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Family science capital moderates gender differences in parent–child scientific conversation

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A B S T R A C T

This study examined whether variation in parent–child conversations about scientific processes can be explained by child gender and the science-related resources available to parents, known as scientific capital. Parents of 4- and 5-year-old children (N = 70) from across the United States completed a survey of science capital and were then videotaped with their children at home interacting with two science activities (i.e., balance scale and circuit toy). Videos were transcribed and analyzed for parents' science process language. Results indicated that parents' science process language occurred significantly more often during conversations with boys, among families with higher levels of scientific capital, and during the scale activity. Gender differences in science process language were not apparent at higher levels of science capital and during the scale activity. These effects speak to the need for measuring child, family, and contextual characteristics when identifying factors that promote children's early science engagement and learning. Results are discussed in terms of future interventions that could build scientific capital as a means to counteract stereotypes around gender and science.

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Introduction

Preschool-aged children are inherently curious about scientific phenomena and are increasingly capable of engaging in scientific thinking (Callanan, 1992; Chouinard, 2007; Frazier et al., 2009). Conversations about scientific processes, which emphasize causal relationships, hypotheses, connections, and predictions, are particularly effective at promoting the acquisition of scientific concepts, inquiry, and scientific exploration (Benjamin et al., 2010; Callanan & Jipson, 2001; Crowley, Callanan, Jipson, et al., 2001; Haden, 2010; Haden et al., 2014; Jant et al., 2014; Leinhardt et al., 2002; Marcus et al., 2017; Pattison & Dierking, 2019). Opportunities to converse about scientific processes are thought to equip children with the skills and attitudes needed for engagement in K–12 science learning, which requires an understanding of how science is a process of inquiry, experimentation, and observation (e.g., Abd-El-Khalick & Lederman, 2000; Bybee, 2013; Chalmers, 2013; NGSS [Next Generation Science Standards] Lead States, 2013).

Parents have been found to vary in the frequency and ways in which they engage their children in conversations about scientific processes; however, the sources of such variation are less clear. In this study, we examined the extent to which two factors explain individual differences in parents' science process language: their children's gender and the cultural capital available to families. We also explored the intersection of these factors by examining how gender differences in parental language may be more pronounced at differing levels of cultural capital. A contribution of this study is the application of a multidimensional form of cultural capital, *scientific capital* (Archer et al., 2015; DeWitt et al., 2016), to research on parent–child conversation. Although a well-established factor in explaining scientific participation and interest among adolescents and young adults (e.g., DeWitt et al., 2016), the contribution of scientific capital to variation in parenting and communication with young children is not fully understood.

In line with social-interactionist theories of development (Bruner, 1983; Vygotsky, 1978), parent–child conversations about science provide children with information they cannot always acquire through firsthand experience. Conversations that center around science processes, such as discussing the steps of an experiment and analyzing cause–effect relationships, can provide a foundation for future learning about science and general literacy (Callanan & Jipson, 2001; Snow & Kurland, 1996). For instance, Tenenbaum et al. (2005) reported that the proportion of parents' science talk to children during a joint magnet activity predicted children's comprehension of science texts over and above the effects of maternal education and children's own use of science process language. Conversations about science processes are thought to provide children with background information about scientific concepts (Tenenbaum et al., 2005), and information about the nature of science as a form of inquiry (Abd-El-Khalick & Lederman, 2000; Chalmers, 2013; Korpan et al., 1997). These conversations also target children's conceptual understanding, which can promote knowledge transfer (Lombrozo, 2011; Lombrozo et al., 2018; Marcus et al., 2017, 2018). The importance of science processes is also reflected in educational standards, such as the Next Generation Science Standards, in which references to scientific processes appear in each of the three dimensions of learning (i.e., cross-cutting concepts, disciplinary core ideas, and science and engineering practices; NGSS Lead States, 2013).

One potential source of variation in parents' talk about scientific processes is child gender. Studies that have examined parents' use of science process language with children have found mixed results concerning child gender. Some studies find that girls are, on average, exposed to less science-related language from parents compared with boys (Crowley, Callanan, Tenenbaum, et al., 2001; Eberbach & Crowley, 2017; Ocular et al., 2022; Simpkins et al., 2005; Tenenbaum et al., 2005). Even during play with STEM (science, technology, engineering, and mathematics)-related toys, parents of girls tend to focus more on reading instructions, whereas parents of boys spend more time discussing STEM-related concepts (Coyle & Liben, 2020). One possibility for these gender differences is that boys simply elicit more input from parents because they themselves talk more about science or are more engaged with the topic at hand. However, there is not strong empirical support for this claim; for instance, Crowley, Callanan, Tenenbaum, et al. (2001) found that although parents used more scientific explanations with boys than with girls at a museum, there were no differences by child gender in engagement with the exhibit. This finding aligns with other research indicating that prior to formal schooling, boys and girls show comparable levels of ability and interest in science (Greenfield, 1997). The nature of the relation between child gender and parental input is further complicated by the fact that other studies find no significant gender differences (Acosta et al., 2021; Benjamin et al., 2010; Callanan et al., 2020; Sobel et al., 2021) or differences in the opposite direction (i.e., more language to girls than to boys; Shirefley & Leaper, 2022). These equivocal findings suggest that factors beyond child gender should also be considered when examining variation in parent–child conversation.

