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Who Has Authority over Their Knowledge? A Case Study of Academic Language Use in Science Education

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Abstract
An important goal in early childhood science education is students' development of academic language. However, scholars disagree on whether academic language must be explicitly taught or whether it can be learned through immersive science experiences. In this case study of a co-taught second grade classroom, we use positioning theory and framings of authority of knowledge to examine teachers' and students' use of both every day and academic language. Findings suggest that inside science classrooms operating as knowledge generation environments, students can claim authority over their own knowledge and teachers are able to position students as having this authority. Findings further suggest that when teachers take the stance of negotiator within these learning environments, students can develop academic language in science through immersive experiences. This study points to the importance of early childhood teachers operating as active negotiators with students within science classrooms to meet the goal of developing their academic language knowledge and skills.

Keywords Science · Academic language · Dialogue · Argumentation

Introduction

When it comes to teaching science, early childhood teachers lead the way in valuing their students' curiosity and questions about the natural world (Nxumalo et al., 2020). Within student-led learning, teachers often view themselves as facilitators rather than authority figures (Biesta & Safstrom, 2011; Hamel et al., 2021). While the desire to shift the locus of authority in classrooms is a valid goal, we argue (Hand & Cavagnetto, 2023) that for education to be truly emancipatory, teachers must abandon the stance of passive facilitators, and instead, claim the stance of active negotiators who value their students' intellectual capabilities (Biesta, 2017). The stance of teacher as negotiator is aligned with the goals of the National Research Council ([NRC], 2012) and the Next Generation Science Standards ([NGSS] NGSS Lead States, 2013]) which emphasize the epistemic practices of the sciences rather than just the activities of the sciences. These goals have been translated into practice through argument-based inquiry approaches that, while popular in secondary education, have received less attention amongst early childhood educators (Weiss et al., 2022).

Language has unmatched importance in learning environments such as this, which are based on dialogue and negotiation (Ding et al., 2023; Hand et al., 2016; Hamel et al., 2021). Specifically, constructing scientific arguments requires students to master academic language, defined as "the collection of language or discourse features necessary for schooling" (Thompson & Watkins, 2021, p. 557). In reality, young learners typically express their questions through their everyday language, which is bound to their families/ communities (Heath, 1983) and rooted in their experiences in the world, including the things they see, touch, and hear daily (Norton-Meier, 2005). For students to expand their knowledge of scientific vocabulary (Anderson et al., 2023; Wright & Gotwals, 2017) and their ability to construct scientific arguments (Cavagnetto, 2010) they must

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be encouraged to use and express the language they already have (Hand et al., 2021).

In our research, we define immersive language-rich environments in science as knowledge generation environments (Hand et al., 2021). Within knowledge generation environments, teachers utilize dialogue to enact the position that all students—including those still building fluency in academic language—nevertheless have an "equity of intelligence" that enables them to define and solve novel problems (Biesta, 2017). Within knowledge generation environments, students learn scientific academic language during rather than before the process of scientific investigation. Accordingly, the purpose of the current study is to examine one classroom where a knowledge generation environment was used for science learning. Our goal was to examine how this approach influences language growth, particularly with early childhood learners. The research questions driving this study are:

1. How can teacher and student language use be characterized in an early childhood science classroom functioning as a knowledge generation environment?
2. Considering both students and teachers, who holds authority of knowledge in an early childhood science classroom functioning as a knowledge generation environment?

Conceptual Framework for Learning Environments

There are two major pathways to developing early childhood students' language practices for school settings. The first is rooted theoretically in the idea that extensive explicit instruction in word learning is needed. This pathway is teacher-centered (Widger & Schofield, 2012) since the teacher functions as the authority (Biesta, 2017). The second is an immersive and student-centered (Widger & Schofield, 2012) approach. We contrast these approaches to developing early childhood students' academic language in science to show why learning through immersion served as a guiding conceptual framework for the current study.

Pathway One: Explicit Instruction

Early childhood education has received increased attention as a global funding priority (Organization for Economic Co-Operation and Development [OCED], 2015) stemming from increased international recognition that students' first experiences of schooling have a lasting formative impact. Since literacy rates are associated with a range of educational, health, and social outcomes (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2023), a particular area of emphasis is children's linguistic competence and vocabulary knowledge. These policies promote school readiness for all students, including those from low socioeconomic status families (Adair et al., 2017; Takanishi, 2016).

