and one teacher who read in English showed a decrease. Requests for information showed a different trend, with half of the teachers remaining relatively stable and most being teachers that read in English. Two teachers who read in Spanish asked more STEM questions related to the story upon re-reading, and two teachers who read in English asked less.

To investigate teachers’ motivations behind their reading strategies, brief post-interviews were conducted in the teacher’s language of preference, and any Spanish information was translated to English for incorporation into this paper (see Appendix A for interview questions).

As the study was conducted in an intentionally bilingual school, where all but one teacher was bilingual, teachers were asked about their decision to use Spanish and English the way they did in their reading session. One teacher shared that they are assigned languages of instruction in an effort to ensure the students receive a significant and balanced exposure to both Spanish and English; *“Hay dos maestras, una en español y otra en inglés... ya los niños están preparados cuando es que le toca el español y cuando es en inglés.”* [There are two teachers, one for Spanish and one for English in each classroom]. This was reflected in the single-language reading of the storybook text by all eight teachers in their assigned language, as well as a large majority of all other talk in the reading sessions being in their assigned language. In the case of students engaging in the opposite language during the reading session, two teachers report that they adjust flexibly to the students’ comfort and encourage participation in the students’ preferred language, while two other teachers shared that the co-teacher who is assigned that language of instruction will engage with those students during the shared book reading sessions. Five teachers shared that they didn’t view language dominance as a barrier to understanding and engagement in the shared book reading sessions, especially given three of the four classrooms had one teacher who read in each language, so the students heard the book in both languages. One teacher who read in Spanish after the other teacher in her classroom read in English, asked students to explain in Spanish what they remembered from the English reading session to build that connection.

“Tuve la fortuna de que ya lo habían leído en inglés. Entonces ellos tenían ya una opinión al respecto, un conocimiento previo... Entonces ya están como conectando otra vez lo que previamente leímos y él lo está haciendo un niño en su idioma, en su vocabulario, usando palabras que ellos entienden más entre ellos.”

[I was fortunate that they had already read it in English. So they already had an opinion about it, some prior knowledge... So now they are kind of connecting again what we previously read, and he is doing it as a child in his own language, in his own vocabulary, using words that they understand better among themselves.]

The teachers in Classroom 4 allowed students to engage and make connections in either language to promote bilingual understanding, rather than limiting them to the language they were reading in.

3.2. Aim 2: What Supplemental Behavioral Practices, If Any, Do Teachers Engage in Across The Full Shared Book Reading Session With a Bilingual Science Book, Including Interactions Immediately Before and After Reading The Book, to Reinforce STEM Learning When Reading a Bilingual Science Book? Do These Vary Based on Language Usage (e.g., English, Spanish, Both) and Across Repeated Readings?

The video recordings of the shared book reading sessions complemented the analyses with non-verbal behaviors or gestures that were inductively coded and analyzed. These were transcribed using CHAT conventions (e.g., [=! point:eyes] when a teacher pointed to her eyes during a discussion of sun protection) and sorted into themes.

Teachers used a variety of supplemental behaviors during their shared book reading sessions to reinforce STEM learning (see Table 3). All teachers, regardless of language read in, used book-related gestures, including behaviors like: connecting the book to real life (i.e., pointing outside when reading about how the sky looked); using facial expressions, gestures, or sounds to support communication of the story (i.e., imitating an alarm beeping when discussing how technology helps them wake up in the morning; multiple teachers imitated brushing their teeth when reading that part of the story); bringing physical materials to support student understanding (i.e., using a round and square block to demonstrate roll versus slide when reading about wheels); using flashcards with

vocabulary words and pictures based on the story content. One teacher joined in on a song the students began singing related to story content (wheels on the bus during the discussion of round wheels on the car) and provided words to students when they trailed off. One teacher broke down a vocabulary word into syllables with clapping to support the students' understanding.

Table 3. Behavioral codes during the reading session. Behaviors in support of STEM learning were categorized into themes as shown in the table. The counts of the number of behaviors from each category are separated by teacher and reading session.

Behavior Teacher and Session	Language Read In	Task Organization	Numeracy Awareness	Picture Alignment	Book-Related
148 S1	EN	-	-	3	2
148 S2	EN	1	2	5	3
25 S1	EN	2	1	9	35
25 S2	EN	-	-	7	6
141 S1	EN	8	-	5	20
141 S2	EN	1	-	2	16
121 S1	EN	39	-	18	86
121 S2	EN	18	4	8	74
22 S1	EN	8	-	2	4
22 S2	EN	5	-	4	31
51 S1	SP	2	-	1	25
51 S2	SP	1	-	12	12
57 S1	SP	9	-	16	37
57 S2	SP	5	-	11	41
116 S1	SP	9	-	3	23
116 S2	SP	6	5	-	33

EN = English, SP = Spanish.

All teachers engaged in task organization behaviors in both of their reading sessions, except for two teachers who only used these behaviors in one of their reading sessions. These included modeling the desired behavior (i.e., multiple teachers raised their hand to reinforce the fact that they wanted students to show the desire to participate in that way) or organization of student participation (i.e., one teacher pointed to herself while explaining when it was her turn to read). From Classroom 3, both teachers modeled thinking and questioning (i.e., putting on a thinking cap when asking students to think, gesturing with palm up when asking a question), practices highlighted in the Early Science Framework. One teacher held up her hand when asking students to stop talking over each other and allow all students to engage with creating connections to the story.

Picture alignment behaviors, showing students the book picture to emphasize the storybook text with or without pointing to specific parts, were used in each of the teachers' reading sessions except one teacher who only used this behavior in one reading session. After a storybook-prompted question, one teacher brought the book closer to the students so they could see the picture as they considered their answers. These gestures connected the text to the photo to scaffold the open-ended questions asked about each concept.

Numeracy awareness behaviors were engaged in by four teachers in their reading sessions, all using their fingers to visually represent numbers. One teacher held up the number of fingers showing how many students she wanted to share, as well as when counting the number of syllables in one of the book's bolded vocabulary words (structured). Another teacher held up the number of fingers showing how many things she wanted the students to share and counted on her fingers the number of times a student

shared they typically brush their teeth. One teacher counted on her fingers while recalling the story's sequence of events. Another teacher counted on her fingers as the class counted wheels, and at the end of the session she encouraged students to clap with her using a decreasing number of fingers (i.e., clap with four fingers, three fingers, two fingers, one finger).