In this study, we investigated whether family characteristics may partly be responsible for equivocal findings of how child gender is related to parents' science process talk. Indeed, theoretical accounts of child development, such as bioecological systems theories, describe how family characteristics such as social and cultural capital affect the nature of parent–child interaction (Bronfenbrenner & Morris, 1998). For example, parents with more years of Western education engage in more science process talk, such as providing explanations and drawing connections, while interacting with their children (Acosta et al., 2021; Szechter & Carey, 2009; Tenenbaum & Callanan, 2008). The current study went beyond parent education as an explanation of variation in parent–child scientific conversations by measuring parents' science-related social and cultural capital, known as scientific capital (Archer et al., 2013, 2015).

The construct of science capital is informed by Bourdieu's (1984, 1986) theory of social reproduction, which emphasizes how an individual's *habitus* (i.e., dispositions and values) and access to forms of capital (i.e., social, cultural, economic, and symbolic) interact to perpetuate inequalities, particularly related to education. Drawing on Bourdieu's conceptualization of habitus and capital, science capital extends beyond individuals' scientific knowledge to also encapsulate science identity and science participation (Archer et al., 2015). Science capital falls under four, related dimensions: what science you know, who you know, how you think, and what you do (DeWitt et al., 2016). Adolescent students who report higher levels of science capital are more likely to pursue science-related courses and careers, compared with peers with lower science capital, despite equal access to other forms of cultural capital (Archer & DeWitt, 2016; DeWitt et al., 2016). Science capital explains significantly more variation in adolescents' career and course decisions than their parents' educational attainment or household income.

Because science capital is an effective framework for identifying factors that promote or constrain science participation among adolescents and adults, we argue that it may also prove to be informative for explaining the resources parents draw on to socialize their young children into science. Indeed, prior work has shown that individual dimensions of science capital, such as parents' attitudes toward science, are positively associated with how families talk about science (Callanan et al., 2020; Szechter & Carey, 2009; Tare et al., 2011; Weisberg & Sobel, 2022). For instance, parents with more positive attitudes about science and scientists have been found to use more causal language with children at museum exhibits (Callanan et al., 2020). This work has primarily been conducted in museum-based research studies, raising the question of whether the construct of science capital operates similarly in other informal settings such as the home. Here, we examined whether a composite science capital measure—reflective of what science you know, who you know, how you think, and what you do—is associated with the quantity of science process language parents use with children in a home-based setting. Because what *capital* is valued is determined by one's social context (Bourdieu, 1984), we adapted prior science capital survey items designed for adolescents (DeWitt et al., 2011, 2016) to be appropriate for parents with young children. For instance, instead of probing science-related interactions in school, survey items focused on interactions in the workplace, in the neighborhood/community, or with family members. In doing so, we sought to understand how science capital is built through everyday interactions not limited to the workplace.

The primary goals of this study were to investigate differences in parent–child scientific conversations as a function of child gender and to examine the role of science capital in shaping such conversations. We recruited parent–child dyads (equal numbers of 4- and 5-year-old boys and girls) of varying levels of scientific capital and recorded their conversations while engaging in two science-based activities. We transcribed each video recording and analyzed the transcripts for words reflective of scientific processes. This study had three primary research questions. The first question asked whether there are differences in parents' science process language based on whether parents are interacting with their son or daughter. The second research question examined to what extent science-specific capital relates to parents' science process language. To our knowledge, this is the first study to examine how a composite science capital measure—which encompasses attitudes, knowledge, experience, and practices—is associated with parent–child communication about science.

Finally, the equivocal findings regarding whether child gender is associated with parents' scientific language led us to hypothesize that this association might not exist systematically across the population. Thus, our third research question determined whether the effects of child gender on parental talk were conditional on (i.e., statistically moderated by) families' science capital. We predicted that science capital would moderate the relationship between child gender and parental use of science process language, such that the gender difference in language use would be greater for parents with lower levels of capital. This hypothesis is informed by prior research with European American families indicating that parents use more science talk with boys than with girls, but only among parents without a 4-year college degree (Shirefley et al., 2020). We are unaware of any study that specifically examined science capital as a moderator but predicted that this variable would function similarly to education.