In the United States, programs to improve the quality of interactions between infants and caregivers have emerged with the goal of improving children's vocabulary before arrival at school (i.e., Georgia Department of Education, 2016). These programs, which provide protocols to make word learning explicit, are consistent with the assumption that academic language is necessary for disciplinary learning, and therefore should be directly taught (e.g., Schleppegrell, 2004; Uccelli & Phillips Galloway, 2016; Wright & Gotwals, 2017). Relatedly, classroom interventions such as shared reading of scientific texts with teacher-led pauses to review definitions of key vocabulary have been shown to increase kindergartener's scientific vocabulary learning (i.e., Gibbs & Reed, 2021). These initiatives typically include far greater attention to verbal academic language than academic language expressed in writing or through modes such as drawing and sketching (Hand et al., 2016).

We argue that this approach is consistent with the idea of teacher (or caregiver) as an authority on the correct use of language, and as one who transmits this knowledge to young learners. In this way, children are provided with the vocabulary needed for concepts they will encounter in their future science learning. However, as Biesta (2017) has noted, "the critique of traditional teaching is a critique of teaching as control… in traditional teaching the student can only appear as an object of the teacher's interventions, but never as a subject in its own right" (p. 43). In these models, teachers attempt to control which vocabulary students learn rather than building from their everyday language (Norton-Meier, 2005). As such, an alternative model for the development of scientific language through immersion is required.

Pathway Two: Immersive Approaches

In contrast to direct instruction approaches targeting word-level learning, immersive approaches are those that enable students to learn academic language through the process of using academic language. In science education, particular attention is given to argument-based inquiry (ABI) approaches as a pathway for teaching science through immersion. In these environments, students build upon their everyday language practices and knowledge as they moved toward disciplinary and scientific ways of using language. Weiss et al. (2022) reviewed the characteristics of learning environments described in studies utilizing 16 different ABI approaches and identified the following universal features of ABI: engagement in argumentation, small group work, discussion, and investigation. ABI models are most consistent with the idea of teacher as negotiator (Biesta, 2017) who engages in dialogue with students to spur growth in their conceptualizations of science. Fundamentally, this approach is rooted in the view that "If we tie the student only to his or her past, only to everything that is known so far, we bought the possibility of a different future" (Biesta, 2017. p. 94). In immersive knowledge generation environments, student-originated scientific exploration serves as a catalyst for vocabulary development as students require language for increasingly sophisticated natural phenomena (Lammert & Hand, 2022). These environments also invite students to attend to the interrelatedness of written, drawn, and verbal texts through their use of multimodality (Hand et al., 2016).

While the idea of early childhood students learning in a generative ABI environment holds promise, only one of the approaches found by Weiss et al. (2022) was utilized in Kindergarten (i.e., the Science Writing Heuristic, Keys et al., 1999). Just two others, Concept Cartoons (Naylor et al., 2007) and Wild Backyard Investigation (Manz, 2016) were targeted to elementary grades. With such research focus on secondary science, it remains unknown what language learning might occur for early childhood students in knowledge generation environments.

Review of Literature

With these learning pathways in mind, we turn to what is known about the role of academic language in science learning. Academic language can be understood as "the collection of language or discourse features necessary for schooling" (Thompson & Watkins, 2021, p. 557). One perspective is that academic language is functionally necessary for classroom learning, and as such, it must be explicitly taught to ensure equity of access for students, especially Emergent Bilinguals (Cummins & Swain, 2014; Haneda, 2014; Uccelli & Phillips Galloway, 2016). In science, explanations for natural phenomena are often conceptually complex; as a result, scientific explanations can be syntactically and grammatically complex as well (Schleppegrell, 2004). By analyzing the discourses typically used in upper elementary and middle school classrooms, as well as the discourses utilized by professionals in various disciplines (e.g., biology, chemistry) researchers have identified specific lexical and grammatical features of academic language registers (e.g., Christie & Derewainka, 2010; Townsend, 2015; Valdés, 2010). Schleppegrell notes that "Academic registers are not just pretentious ways of using language…The kinds of meanings that are created in academic contexts often *cannot be expressed* in the language of ordinary interaction" (Schleppegrell, 2004, p. 137, emphasis added). If academic language is functionally required for learning science, then it stands that teaching students to utilize this academic register in speech in writing would support effective and equitable learning outcomes.