Generally, all teachers engaged in multiple categories of behavior to complement their shared book reading, with book-related gestures in support of STEM learning being most frequently used in every reading session. There were no visible differences based on the language the teacher read in, with all teachers engaging in similar types and frequencies of supplemental behaviors.

3.3. Aim 3: What Benefits and Challenges Do Teachers Perceive When Using a Bilingual Storybook to Promote STEM Learning in Bilingual Classrooms?

Post-interview audio data were transcribed with Atlas.ti (Version 23.2.1) auto transcription and checked for accuracy as in the first aim. Results were qualitatively analyzed for emerging themes and described.

Among the post-interview questions, teachers were asked the advantages and disadvantages they perceived with the structure and format of the storybook. This included its translational equivalent format, as well as its STEM-embedded content, as a way to support the preschoolers in their classrooms and the teachers themselves in communicating this content. Teachers generally appreciated the format of a storybook to facilitate STEM learning. One teacher shared that *"Los niños se conectan fácilmente en todos los aspectos, en todas las áreas, emocional, cultural, lenguaje, feelings, todo... Los libros traen gran mensaje, son historias de vida... Es una buena manera de atraer la atención de un pequeño que está empezando, de conocer el mundo a través de los libros."* [Children connect easily [to the storybooks] in every aspect, in every area: emotional, cultural, linguistic, feelings, everything... Books carry great messages, they are stories of life... It is a good way to capture the attention of a young child who is just starting out, to learn about the world through books].

Seven of the eight teachers reported seeing no disadvantages of the format and structure of the storybook, with many instead reiterating the strengths they saw. One teacher practices strict language separation in her classroom and reported that it may be confusing to students to see both languages at the same time in language-specific instruction, and another shared that some students *"might understand, but are not able to communicate"* in the other language in the book as a potential challenge.

Teachers shared many similar advantages of the bilingual structure of the storybook. One common advantage shared was the ability to ensure all students could understand the story by including both of their languages, as well as modeling how to navigate between languages and immediately clarify vocabulary words and meanings, given the ability to reference the text in either language in real-time. Many teachers also shared that the translational equivalent format supported the students' bilingual comprehension, with one teacher adding that this is a benefit for the teachers as well (*"Muy importante, tanto para el maestro como para el niño."* [It is very important for both the teacher and the child.]). Some teachers also shared appreciation for the ability to use the exact same materials in their respective languages, allowing both teachers to communicate about the book's content with ease. Overall, they appreciated how the bilingual format fit in their bilingual school community, with one teacher sharing *"me encantaría que todos los libros fueran así"* [I would love if all books were like this] and another stating that she *"would highly encourage that most of the books, especially this school is bilingual school"*, highlighting the increased benefit of having translational equivalent, high-quality STEM language embedded into the storybook as a way to support STEM learning in early childhood education classrooms.

4. Discussion

This exploratory study observed preschool teachers' classroom practices using a bilingual STEM-focused storybook created from an integrated early childhood STEM framework (Greenfield et al., 2017) in a Spanish-English bilingual school. It investigated the integration of STEM and literacy, and the use of a translational equivalent format for support of DLLs, with the goal of finding an easy-to-use medium for teachers to incorporate more high-quality 3D STEM learning. The study drew attention to the role of the teacher, investigating the degree to which teachers used STEM language before, during, and after within the repeated shared book reading sessions, with the hope that teachers begin to use these domains in their own talk to support the students. It highlights that, despite variability in teachers' approaches to using a storybook to support STEM learning, all teachers extended their STEM talk either immediately before or after reading the story, and most increased their science talk in their second reading. Thus, although teachers differed in the functions and frequencies of their instructional practices, several consistent patterns emerged within and across classrooms. The study further does this with a focus on a combined translational equivalent format book to begin to understand teacher practices with this style of book. The storybook involves an engaging robot main character (*"El solo hecho del robot le llamó la atención a los niños"* [*Just the fact of the robot caught the children's attention.*]) across a morning of familiar daily routines of young children (e.g., getting up, eating breakfast, getting dressed, going to school). Rich STEM language and open-ended questions were embedded in these routines to scaffold the discussion of three 3D STEM learning.

Using an integrated early childhood STEM framework (Greenfield et al., 2017) for a STEM focused storybook with an engaging character going about typical preschool morning routines, shows promise in supporting STEM learning for preschoolers, including bilingual children. Results showed that the translational equivalent storybook could be an effective method for increasing the amount of rich STEM language and learning in early education classrooms with a diverse student population. Upon rereading the storybook, teachers often engaged in more STEM talk with their students, with most teachers including more STEM-related provisions of information, and some including more STEM questions. Many teachers provided more STEM-related information, which may suggest a higher degree of scaffolding from an increased comfort or confidence in communicating STEM concepts as supported through the structure of the storybook. Teachers produced more STEM talk in their second reading session, extending the conversations had in the first reading session. The result of most teachers asking a stable amount of STEM-related questions to the students might suggest that the embedded open-ended questions provide enough scaffolding of the concepts and elicit enough student engagement in critically thinking how the story applies to their lives. Student engagement is often a key predictor in learning (Barnes & Puccioni, 2017; Flack et al., 2018) and encouraging teachers to elicit student understanding and support in creating connections to the STEM content may further the benefits of this strategy. Whether increased provisions of information or requests for information are most effective in scaffolding STEM instruction, while supporting bilingual language development, should be further explored.

Bronfenbrenner's ecological systems theory provides a useful framework for interpreting these findings. At the micro-level, teachers supported children's engagement in STEM through discussions connecting their daily routines and experiences to those shared in the storybook. These interactions may help bridge learning across home and school contexts, highlighting the mesosystem connections that are particularly important for multilingual learners. The use of bilingual storybooks also reflects broader language environments and educational values that support multilingualism, illustrating how influences beyond the immediate classroom can shape opportunities for STEM learning and

the way culture is embedded at every level, as stated in the theory's cultural revision (Bronfenbrenner, 2000; Vélez-Agosto et al., 2017). Viewed through this ecological lens, storybook reading represents a context in which multiple systems interact to support children's developing understanding of STEM concepts.