In addition to the primary questions concerning child gender and science capital, the study design afforded the opportunity to also examine how the activity setting influenced parents' science process language. Indeed, sociocultural perspectives on learning highlight how different social contexts can lead to variation in the quantity and quality of parental language input (Bruner, 1983; Vygotsky, 1978). Most research on scientific conversation and children's learning has compared formal and informal contexts, different museum exhibits, or varied goal structures, (e.g., open-ended play vs. guided play; e.g., Weisberg et al., 2013). Here, we took a different approach by inviting dyads to engage with two open-ended, informal learning activities (balance scale and circuit toy) and comparing the talk across activities. Both activities provided opportunities to talk about science processes and to engage with science-related materials. Thus, it is possible that these contexts would lead parents to use similar quantities of science talk. Alternatively, it is possible that the underlying scientific phenomena of the activities would result in different amounts of talk. That is, the concepts of weight and balance are more visible and less abstract than electricity, which for parents and their preschool-aged children may invite more talk about science.

Method

Participants

A total of 70 parents (n = 62 mothers, n = 8 fathers) with a 4- or 5-year-old child (i.e., target child) were recruited by an online research firm using social media platforms, panels, and e-mails. Families lived across the United States (Midwest: n = 20; Northeast: n = 17; South: n = 23; West: n = 10). To be included in the study, participants were required to live in the United States, speak English at home at least 75% of the time, and have adequate internet access to complete the online survey and remote session. An additional 10 families consented to participate but were not included in the final sample because their parent–child interaction was not recorded (n = 1) or because they failed to schedule or attend the remote session (n = 9). Complete demographic information on parent participants and their target child is presented in Tables 1 and 2.

Procedure

The data for this study included a parent survey and videotaped parent–child interaction conducted remotely in the families' homes. Upon consent, parents were e-mailed a link to an online survey to collect science capital and demographic information. After parents completed the survey, they were mailed a STEM activity box containing four activities to be used during an upcoming virtual visit with a member of the study team. Families were instructed not to play with the toys and materials before the virtual visit. During the 45-min visit, a research assistant invited families to engage with the STEM activities for 5 min each in a fixed order. In this study, we analyzed data from the two science-focused activities: a balance scale and a circuit toy. The balance scale activity featured a scale and approximately 50 1-inch-sized plastic bears, similar to the stimuli used by Leech et al. (2023). The

Table 1
Parent and family characteristics (N = 70)

Variable		*n*
Parent Gender	Female	62
	Male	8
Race	American Indian/Alaska Native	3
	Asian	7
	Black or African American	8
	Native Hawaiian/Pacific Islander	0
	White	52
	Other	5
Ethnicity	Hispanic	11
	Not Hispanic	58
	No response	1
Education	High school degree	13
	Vocational/associate degree	11
	Bachelor's degree	29
	Graduate/professional degree	17
Household income	Under $30,000	4
	$30,000–$39,999	10
	$40,000–$49,999	2
	$50,000–$59,999	9
	$60,000–$74,999	20
	$75,000–$99,999	11
	$100,000+	13
	No response	1
Household size (in people)	2	3
	3	8
	4	30
	5	14
	6	9
	>7	6
Employment	Full-time	25
	Part-time	9
	Unemployed	27
	Student	1
	Self-employed	6
	No response	2
Language(s) spoken at home	English only	61
	English and other language	9

Some individuals reported more than 1 race. Thus, the numbers add up to more than 75.

Table 2
Target child characteristics

Variable		*n*
Gender	Female	35
	Male	35
Age (years)	4	39
	5	31
Race	American Indian/Alaska Native	3
	Asian	6
	Black or African American	11
	Native Hawaiian/Pacific Islander	1
	White	50
	Other	2
Ethnicity	Hispanic	12
	Non-Hispanic	58
In child care outside the home	Yes	40
	No	30

researcher instructed parents to play with their children as they typically would at home. The circuit activity occurred immediately after and featured a SnapCircuit board and corresponding pieces (i.e., a light or fan, wire pieces, a press switch, and a battery pack). While the families interacted, the researcher turned off her camera and muted her microphone. Families rarely had questions during the interaction; if they did, the researcher answered them briefly. Parent–child conversations were videotaped for later transcription and coding (see methods below). Researcher–family conversations were not transcribed and thus were excluded from the analyses.

As study compensation, families kept the activities and received a $25 gift certificate. This study's design and analyses were not preregistered, but the predictions were specified a priori in a National Science Foundation grant proposal. This study was reviewed and approved by the university's institutional review board. The data were collected from May to August 2022.