Others contend that academic language is not functionally required for disciplinary learning therefore teaching it replicates rather than eliminates inequity (Jensen & Thompson, 2020). Considering this view is crucial since students from lower socioeconomic status families and English learners are generally less proficient at using academic language than their wealthier English-proficient peers (Heath, 1983; Uccelli & Phillips Galloway, 2016). Therefore, the time and effort required for them to adopt academic language is greater than it is for their peers. The question of whether it constitutes equitable educational practice to ask linguistically minoritized students to adopt an academic language register far from their everyday language depends on the necessity of academic language itself (Delpit, 1988), which remains unsettled.

One point of agreement is that academic language includes but is much more than vocabulary (Anderson et al., 2023; Jensen & Thompson, 2020; Wright & Gotwals, 2017). As such, recent interventions designed to support academic language growth (e.g., Uccelli et al., 2015) have focused more broadly on syntax, grammar, and argumentation structures (Cavagnetto, 2010) as well as vocabulary. However, the point of emphasis in most research on language in science education is typically the teacher's use of scientific terminology and questioning (Hamel et al., 2021) rather than the students' knowledge of academic language.

Summary

As the review of literature has shown, within the field of early childhood science education, a generally agreed upon goal is for students to learn to engage in scientific dialogue, base claims on evidence, and engage in argumentation (NGSS, 2013). When it comes to the role of academic language, scholars diverge on the questions of (A) what level of linguistic competence is needed to do so, and (B) how this linguistic competence should best be developed. To the first point, some argue that academic language is not truly required to communicate scientific ideas, but functions as a gatekeeping mechanism (Adair et al., 2017; Thompson & Watkins, 2021) while others adamantly defend its necessity (Schleppegrell, 2004l; Uccelli & Phillips Galloway, 2016). This study does not attempt to settle the first question. Instead, it addresses the second of how to develop students' academic language knowledge. Specifically, it remains unclear whether language learning can occur through immersion in environments that builds from students' everyday language, or whether direct, explicit instruction is needed (Wright & Gotwals, 2017). When students experience immersive science learning environments, it is unknown what types of language learning might occur (i.e., what academic vocabulary is learned) and how language use might spur science learning (i.e., what science content could be understood through academic vocabulary). The current study exists in this gap.

Methods

The purpose of this research is to characterize how teachers and students use academic language in a science classroom operating as a knowledge generation environment. Since our goal was rich characterization, we utilized a case study approach (Yin, 2013).

Case Selection

Case selection reflects and frames the goals of a study (Yin, 2013). Here, the case was selected based on the results of a prior study (Lammert & Hand, 2022; Lammert et al., 2023) involving 120 K-5 teachers learning to use language as an epistemic tool for teaching science. We relied on purposive case selection practices (Creswell & Plano Clark, 2011) by identifying exemplary science teachers based on two existing measures: (A) teachers' scores on the Epistemic Orientation Toward teaching Science for Knowledge Generation (EOTS-KG) scale, a validated measure of teachers' epistemic orientations for teaching science (Suh et al., 2022) and (B) teachers' implementation scores on a classroom observational protocol as recorded on a 0–3 scale across 8 dimensions by professional development coaches. We selected these measures because one represented participants' orientation toward learning while the other represented their observable teaching practices. In spring 2020, the early childhood teacher participants' ($n = 28$) mean score on the EOTS-KG was 176.5 with a Standard Deviation of 15. To locate exemplary teachers, we first identified which teachers scored more than one Standard Deviation above the mean. Of these teachers, we selected those with the highest implementation scores.

The teachers we selected were a pair of co-teachers in a second-grade classroom. Their scores on the EOTS-KG were significantly above the mean at 199 and 201, and their implementation scores were 2.7/3, which were the highest of any participant. "Mrs. A[1]" had 13 years of teaching experience while "Mrs. B" had 15 years of teaching experience. Both teachers identified as white English-speaking women and had master's degrees. They were state certified as preschool and elementary generalists.

The focal classroom was their second-grade classroom serving students ages seven to eight. The school district where this classroom was located serves five adjacent towns in a rural area of a midwestern U.S. state. The district is classified as rural-remote (National Center for Education Statistics [NCES], 2022) indicating that the community has low population density and high distance from an urban center. The community is 96% white (non-Hispanic) and just 3.6% of the population speaks a language in addition to English. The median household income is $55,844, well below the national average of $69,012 (NCES, 2022).