The storybook was purposefully written to foreground 3D STEM in a way that easily connects to preschool children's daily lives, using common parts of a morning routine and highlighting the opportunities for STEM learning within them. This is a strategy that could be successfully implemented by teachers and parents in everyday activities these young students naturally engage in. Further, these everyday activities from the book can be readily linked to active learning and concept development. Teachers reported engaging in related activities in the days following the storybook reading, including ones discussed in the story (*"El libro hablaba también de experimentos, entonces los experimentos se los hice visualmente para que ellos lo vieran."* [The book also talked about experiments, so I performed them visually so that they could see them.]). Many teachers also reported students talking about concepts from the story as they engaged in their daily routines in the classroom (*"One of my students was like, remember the robot did this in the book? And I was like, and what made it bubbly? And they're like, the water made the toothpaste bubbly. So now they're connecting it back to real life."*).

Storybooks as a strategy for supporting early STEM learning can fortify student outcomes without placing additional burden on early childhood education teachers. By designing a book on daily activities familiar to adults and children, the topics can be easily discussed prior to reading to prepare the students. By framing 3D STEM learning as hands-on, active exploration within daily routines and incorporating crosscutting concepts that connect across STEM domains, this storybook provides a more coherent view of how the world works, one that aligns with young children's natural curiosity. Teachers appreciated this strategy in scaffolding STEM discussions with their students, and as a resource for themselves through which to engage.

Beyond the verbal language used, teachers also engaged in supplemental behaviors to facilitate the shared book reading session and scaffold the STEM learning in the storybook. Teachers inherently create hands-on learning opportunities for young students by bringing in objects or using gestures. The storybook provides the language to support the teachers as they naturally engage in these interactive strategies to scaffold student engagement and comprehension. These behaviors did not exclusively occur in the reading phase (i.e., one classroom used popsicle sticks with vocabulary words and pictures from the story in the prereading phase to prepare the students for the concepts they would read about). Future studies should explore how this practice may be leveraged in other classroom areas to extend STEM learning and allow for deeper connections across content areas.

Alongside supporting the incorporation of STEM into early childhood education classrooms, the bilingual format of the book presents STEM in a way that advantages DLL students by providing the concepts and academic vocabulary in both of the children's and teachers' languages. This study was conducted in a purposefully bilingual setting with explicit language roles for the teachers. Results showed similar amounts and functions of input by each teacher in their single-language, independent reading sessions that supports balanced input of high-quality academic language in both Spanish and English. Teachers appreciated having both languages available within the same storybook as support for bilingual comprehension, particularly in this school where teachers were confident that a student's dominant language was not seen as a barrier to understanding or engagement in any of the classrooms.

4.1. Limitations and Future Directions

This study is not without its limitations, one of which being the high-quality early education program of the Educare Learning Network potentially limiting generalizability of these findings to typical early education contexts. An additional limitation is the small sample size of teachers. Also, this study did not collect proximal measures to assess language and STEM targeted by the storybook content, which could limit the understanding of the impact on child outcomes. DLLs' school readiness and long-term language development is often enhanced by participation in high-quality early education programs (Hammer et al., 2014) and exposure to native-speaker input in both languages which is shown to be beneficial for robust language development (Place & Hoff, 2011, 2016) and could be a contributing factor to the language development of the students in this sample. Future work should extend to other, larger early childhood education settings to gain a broader perspective on teacher practices. The addition of collecting proximal measures to capture the learning and skills gained from reading and rereading a STEM-embedded story would also be beneficial.

A closer look at the language occurring in these classroom settings, both during and after storybook reading, may reveal more nuanced patterns of STEM talk as it relates to supporting student understanding of STEM learning. Investigating how the STEM-language from the storybook focused on three crosscutting concepts that allow for cross-domain learning that may extend beyond the shared book reading context and into other classroom activities such as those reported in the post-interviews may provide a better understanding of the full impact this integration may have as a STEM support. Further, this study showed that majority of teacher talk occurs during the reading phase of the storybook, leaving opportunities to assist teachers in engaging in prereading and post-reading to increase the support of children's learning. The increased engagement in STEM talk observed during the second reading session suggests the potential for further engagement if STEM-related conversations were deliberately introduced before the reading and extended afterwards. It further suggests that the storybook may scaffold teachers' ability to support STEM learning in the classroom as children naturally engage in curious, goal-directed sense-making.

The distinction identified in this study has clear pedagogical relevance and may inform future research on bilingual STEM learning and instructional design. Future studies should examine how variations in teachers' practices during storybook reading relate to child learning outcomes, particularly in science understanding and language development. Research should further consider individual differences in bilingual profiles of both teachers and children, as variation in language proficiency may shape how storybook-based STEM instruction is delivered and received. Additional work is needed to investigate whether these patterns generalize across different bilingual book formats, such as code-switching texts versus dual monolingual (translation-equivalent) books. Teachers in this study appreciated the translational equivalent approach, however there is likely no one-size-fits-all approach to bilingual STEM storybook instruction. Comparative research is also needed to evaluate how different bilingual storybook approaches may differentially support learning, particularly given that teachers may vary in comfort and proficiency with code-switching.

4.2. Implications

The integration of STEM content with literacy in the format of a storybook shows promise as a way to support teachers and increase the STEM learning occurring in early childhood education classrooms. This medium is commonly used by teachers, and they are comfortable using storybooks to share information with young students, who enjoy the reading of storybooks. This specific book exposes the teachers and students to 3D STEM language that integrates the STEM disciplines in an engaging and developmentally

appropriate way, while providing opportunities for discussions about the content before, during, and after the readings. The topics in the storybook were designed to be easily extended in classrooms and at home because of the way it was purposefully written about a robot in routine contexts children engage in every day. The bilingual format provides an additional opportunity for supporting monolingual and bilingual students, as it is appropriate for supporting the languages together and each language individually. Overall, results from this study shed light on preschool teachers' classroom practices in support of STEM and bilingual language learning by taking advantage of a medium frequently used across languages and classrooms, lessening the burden on teachers while increasing the benefits for those in early childhood education settings by bringing forward opportunities to engage in this high-quality learning. (*"La ciencia está en todo. Entonces, siempre conectamos cada día, tanto en la rutina, porque es parte del día."* [Science is everywhere. Therefore, we are always connected to it every day, even in our daily routine, because it is part of the day.]).

Author Contributions: Conceptualization, methodology, software, validation, investigation, resources, analysis, project administration, writing—original draft preparation, K.P.; supervision, writing—review and editing, D.B.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. Access to the classrooms was provided by a partnership between the second author and the United Way as part of their membership in the National Educare Learning Network.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of The University of Miami (protocol code 20090301 on 29 May 2009).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets presented in this study are not readily available because they contain sensitive information from participants and are part of an ongoing research program. Requests to access the datasets should be directed to the corresponding author.

Acknowledgments: We would like to thank the teachers and students who participated in the study and allowed us to use their data for this project, without whose partnership this would not have been possible.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

STEM	Science, Technology, Engineering, and Mathematics
DLL	Dual-language Learner
3D	Three-dimensional

Appendix A. Qualitative Post-Interview Questions

English:

*** Remind them that there is no right or wrong answer, these questions are just to better understand the reasons for how they read the book

1. Before reading a new book to the class, are there strategies you have to prepare yourself and the students? If so, what are they?
 - a. Did you do anything different for this book?

- b. Given your class is bilingual, is there anything you do in relation to the children's 2 languages?
2. When you are reading, what are your strategies to engage the students?
3. What was your strategy in how to read the book, knowing you had both languages available?
 - a. I notice that you chose to read in a single language, how did you choose which language to read in?
 - i. Did you include the other language while reading? If so, what was your strategy for doing that?
 - ii. What were your thoughts about the students whose dominant language was not the language you chose to read in?
4. What are your thoughts about the advantages of having both languages on the same page?
 - a. What are your thoughts about the disadvantages of having both languages on the same page?
5. Did you do any activities related to the book after reading it? If so, what were they?
 - a. If not, can you give an example of a follow-up activity you did with another book?
 - b. If yes, do you typically do this with new books that you read?

Spanish:

*** Remind them that there is no right or wrong answer, these questions are just to better understand the reasons for how they read the book — “No hay una respuesta correcta o incorrecta, estas preguntas son solo para comprender mejor las razones de cómo leyó el libro.”

1. Antes de leer un libro nuevo en la clase, ¿tiene estrategias para prepararse y preparar a los estudiantes? Si es así, ¿cuáles son?
 - a. ¿Hizo algo diferente para este libro?
 - b. Dado que su clase es bilingüe, ¿hay algo que haga en relación con los dos idiomas de los niños?
2. Cuando usted está leyendo, ¿cuáles son sus estrategias para involucrar a los estudiantes?
3. ¿Cuáles son sus estrategias para leer el libro, sabiendo que tenía ambos idiomas disponibles?
 - a. Eligió leer solo en un idioma, ¿cómo eligió en qué idioma leer?
 - i. ¿Incluyó el otro idioma al leer? Si es así, ¿cuál fue su estrategia para hacer esto?
 - ii. ¿Qué pensó sobre los estudiantes cuyo idioma dominante no era el idioma que eligió para leer?
4. ¿Cuáles cree que son las ventajas de tener ambos idiomas en la misma página?
 - a. ¿Cuáles cree que son las desventajas de tener ambos idiomas en la misma página?
5. ¿Realizó alguna actividad relacionada con el libro después de leerlo? Si es así, ¿cuáles fueron?
 - a. Si no es así, ¿puede darme un ejemplo de una actividad de seguimiento que ha hecho con otro libro?
 - b. Si es así, ¿hace esto con los libros nuevos que lee?

Appendix B. STEM Codes from the Language Coding Scheme

<https://doi.org/10.3390/educsci16071043>

Adult-Child Science Book Reading Styles Coding Manual

Adapted from Schick et al. (2021) & Miller-Goldwater et al. (2023)

General Guidelines:

- This coding scheme will be used for teacher-child and parent-child interactions during shared book reading sessions.
- All interactions are coded using ELAN.
 - o **Practices** codes go under the %prc tier.
 - o **Crosscutting Concepts** codes go under the %ccc tier.
 - o **Core Ideas** codes go under the %cor tier.
- All interactions are coded on the utterance level. Utterances were identified at the time of transcription by grammatical closure and intonation.

6. STEM TALK—PRACTICES

General Guidelines:

- Only utterances that are coded as PRO, REQ, or RES for Pragmatic Function will be considered for the following subsections.
- Any utterance may include one or none of the codes in the following subsection.

Code	Definition	Example
Observing and describing :OBS	Utterances related to using senses and tools to collect information.	*TEA: what do you see?
Asking questions and defining problems :ASK	Utterances related to displaying interest and curiosity, demonstrating what they know and what they do not, and identifying something that needs a solution.	*PAR: what's inside of a ball? *PAR: the juice spilled on the floor and we need to clean it up.
Making predictions :PRD	Utterances related to using knowledge from observations and prior experiences to make an informed hypothesis.	*TEA: what do you think will happen if I put ice cubes in my lunchbox?
Developing and using models :MOD	Utterances related to mentally and physically representing real world phenomena to develop and deepen their understanding.	*TEA: let us use this ball like a wheel to see how it moves.
Planning and carrying out investigations :INV	Utterances related to encouraging or helping children organize and implement a procedure to test a hypothesis.	*TEA: if we want to see what would happen to the cereal how would we do that?
Using math and computational skills :MAT	Utterances related to encouraging or helping children use math to quantify and describe their world.	*TEA: and how many wheels does a car have? *TEA: one two three four.
Documenting, analyzing, and interpreting :DOC	Utterances related to encouraging or helping children record, organize, and make sense of data.	*TEA: why would he choose to wear the t shirt?
Constructing explanations and designing evidence-based solutions :EXP	Utterances related to interpreting data to gather evidence-based answers to their questions and design solutions to problems.	*PAR: I know spiders are alive because they crawl.
Obtaining, evaluating, and communicating information :COM	Utterances related to encouraging or helping children document and share their observations, explanations, and conclusions.	*TEA: why do you think that?