Since the teachers co-taught together, and since our conceptual framework focuses on the learning environment (Weiss et al., 2022) rather than individual experiences, we bounded the case at the unit of the classroom (Yin, 2013), including students and teachers. Thus, we conducted our analysis at the level of the classroom dialogue rather than focusing on individual students. The teachers had previously participated in professional development with the research team, however, during the year of the study they were no longer receiving coaching or attending workshops. Their school district provided open-ended curricular resources (i.e., FOSS kits) and the teachers were encouraged by school administrators to plan their own science lessons in alignment with the state content standards.

Data Sources

Four full units of study were included in this analysis, including 46 different science lessons. Lessons varied in length from 14:30 to 52:00 with an average video length of approximately 30 min. Videos were collected from late August 2022 through early March 2023, spanning most of the school year. Each unit had a different focus. The first unit was "What is a Scientist?" and emphasized scientific practices. The second was forces and motion in physics, the third was rocks, erosion, and weathering in geology, and the fourth unit was landforms and earth science. Teaching videos were collected using a non-obtrusive Swivl video and portable audio recording device worn around the teacher's neck. The teachers were trained in how to use the recorder and how to upload the videos to a secured digital storage platform for researchers to access. In this way, video was recorded without the physical presence of researchers to avoid altering student and/or teacher behaviors.

Coding Protocol

The initial coding protocol was collaboratively developed by faculty and graduate students to highlight two categories

[1] All names are pseudonyms.

Table 1 Coding protocol

Language and representation	Authority of knowledge
Scientific (S); Academic language, scientific terms for science concepts (i.e., friction) or science practices (i.e., observation).	**Teacher: I (TI);** Teacher states their individual knowledge; replicative stance intended for students to learn what is already known.
Multimodal Representation (MR); Use of various modes (e.g., video, image, text) to state, restate, or show ideas and concepts.	**Teacher: We (TW);** Teacher references collective knowledge of the community; generative stance intended for students to compare what they have learned.
Management Language (B); Use of language to build community or define boundaries of behavioral norms.	**Teacher: You (TY);** Individual reference between teacher and student; teacher asks one student a question about their ideas.
Reword (RE); Restating students' ideas with new vocabulary; A method for helping students move from every day to academic language.	**Student: I (SI);** Student states their individual knowledge; student responds to a teacher or another students' question about their ideas.
Argument (A); Formed through negotiation with self and others; relies on Questions, Claims and Evidence as a structure.	**Student: We (SW);** Student references collective knowledge of the community; generative stance intended to compare different argument.
	Student: You (SY); Individual student communicates their knowledge or argument to another student or other students.

Table 2 Degree of codes

Description	Score	Explanation of score for the code "S" scientific language
Not observed	0	An example of the code was not observed at any time across the lesson. In this case, no scientific terminology was read, spoken, or written.
Minimally observed	1	An example of the code was observed one time during one lesson component. For example, a scientific vocabulary term was said once by the teacher during direct instruction.
Moderately observed	2	An example of the code was observed more than once in two different lesson components. For example, scientific vocabulary was spoken by the teacher during direct instruction and was written by students in their final summaries. However, in some lesson components (i.e., small group investigations) the code was not observed.
Fully observed	3	Examples of the code were observed multiple times during each lesson component. For example, the students and teacher used multiple scientific vocabulary terms orally during direct instruction, small group investigations, and in student summary writing that closed the lesson.

consistent with knowledge generation environments: (A) Language and Representations, which attends to the types of language used including scientific language, everyday language, and visual representations, and (B) Authority of Knowledge, which tracked who (i.e., students, teachers, or external scientists) was the source of scientific claims. The authority of knowledge codes were designed based on positioning theory, specifically the idea that "it is with words that we ascribe rights and claim them for ourselves and place duties on others" (Moghaddam & Harré, 2010, p. 3). As such, we tracked the pronouns used by students and teachers (i.e., I, we, you) as they offered, compared, and negotiated different arguments. The coding protocol is in Table 1.