7. STEM TALK—CROSSCUTTING CONCEPTS

General Guidelines:

- Only utterances that are coded as PRO, REQ, or RES for Pragmatic Function will be considered for the following subsections.
- Any utterance may include one or none of the codes in the following subsection.

Code	Definition	Example
Patterns :PAT	Utterances related to the idea that processes, events, and structures repeat.	*TEA: the sun rises in the morning and sets at night each day.
Cause and Effect :CE	Utterances related to the idea that change in one event, process, or structure is the result of something else.	*TEA: the ice melted and made the lunch-box all wet.
Scale, Proportion, and Quantity :SPQ	Utterances related to the idea that things differ in size and quantity, which can be used to help identify patterns and draw conclusions.	*TEA: is the robot big or small?
Systems and System Models :SSM	Utterances related to the idea that all things exist and interact in organized systems.	*PAR: the gears and parts of a wind-up toy exist within a system and interact to make it function.
Structure and Function :SF	Utterances related to the idea that the way things are built and/or organized determines what they do and how they do it.	*TEA: round things roll.
Stability and Change :SC	Utterances related to the idea that some things change and some things stay the same.	*TEA: the ice pack helps the lunch to stay cold.
Energy and Matter :EM	Utterances related to the idea that all things take up space and some things have the ability to do work and change puddles, other things.	*PAR: the sun heats up and evaporates

8. STEM TALK—CORE IDEAS

General Guidelines:

- Only utterances that are coded as PRO, REQ, or RES for Pragmatic Function will be considered for the following subsections.
- Any utterance may include one or none of the codes in the following subsection.

Code	Definition	Example
Physical Science :PS	Utterances related to physical properties, forces, energy, or light and sound.	Physical Properties—*PAR: liquid can be made solid by freezing. Forces—*PAR: kicking a ball makes it roll. Energy—*PAR: winding a toy makes it move. Light and Sound—*PAR: light waves can be blocked by certain objects creating a shadow.
Life Science :LS	Utterances related to living things, ecosystems, heredity and traits, or biological evolution.	Living Things—*PAR: roots help trees absorb water. Ecosystems—*PAR: birds use twigs from their surroundings to build nests. Hereditary and Traits—*PAR: all dogs have four legs, but some are small and others are big.

Earth and Space Science :ESS	Utterances relate to Earth's place in the universe, systems, or Earth and human activity.	Biological Evolution—*PAR: lizards resemble dinosaurs.
		Earth's Place in the Universe—*PAR: the sun is visible during the day and the moon is best visible during the night.
		Systems— - Rivers, civilizations *PAR: a squirrel lives in a place with lots of trees because it uses trees for shelter and food.
Engineering and Technology :ET	Utterances related to engineering design or the links among science and technology and society.	Earth and Human Activity—*PAR: humans need water, air, and resources from the land to live.
		Engineering Design—*PAR: a child uses a wood plank to cross a small stream on a nature walk.
		Links among STE and Society—*PAR: using a magnifying glass to observe the parts of a leaf.

References

- Aikens, N. L., & Barbarin, O. (2008). Socioeconomic differences in reading trajectories: The contribution of family, neighborhood, and school contexts. *Journal of Educational Psychology, 100*(2), 235–251.
- Alatalo, T., & Westlund, B. (2021). Preschool teachers' perceptions about read-alouds as a means to support children's early literacy and language development. *Journal of Early Childhood Literacy, 21*(3), 413–435.
- American Speech-Language-Hearing Association. (2015). *Recommended protocols for instrumental assessment of voice [draft summary, expert panel to develop a protocol for instrumental assessment of vocal function]*. American Speech-Language-Hearing Association.
- Anderson, R. C., Hiebert, E. H., Wilkinson, I. A. G., & Scott, J. (1985). *Becoming a nation of readers: The report of the commission on reading*. National Institute of Education.
- ATLAS.ti Scientific Software Development GmbH. (2023). *ATLAS.ti windows* (version 23.2.1) [Qualitative data analysis software]. ATLAS.ti Scientific Software Development GmbH.
- Bandura, A. (1971). *Social learning theory* (Vol. 1, pp. 141–154). Prentice hall.
- Barnes, E. M., & Dickinson, D. K. (2017). The impact of teachers' commenting strategies on children's vocabulary growth. *Exceptionality, 25*(3), 186–206.
- Barnes, E. M., & Puccioni, J. (2017). Shared book reading and preschool children's academic achievement: Evidence from the early childhood longitudinal study—Birth cohort. *Infant and Child Development, 26*(6), e2035.
- Barnett, W. S., Yarosz, D. J., Thomas, J., Jung, K., & Blanco, D. (2007). Two-way and monolingual English immersion in preschool education: An experimental comparison. *Early Childhood Research Quarterly, 22*(3), 277–293.
- Betancur, L., Votruba-Drzal, E. & Schunn, C. (2018). Socioeconomic gaps in science achievement. *International Journal of STEM Education, 5*(1), 38.
- Blewitt, P., & Langan, R. (2016). Learning words during shared book reading: The role of extratextual talk designed to increase child engagement. *Journal of Experimental Child Psychology, 150*, 404–410.
- Breitfeld, E., Potter, C. E., & Lew-Williams, C. (2021). Children simultaneously learn multiple dimensions of information during shared book reading. *Journal of Cognition and Development, 22*(5), 744–766.
- Bronfenbrenner, U. (2000). *Ecological systems theory*. American Psychological Association.
- Brouillard, M., Dubé, D., & Byers-Heinlein, K. (2022). Reading to bilingual preschoolers: An experimental study of two book formats. *Infant and Child Development, 31*(3), e2294.
- Brown, C. S. (2014). Language and literacy development in the early years: Foundational skills that support emergent readers. *Language and Literacy Spectrum, 24*(2), 35–49.
- Burchinal, M., Field, S., López, M. L., Howes, C., & Pianta, R. (2012). Instruction in Spanish in pre-kindergarten classrooms and child outcomes for English language learners. *Early Childhood Research Quarterly, 27*(2), 188–197.

- Bus, A. G., Van IJzendoorn, M. H., & Pellegrini, A. D. (1995). Joint book reading makes for success in learning to read: A metaanalysis on intergenerational transmission of literacy. *Review of Educational Research*, 65(1), 1–21.
- Bustamante, A. S., White, L. J., & Greenfield, D. B. (2018). Approaches to learning and science education in Head Start: Examining bidirectionality. *Early Childhood Research Quarterly*, 44, 34–42.
- Chaudhri, A., & Torres, L. (2022). “Jugos there?” Codeswitching strategies in bilingual picturebooks. *Children’s Literature in Education*, 53(2), 221–237.
- Choi, B. (2016). *Early science learning among low-income Latino preschool children: The role of parent and teacher values, beliefs, and practices* (Publication No. 10125908) [Doctoral dissertation, University of California, Irvine]. ProQuest Dissertations and Theses Global.
- Curran, F. C., & Kellogg, A. T. (2016). Understanding science achievement gaps by race/ethnicity and gender in kindergarten and first grade. *Educational Researcher*, 45(5), 273–282.
- Deshmukh, R. S., Pentimonti, J. M., Zucker, T. A., & Curry, B. (2022). Teachers’ use of scaffolds within conversations during shared book reading. *Language, Speech, and Hearing Services in Schools*, 53(1), 150–166.
- Deshmukh, R. S., Zucker, T. A., Tambyraja, S. R., Pentimonti, J. M., Bowles, R. P., & Justice, L. M. (2019). Teachers’ use of questions during shared book reading: Relations to child responses. *Early Childhood Research Quarterly*, 49, 59–68.
- Dickinson, D. K., & Smith, M. W. (1994). Long-term effects of preschool teachers’ book readings on low-income children’s vocabulary and story comprehension. *Reading Research Quarterly*, 29, 105–122.
- Domke, L. (2018). Probing the promise of dual-language books. *Reading Horizons: A Journal of Literacy and Language Arts*, 57(3), 20–48.
- Dowdall, N., Melendez-Torres, G. J., Murray, L., Gardner, F., Hartford, L., & Cooper, P. J. (2020). Shared picture book reading interventions for child language development: A systematic review and meta-analysis. *Child Development*, 91(2), e383–e399.
- Duursma, E., Romero-Contreras, S., Szuber, A., Proctor, P., Snow, C., August, D., & Calderón, M. (2007). The role of home literacy and language environment on bilinguals’ English and Spanish vocabulary development. *Applied Psycholinguistics*, 28(1), 171–190.
- Early Childhood STEM Working Group at the University of Chicago. (2017). *Early STEM matters: Providing high-quality STEM experiences for all young leaders*. UChicago STEM Education.
- Eilers, P. H., Currie, I. D., & Durbán, M. (2006). Fast and compact smoothing on large multidimensional grids. *Computational Statistics & Data Analysis*, 50(1), 61–76.
- ELAN (Version 7.1) [Computer software]. (2026). *Max planck institute for psycholinguistics, the language archive*. Available online: <https://archive.mpi.nl/tla/elan> (accessed on 7 July 2025).
- Espinosa, L. M. (2013). *Early education for dual language learners: Promoting school readiness and early school success*. Migration Policy Institute.
- Evans, B. A., & Hornberger, N. H. (2005). No child left behind: Repealing and unpeeling federal language education policy in the United States. *Language Policy*, 4(1), 87–106.
- Farrant, B. M., & Zubrick, S. R. (2012). Early vocabulary development: The importance of joint attention and parent-child book reading. *First Language*, 32(3), 343–364.
- Fitton, L., McIlraith, A. L., & Wood, C. L. (2018). Shared book reading interventions with English learners: A meta-analysis. *Review of Educational Research*, 88(5), 712–751.
- Flack, Z. M., Field, A. P., & Horst, J. S. (2018). The effects of shared storybook reading on word learning: A meta-analysis. *Developmental Psychology*, 54(7), 1334–1346.
- Gerde, H. K., Pierce, S. J., Lee, K., & Van Egeren, L. A. (2018). Early childhood educators’ self-efficacy in science, math, and literacy instruction and science practice in the classroom. *Early Education and Development*, 29(1), 70–90.
- Goldenberg, C. (2013). Unlocking the research on English learners: What we know—And don’t yet know—About effective instruction. *American Educator*, 37(2), 4.
- Gonzalez-Barrero, A. M., Salama-Siroishka, N., Dubé, D., Brouillard, M., & Byers-Heinlein, K. (2021). Effects of language dominance on home reading practices of bilingual families. *International Journal of Bilingualism*, 25(1), 77–99.
- Gopnik, A. (2012). Scientific thinking in young children: Theoretical advances, empirical research, and policy implications. *Science*, 337(6102), 1623–1627.
- Greenfield, D. B., Alexander, A., & Frechette, E. (2017). Unleashing the power of science in early childhood: A foundation for high-quality interactions and learning. *Zero To Three*, 37(5), 13–21.
- Greenfield, D. B., Jirout, J., Domínguez, X., Greenberg, A., Maier, M.F., & Fuccillo, J.M. (2009). Science in the preschool classroom: A programmatic research agenda to improve science readiness. *Early Education and Development*, 20, 238–264.
- Guo, Y., Wang, S., Hall, A. H., Breit-Smith, A., & Busch, J. (2016). The effects of science instruction on young children’s vocabulary learning: A research synthesis. *Early Childhood Education Journal*, 44(4), 359–367.