Coding Procedure

Three scorers coded the bank of 46 videos: two graduate students and one faculty member. The first coder developed the protocol and applied it to a set of eight videos from a single unit of teaching. Once the first scorer was able to reliably apply the codes, they trained the second and third scorers by providing and discussing example clips for each code. To improve trustworthiness and ensure that dialogue could be accurately contextualized inside classroom activity, coding was conducted on the videos rather than transcripts. To apply the codes, scorers independently viewed each video and kept a running frequency count of each code. Videos were frequently paused and pertinent sections were re-watched 2–3 times to ensure the coding consistency.

Since the unit of analysis was the classroom, including the teachers and their students, all talk that was intelligible to the researchers was included in the codes regardless of the speaker. The degree of codes was applied using a 3-point scale. A score of zero meant a particular communication was not observed within the lesson. Scores increased incrementally when commentary fitting each code was observed at varying frequencies. A score of three meant that a particular type of communication dominated the lesson. Table 2 shows an example of the 3-point scale using the code S; Scientific Language.

The coding was then examined for inter-rater reliability. Cohen's kappa indicated 96.2% overall agreement between all three scorer's codes on one independently scored sample video. Disagreements were resolved through re-watching of the videos and negotiation. Then, these trained scorers coded and analyzed all videos in this data set. Once the top two most salient codes were identified across each category, two of the coders reviewed the video clips again to identify representative quotations of each salient code. Since one purpose of this research is to characterize what knowledge generation environments look and sound like, they selected representative quotations to provide contextualized examples of how language use in this classroom.

Results

Results are presented separately for each generative learning matrix area. In each section, we provide a summary table organized from highest to lowest mean per code followed by qualitative results.

Language and Representation

The findings for Language and Representation are summarized Table 3.

The most frequent code in the Language and Representation area was Scientific Language. The classroom earned a “3” in this code in all but four of the 46 lessons, indicating that academic language was highly infused in the classroom. Qualitative analysis revealed that the teacher engaged with three main types of scientific language: language for the practices of the sciences, language for the components of an argument, and scientific vocabulary.

The Language of Scientific Practices

In the first unit, which focused on defining scientific practices, the teacher regularly offered students terms for scientific activities such as asking questions, planning and carrying out investigations, analyzing and interpreting data, and forming explanations (NGSS, 2013). In particular, the teacher showed that scientists need to shift ideas, change designs, and alter plans when they find new information. In one exchange, Mrs. B asked two students to explain why their design had changed. She stated, “So, [student names] actually- they started with something much larger, didn’t you? So why- they had to change their design right away. Why was that?” (9.23.22, 8:09). The students explained that their initial testing rounds had failed in dramatic fashion, so they realized that small adjustments were not going to lead to success. In turn, they began anew on their design.

In addition, the teacher emphasized the importance of attentive noticing as a scientific practice. During bridge building, the teacher regularly encouraged students to compare different designs, using prompts such as, “What do you notice about their bridge, boys and girls, compared to the other ones?” (9.16.22, 29:21; Mrs. A) and, “You noticed in the middle it kind of wiggled, like it pressed down a little bit more… what does that mean?” (9.19.22, 2:59; Mrs. A). In addition, as the unit progressed, the teacher encouraged students to notice trends and patterns in addition to individual instances. As she moved the discussion toward drawing conclusions about bridge design, she asked, “Did you guys notice any patterns or anything people used that seemed to work well? (9.19.22, 1:42).” With prompts such as these, she encouraged students to look across multiple designs to generalize trends- an important science and engineering practice (NGSS, 2013).

Table 3 Language and representation results

Code	Mean	Standard deviation	N of scores: 1	N of scores: 2	N of scores: 3
Scientific Language	2.89	0.37	1	3	42
Multimodal Representation	2.63	0.60	3	11	32
Argument	2.19	0.71	8	21	17
Reword	1.86	0.77	17	18	11
Management Language	1.63	0.60	20	23	3

The Language of Argumentation

The teacher also offered students language for scientific argumentation. In one lesson, Mrs. B introduced the idea of a claim, asking “Does anyone know what a claim is or, what they think it might be?” (9.7.22, 1:19). Then, she connected the idea of a claim to the idea of a statement. Mrs. B elaborated, “Do you know what a statement is? Like a telling sentence that answers a question” (9.7.22, 3:15). In doing so, the teacher linked students’ existing knowledge of statements with their emergent knowledge of how claims support arguments. In the next lesson, Mrs. A offered the idea of negotiation, reminding the students that, “negotiate means we’re talking to each other and we’re trying to figure it out together” (9.8.22, 2:39). Importantly, while the teacher connected the idea of negotiation to familiar terms such as “talking to each other,” and “figure it out together,” she pushed students to see negotiation in science as a specific form of academic language with its own rules, norms, and characteristics. Once the students learned that argumentation was a core practice in science, it was used often. Here, Mrs. A helped a student build her argument by identifying evidence and discussing that evidence with a peer.