- Halle, T., Hair, E., Wandner, L., McNamara, M., & Chien, N. (2012). Predictors and outcomes of early vs. later English language proficiency among English language learners. *Early Childhood Research Quarterly*, 27(1), 1–20.
- Halpin, E., Prishker, N., & Melzi, G. (2023). The language diversity and science readiness skills of latino preschoolers. *Language, Speech, and Hearing Services in Schools*, 54(1), 275–298.
- Hammer, C. S., Hoff, E., Uchikoshi, Y., Gillanders, C., Castro, D., & Sandilos, L. E. (2014). The Language and Literacy Development of Young Dual Language Learners: A Critical Review. *Early Childhood Research Quarterly*, 29(4), 715–733.
- Han, W.J. (2012). Bilingualism and academic achievement. *Child Development*, 83(1), 300–321.
- Harris, A. J., & Sipay, E. R. (1990). *How to increase reading ability: A guide to developmental & remedial methods*. Longman.
- Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: Implications for closing achievement gaps. *Developmental Psychology*, 49(1), 4–14.
- Hopkins, E. J., & Weisberg, D. S. (2021). Investigating the effectiveness of fantasy stories for teaching scientific principles. *Journal of Experimental Child Psychology*, 203, 105047.
- Horst, J. S., Parsons, K. L., & Bryan, N. M. (2011). Get the story straight: Contextual repetition promotes word learning from story-books. *Frontiers in Psychology*, 2, 17.
- Hurtado, A., & Vega, L. A. (2004). Shift happens: Spanish and English transmission between parents and their children. *Journal of Social Issues*, 60(1), 137–155.
- Hurtado, N., Grüter, T., Marchman, V. A., & Fernald, A. (2014). Relative language exposure, processing efficiency and vocabulary in Spanish–English bilingual toddlers. *Bilingualism: Language and Cognition*, 17(1), 189–202.
- Jang, W., Kwon, K.-A., & Horm, D. (2024). The role of language and literacy skills in science learning from kindergarten to 5th grade: Mitigating gender, racial/ethnic, and socio-economic disparities. *Education Sciences*, 14(9), 9.
- Kermani, H., & Aldemir, J. (2015). Preparing children for success: Integrating science, math, and technology in early childhood classroom. *Early Child Development and Care*, 185(9), 1504–1527.
- Leech, K. A., Haber, A. S., Jalkh, Y., & Corriveau, K. H. (2020). Embedding scientific explanations into storybooks impacts children’s scientific discourse and learning. *Frontiers in Psychology*, 11, 1016.
- Leung, C. B. (2008). Preschoolers’ acquisition of scientific vocabulary through repeated read-aloud events, retellings, and hands-on science activities. *Reading Psychology*, 29(2), 165–193.
- López, M. H., & Gonzalez-Barrera, A. (2015). *What is the future of Spanish in the United States?* Pew Research Center.
- Magruder, E. S., Hayslip, W. W., Espinosa, L. M., & Matera, C. (2013). Many languages, one teacher: Supporting language and literacy development for preschool dual language learners. *Young Children*, 68(1), 8–15.
- Mantzicopoulos, P., & Patrick, H. (2010). “The seesaw is a machine that goes up and down”: Young children’s narrative responses to science-related informational text. *Early Education and Development*, 21(3), 412–444.
- Melzi, G., & Caspe, M. (2005). Variations in maternal narrative styles during book reading interactions. *Narrative Inquiry*, 15(1), 101–125.
- Méndez, L. I., Crais, E. R., Castro, D. C., & Kainz, K. (2015). A culturally and linguistically responsive vocabulary approach for young Latino dual language learners. *Journal of Speech, Language, and Hearing Research: JSLHR*, 58(1), 93–106.
- Miller-Goldwater, H. E., Cronin-Golomb, L. M., Hanft, M. H., & Bauer, P. J. (2023). The influence of books’ textual features and caregivers’ extratextual talk on children’s science learning in the context of shared book reading. *Developmental Psychology*, 59(2), 390–411.
- Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher*, 45(1), 18–35.
- Naqvi, R., Thorne, K. J., Pfitscher, C. M., Nordstokke, D. W., & McKeough, A. (2013). Reading dual language books: Improving early literacy skills in linguistically diverse classrooms. *Journal of Early Childhood Research*, 11(1), 3–15.
- National Academies of Sciences, Engineering, and Medicine (NASEM). (2020). *The integration of literacy, science, and engineering in prekindergarten through fifth grade*. The National Academies Press.
- National Academies of Sciences, Engineering, and Medicine (NASEM). (2022). *Science and engineering in preschool through elementary grades: The brilliance of children and the strengths of educators*. The National Academies Press.
- National Academies of Sciences, Engineering, and Medicine (NASEM). (2023). *Closing the opportunity gap for young children*. The National Academies Press.
- National Academies of Sciences, Engineering, and Medicine (NASEM). (2024). *A new vision for high-quality preschool curriculum*. The National Academies Press.
- National Center for Education Statistics (NCES). (2013). *Condition of education*. U.S. Department of Education.