Mrs. A: Okay, Ollie, what did your group notice yesterday?
Ollie: The maze didn’t work but the other one did. [Student pointing]
Mrs. A: Which one are you pointing to, the marble maze or the one with the black car and the little ramps?
Ollie: [points to the long maze].
Mrs. A: Yeah, okay. We hated the long.
Ollie: We stacked the books to make it go down.
Mrs. A: It goes down. What do you mean by stacks of books? Okay, who is in Ollie’s group that can expand on that? Alice can you add on to that one? (12.3.2022, 2:00-2:47)

In subsequent lessons, the teachers reminded students that negotiation was “about ideas, not people,” (Multiple timestamps) to encourage them to focus on the claims being made rather than personally challenging the individuals making those claims.

The Language of Scientific Vocabulary

Third, the teacher taught scientific vocabulary, and she did so by connecting students' everyday language to scientific terms. A common response pattern she utilized was asking clarifying questions about everyday terms students used. For instance, in a natural sciences unit, a student mentioned that "Earth has plates." The teacher responded by stating "Earth is made of plates.' Is that what you meant…Or Earth has plates? Does that mean like plates that we eat off of?" (3.7.23, 1:49; Mrs. A). The students chuckled at the idea of plates for meals but circled back to the topic at hand and agreed with Mrs. A. "Both," he explained with a smile, noting that we do have dining plates on Earth, but Earth is also made of plates. He elaborated, "It's plates that shift every once in a while to make like mountains and volcanoes and rough territories and stuff like that." (3.7.23, 2:03) In this exchange, the teacher honored the students' background knowledge while building this student and their peers' knowledge of academic language.

Mrs. A also used physical motion to teach scientific vocabulary. In one lesson, she used gestures to remind the students of friction. Rubbing her hands together, she explained "This type of friction actually creates… what? [Pause] Heat, warmth." (12.20.22, 2:43). Without being asked to, most students in the class began rubbing their hands together as well, nodding and agreeing. In this way, the teacher used her stance of negotiator to give students the opportunity to connect an embodied experience that was familiar to them (note that average winter temperatures in this state are below 20 degrees F) to scientific vocabulary.

Multimodal Representation

The second most frequent code was Multimodal Representation. All but three lessons were scored at either a "2" or a "3" in this area indicating that students and teachers engaged with more than one representational mode in most lessons. The teacher accomplished this by combining student-generated texts with images and printed language with externally-generated texts such as science trade books and videos. In one lesson Mrs. B explained, "We're gonna watch a video [about making observations] but we're gonna start by showing… some of our sketches that you made the other day" (9.6.22, 0:30). The students examined the sketches they had made, and their peers had made, for evidence of attentive observation. Then, they watched a brief clip showing various scientists engaging in observation. The teacher repeatedly paused the video to ask students to share reactions with one another about their ideas, further introducing layers of academic talk into the lesson.

Table 4 Authority of knowledge results

Code	Mean	Standard deviation	N of scores: 1	N of scores: 2	N of scores: 3
Student: I	2.45	0.65	1	17	28
Teacher: You	2.32	0.73	7	16	23
Teacher: I	2.06	0.82	14	15	17
Student: We	1.80	0.88	23	9	14
Student: You	1.56	0.68	25	16	5
Teacher: We	1.5	0.83	33	3	10

Summary

Overall, the teacher emphasized scientific language in virtually every lesson, earning a "3" score in 42 of the 46 lessons (91.3%) observed. The teacher engaged with the academic language of scientific practices, scientific argumentation, and scientific vocabulary by connecting this academic language through students' everyday language, background knowledge, and common vocabulary. In contrast, the teacher used management language the least often. Rather than coaching student behaviors, she focused on their ideas and the development of their academic language.

Authority of Knowledge

Next, we report results for Authority of Knowledge, which are summarized in Table 4.

Authority of "Student: I"

Within Authority of Knowledge, the most frequent code was Student: I, indicating that students commonly expressed their individual knowledge of a topic. In all but one lesson, Student: I was rated as either a "2" or a "3" score, suggesting that students routinely positioned themselves as authorities on science. Rather than stating that the teacher, the textbook, or an outside scientist was knowledgeable of science, across lessons students confidently claimed authority of their own knowledge.

Students would typically express this when responding to the teachers' questions. For example, when the teacher asked if they knew why using plastic drinking straws to build structures like houses was a bad idea, one student loudly stated, "Yes, I know! Because they're round." (9.19.22, 14:51). Students would routinely report variations on how they generated their knowledge, from "I know" to "I saw" to "I found" (Multiple timestamps) as they reported the scientific knowledge they already held or had recently generated.

This stance was also taken as students made their own arguments about natural phenomena or about how scientific practices worked. For instance, the teacher encouraged students to share what they already knew about how evidence could be used to support claims. One student confidently got the attention of his small group. He explained, “It’s like, if it’s snowing and your cat ran away, there would be paw prints. So, if you followed the paw prints and made it to the end, your cat would be there” (9.7.22, 7:43). His group mates nodded in agreement with the idea—one that would surely be relatable to them in snowy rural winters. In this way, students were positioned as having relevant background knowledge of science as well as relevant background knowledge of scientific practices.

Authority of “Teacher: You”

The second most common code in the Authority of Knowledge category was Teacher: You, indicating that the teacher invited students to share their ideas, be that in academic or everyday language. The Teacher: You code earned a “2” or a “3” in 39 of the 46 lessons, indicating that most of the time the teacher created opportunities for students to share what they knew and act as authorities. The teacher often did this in ways that were connected to other language use, including the development of academic language. For example, the teacher began a unit on forces by asking students, “How do you force someone to do something?” (11.28.22, 15:49; Mrs. A). The students shared about the idea of “force” using everyday language and common examples before turning to the way the word is used in the sciences, which was proposed by a student (i.e., a “Student: I” comment as noted above). Rather than beginning by providing a definition of the term “force” for students to learn, the teacher used a Teacher: You stance to help students share their existing schema related to the word force to its science-specific usage.

The teacher also used the Teacher: You stance as she monitored small group investigations, posed questions, and checked in with individual students during interactive learning moments. For example, when checking with a small group of students who were designing bridges, she listened to one very vocal student explain what the group was attempting to do. Then she summarized her ideas and stated, “So, you were thinking that something in the middle might help them? Did anybody else try something? Kenzie?” (9.23.22, 20:00; Mrs. B). In this way, the teacher included students’ ideas in the group’s exploration and modeled asking others for their input.

Sometimes the teacher would take a Teacher: You stance through helping students understand whether the class had reached consensus. She regularly used informal voting to help students gauge the need for additional negotiation. In one lesson she stated, “Thumbs up if you agree with Wyatt that metal is pretty solid and something you would want to use to build with” (9.19.22, 13:18; Mrs. A). Most students agreed, (which resulted in a wide smile on the part of Wyatt). In addition, the students who did not give a “thumbs up” were encouraged to write or talk to process how their ideas matched or clashed with what had occurred so far in the investigation. In this way, students were still positioned as problem-solvers but were encouraged to consider their ideas in relation to the evidence.

Summary

Students commonly took the stance of scientific authorities by reporting their knowledge through the Student: I code. In addition, students were positioned by the teacher as being knowledgeable through the Teacher: You code. Combined, the use of this language foregrounded the teacher’s determination that her students were active thinkers who could use scientific practices to design investigations, solve problems, and make valid arguments. In contrast, the codes utilizing the pronoun “we” were observed less frequently.

Discussion

This research was based on two questions asked within the context of an exemplary early childhood science classroom. First, we asked how teacher and student language use can be characterized in a classroom functioning as a generative learning environment. Our findings suggest that in a knowledge generation environment, scientific academic language is utilized by teachers and students very frequently, and acquired through usage rather than through direct, explicit instruction. At a time when significant resources have been turned toward developing young children’s vocabulary and language ability (UNESCO, 2023) this study has demonstrated that this learning can occur within immersion in science instead of being a precursor to having meaningful scientific learning. Second, we asked who holds authority of knowledge in an early childhood science classroom functioning as a knowledge generation environment. Our findings suggest that in this early childhood classroom, students positioned themselves as authorities on their knowledge using “I” pronouns, and teachers regularly positioned students as authorities by asking them questions. Through a positioning theory lens, (Kayı-Aydar, 2019; Moghaddam & Harré, 2010), we posit that these pronouns are important indicators of students claiming authority within the learning environment.