- National Center for Education Statistics (NCES). (2024). *Condition of education*. U.S. Department of Education.
- National Institute of Child Health and Human Development (NICHD). (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. U.S. Government Printing Office.
- National Research Council (NRC). (2007). *Taking science to school: Learning and teaching science in grades K-8* (R. A. Duschl, H. A. Schweingruber, & A. W. Shouse, Eds.). Committee on Science Learning, Kindergarten Through Eighth Grade. The National Academies Press.
- National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.
- Neuman, S. B., & Danielson, K. (2021). Enacting content-rich curriculum in early childhood: The role of teacher knowledge and pedagogy. *Early Education and Development*, 32(3), 443–458.
- Neuman, S. B., Newman, E. H., & Dwyer, J. (2011). Educational effects of a vocabulary intervention on preschoolers' word knowledge and conceptual development: A cluster-randomized trial. *Reading Research Quarterly*, 46(3), 249–272.
- Noble, C., Cameron-Faulkner, T., Jessop, A., Coates, A., Sawyer, H., Taylor-Ims, R., & Rowland, C. F. (2019). The impact of interactive shared book reading on children's language skills: A randomized controlled trial. *Journal of Speech, Language, and Hearing Research*, 63(6), 1878–1897.
- Noguerón-Liu, S., & Driscoll, K. (2021). Bilingual families' perspectives on literacy resources and supports at home. *The Reading Teacher*, 75(1), 17–25.
- Nores, M., & Barnett, W.S. (2014). *Access to high quality early care and education: Readiness and opportunity gaps in America* (CEELO Policy Report). Center on Enhancing Early Learning Outcomes.
- Oller, D. K., & Eilers, R. E. (Eds.). (2002). *Language and literacy in bilingual children* (Vol. 2). Multilingual Matters.
- Passel, J. S., Cohn, D. V., & Lopez, M. H. (2011). *Hispanics account for more than half of nation's growth in past decade* (pp. 1–7). Pew Hispanic Center.
- Place, S., & Hoff, E. (2011). Properties of dual language exposure that influence 2-year-olds' bilingual proficiency. *Child Development*, 82(6), 1834–1849.
- Place, S., & Hoff, E. (2016). Effects and noneffects of input in bilingual environments on dual language skills in 2 ½-year-olds. *Bilingualism: Language and Cognition*, 19(5), 1023–1041.
- Potter, C. E., Castellana, M. A., Guerra, M. D., & Benitez, V. L. (2024). The balance of Spanish and English child-directed text in bilingual picture books. *Journal of Early Childhood Literacy*, 26(1), 14687984241257400.
- Raikes, H. H., White, L., Green, S., Burchinal, M., Kainz, K., Horm, D., Bingham, G., Cobo-Lewis, A., St. Clair, L., Greenfield, D., & Esteraich, J. (2019). Use of the home language in preschool classrooms and first- and second-language development among dual-language learners. *Early Childhood Research Quarterly*, 47, 145–158.
- Read, K., Contreras, P. D., & Martinez, H. (2021b). Tres formas: Shared reading practices with three types of Spanish and English dual-language learning preschoolers. *Bilingual Research Journal*, 44(3), 360–380.
- Read, K., Contreras, P. D., Rodriguez, B., & Jara, J. (2021a). *¿Read Conmigo?: The effect of code-switching storybooks on dual-language learners' retention of new vocabulary*. Early Education and Development.
- Reardon, S. F., & Portilla, X. A. (2016). Recent trends in income, racial, and ethnic school readiness gaps at kindergarten entry. *AERA Open*, 2(3), 2332858416657343.
- Restrepo, M. A., Morgan, G. P., & Thompson, M. S. (2013). The efficacy of a vocabulary intervention for dual-language learners with language impairment. *Journal of Speech, Language, and Hearing Research*, 56(2), 748–765.
- Rogoff, B. (2003). *The cultural nature of human development*. Oxford University Press.
- Routman, R., & Routman, R. (1994). *Invitations: Changing as teachers and learners K-12*. Heinemann.
- Rumper, B. (2019). *"Estamos buscando acorns!": Examining dual language learning head start children's conceptual science knowledge across languages* (Doctoral dissertation, University of Miami). University of Miami Scholarly Repository.
- Sağkes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. A. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the early childhood longitudinal study. *Journal of Research in Science Teaching*, 48(2), 217–235.
- Scarborough, H. S., Neuman, S., & Dickinson, D. (2009). Connecting early language and literacy to later reading (dis)abilities: Evidence, theory, and practice. *Approaching Difficulties in Literacy Development: Assessment, Pedagogy and Programmes*, 10, 23–38.
- Schick, A. R., Scarola, L., Niño, S., & Melzi, G. (2021). Beyond the written word: The role of text on preschool teachers' book sharing styles. *Journal of Early Childhood Literacy*, 23(3), 445–469.

- Selman, S. B., & Dilworth-Bart, J. E. (2023). Routines and child development: A systematic review. *Journal of Family Theory & Review*, 16(2), 272–328.
- Semingson, P., Pole, K., & Tommerdahl, J. (2015). Using bilingual books to enhance literacy around the world. *European Scientific Journal*, 3(1), 132–139.
- Sénéchal, M., Pagan, S., Lever, R., & Ouellette, G. P. (2008). *Relations among the frequency of shared reading and 4-year-old children's vocabulary, morphological and syntax comprehension, and narrative skills*. Early Education and Development.
- Taboada, A., & Rutherford, V. (2011). Developing reading comprehension and academic vocabulary for English language learners through science content: A formative experiment. *Reading Psychology*, 32(2), 113–157.
- Thompson, K., Richardson, L. P., Newman, H., & George, K. (2019). Interaction effects of socioeconomic status on emerging literacy and literacy skills among pre-kindergarten and kindergarten children: A comparison study. *Journal of Human Services: Training, Research, and Practice*, 4(1), 5.
- Torquati, J., Cutler, K., Gilkerson, D., & Sarver, S. (2013). *Early childhood educators' perceptions of nature, science, and environmental education*. Early Education & Development.
- Tu, T. (2006). Preschool science environment: What is available in a preschool classroom? *Early Childhood Education Journal*, 33(4), 245–251.
- U.S. Census Bureau. (2022). *American Community Survey 1-year estimates*. U.S. Department of Commerce.
- Vélez-Agosto, N. M., Soto-Crespo, J. G., Vizcarrondo-Oppenhimer, M., Vega-Molina, S., & García Coll, C. (2017). Bronfenbrenner's bioecological theory revision: Moving culture from the macro into the micro. *Perspectives on Psychological Science*, 12(5), 900–910.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Welsh, S. N., & Hoff, E. (2021). Language exposure outside the home becomes more English-dominant from 30 to 60 months for children from Spanish-speaking homes in the United States. *International Journal of Bilingualism*, 25(3), 483–499.
- Wilson, S. J., Dickinson, D. K., & Rowe, D. W. (2013). Impact of an early reading first program on the language and literacy achievement of children from diverse language backgrounds. *Early Childhood Research Quarterly*, 28(3), 578–592.
- Worthington, E., Maude, S., Hughes, K., Luisa, T., & Daniels, H. (2011). A qualitative examination of the challenges, resources, and strategies for serving children learning English in head start. *Early Childhood Education Journal*, 39(1), 51–60.
- Wright, T. S., & Gotwals, A. W. (2017). Supporting kindergartners' science talk in the context of an integrated science and disciplinary literacy curriculum. *The Elementary School Journal*, 117(3), 513–537.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.