Implications for Early Childhood Students' Academic Language Growth

A key finding from the current research is that when scientific academic language is taught through immersion in scientific dialogue (as demonstrated through the dominance of the Scientific Language code), students can adopt this language for themselves (as demonstrated through the Student: I code). In fact, it is possible that language learning in this environment was not just *permitted* but *supported* by students' ability to build from everyday language (Adair et al., 2017). Using students' everyday language likely created multiple access points to science learning for students regardless of their lived experiences. This exemplifies how teaching is "the very opposite of control, the very opposite of attempts at approaching students merely as objects, but rather takes the form of approaching students as subjects" (Biesta, 2017, p. 3). Biesta claims that approaching students as subjects must be done "even when there is no evidence that they are capable of it" (2017, p. 3), and we agree. Although the students had little prior knowledge of academic language in science, the teacher positioned them as having the intelligence to develop these characteristics through her stance as negotiator.

Implications for Early Childhood Teaching through Language

We also argue that the low use certain types of language in this classroom is not an irrelevant or unconnected finding. In this classroom environment, where students were engaged in designing investigations to their own questions, the teacher was able to place her focus on science learning and academic language growth through the practices of the sciences. Therefore, her use of management language to remind students of classroom norms, rules, and responsibilities was the least commonly observed language practice. The second least used language practice was rewording students' ideas for clarity. We argue that her resistance to telling students that their ideas were unclear by restating them herself, a move which claims ownership of the ideas themselves, is connected to questions of authority in science. In this classroom, students were permitted to express and clarify their own scientific arguments (Cavagnetto, 2010) rather than the teacher claiming ownership.

Implications for Early Childhood Students' Authority in Science

A second key finding was the willingness early childhood students had to positioning themselves as scientific experts with valid arguments and knowledge to share. This was evidenced through students' confidence making claims using the pronoun "I" (as demonstrated through the Authority of Knowledge codes) as well as through their confidence offering their everyday ideas and background knowledge in response to prompts about scientific terminology (as demonstrated through the Language and Representation codes). The relationship between these two elements merits further examination. We suggest that the teachers' openness to permitting students to share commonly used definitions of terms, and their practice of connecting this knowledge to science-specific vocabulary definitions, supported students' willingness to take authority. Thus, the language use and the authority stances in this knowledge generation environment intersected. While students in secondary science are more often positioned as authorities on knowledge (Weiss et al., 2022) it is rare to see younger learners engaged in taking the same positions toward science.

Limitations

As a case study (Yin, 2013) this work is not intended to produce findings that are directly generalizable. However, the language patterns we observed in this exemplary classroom suggest leverage points early childhood educators can utilize to begin constructing their own generative science learning environments. Further research that examines the trends in language use across multiple early childhood science classrooms using the generative learning matrix is needed. Further, this research was focused on understanding language use at the level of the classroom rather than focusing on the experiences of individual students. Further research that clarifies how students with different characteristics (i.e., gender identity, linguistic background) experience generative learning environments in science will add valuable additional insights.

Conclusion

Early childhood science teachers are experts at constructing play-based and student-centered learning experiences (Hamel et al., 2021; Nxumalo et al., 2020). The current research examined the possibility that within these student-led spaces, teachers still have a valuable role to play as negotiators (Biesta, 2017) who construct knowledge generation environments for learning (Hand et al., 2021) by positioning students as authorities on their own knowledge. In these environments, early childhood students can build academic language in science (Schleppegrell, 2004) through dialogue, negotiation, and through investigations that require their use of language as not just a representational tool but a tool for new learning. Many early childhood educators already reject notions of the teacher as the authority figure in science learning (Hamel et al., 2021). Thus, to advance the field, further articulating the role of early childhood science teacher as negotiator is key. Further, this study showed that programs designed to accelerate children's vocabulary learning in science do not necessarily need to be based on direct instructional models. Through immersion (Weiss et al., 2022) early childhood students are more than capable of developing academic language in science.

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Declarations

Research Involved Human Subjects This research received approval from the Institutional Review Board at the University of Iowa, Approval #201,804,703. All participants provided informed, active consent.

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