Measures

Child gender

Parents were asked to indicate their child's gender using the following survey item: "Does your child identify as female, male, or other—please describe." We designed the item in this way to allow for gender to be analyzed on a spectrum; however, all parents indicated that their child identified as either female (n = 35) or male (n = 35). Thus, child gender was analyzed as a binary variable in all analyses.

Science process language

All speech from videotaped parent–child interactions was manually transcribed by trained research assistants using the Child Language Data Exchange System (CHILDES; MacWhinney, 2000). Every transcript was verified by an independent research assistant to ensure accuracy. The identification of science process language in the transcripts proceeded in a two-step process similar to Polinsky et al. (2023) analysis of spatial words. First, we built a dictionary of science process terms and used the KWAL command in the CLAN program to count their occurrence within the transcripts.

We defined science process language as terms relevant for engaging with and understanding scientific practices; these include language that supports exploration, inquiry, and reasoning necessary within the scientific domain (Abd-El-Khalick & Lederman, 2000; Chalmers, 2013). To operationalize this definition, we started with a list of terms created by Marzano et al. (2012) that aligned with NGSS's crosscutting concepts (CCCs) and science and engineering practices (SEPs). These NGSS dimensions are considered to be essential for facilitating scientific literacy and practices across scientific domains (Bybee, 2013) and were primarily Tier 2 and Tier 3 words based on Beck et al.'s (2013) tiered vocabulary framework. We also included a set of cognitive verbs identified by Marzano et al. (2012) that reflect critical thinking, reasoning skills, and cognitive processing, which are thought to be important dispositions for doing science. Because NGSSs are written for school-aged children (K–12), we recognized that there may be additional words used by parent–preschooler dyads not represented in Marzano et al.'s list. Thus, we used the KWAL command in CLAN to generate a list of all utterances in the corpus to identify terms not in Marzano et al.'s list but that were germane to the specific study contexts (scale and circuit) and the preschool age group (see online supplementary material for the full dictionary). An asterisk (*) was appended to each word in the list that returned not only the base word (e.g., *connect*) but also pluralized, continuous, and tense variations (e.g., *connects, connected, connecting*).

In the second coding step, we used a contextual verification process to ensure that words identified by the dictionary were indeed used in a scientific context. This step was critical because many words, although relevant in scientific discourse, can also be used in everyday language with different meanings. To determine the context of each identified word, we examined the surrounding utterance in which each word appeared. For instance, the word "even" was included when it referenced balance or equality (e.g., "Are the sides *even* now?"; "Can you make it *even*?") because this reference reflects the NGSS SEP of using a mathematical concept such as comparison to solve a science-related problem. Conversely, the same word was excluded when used in nonscientific contexts (e.g., "Are you *even* looking at this?"). Our dictionary results initially returned 3913 utterances that contained at least one science process word, and 80.3% of the utterances (n = 3143; n = 3659 words) were retained after verification. Reliability coding was calculated for 20% of the data, with 94.7% agreement between two independent coders. The quantity of science process language was measured by summing the number of science process words overall and for each activity separately (balance scale or circuit toy) for each speaker.

Non-science process language

We calculated the number of words that did not reference scientific processes by subtracting science process words from the total number of words produced by each speaker. The sum of science process and non-science process words equaled the total number of words produced by each speaker.

Family scientific capital

Parents completed an online survey of science capital designed for this study from existing measures (see supplementary material for survey items). Survey items (N = 25) were adapted from the Science and Technology: Public Attitudes, Knowledge, and Interest Survey (National Science Board, National Science Foundation, 2020), Archer et al. (2015), and DeWitt et al. (2016). The items measured scientific literacy (e.g., true or false: "Lasers work by focusing sound waves"), science identity (e.g., "Other people think of me as a science person"), and science-specific social capital (e.g., "How often do you talk about science with other people?"). To reduce the dimensionality of items, we represented this construct using a principal components analysis (PCA) composite. Factor loadings for each variable were greater than .40 (Floyd & Widaman, 1995), and the eigenvalue of the resulting composite was 2.01, accounting for 40% of the total variance. The resulting composite was a z-score with a mean of 0 and a standard deviation of 1; thus, positive scores (i.e., greater than 0) indicate science capital above the sample mean.

Analysis plan

Our primary results are organized into those that examine the main effects of child gender and science capital on parents' science process language and whether the effect of child gender is conditional on family science capital. Secondary analyses examined differences in parental talk by activity setting. The dependent variable in each model was the number of parents' science process words unless otherwise specified. We modeled data using a series of mixed-effects negative binomial regressions to account for positively skewed count data and overdispersion of the outcome variables. The models included the following fixed-effect covariates: activity setting (0 = circuit, 1 = scale), child age (in years), the child's science process words, and number of non-science process words to control for variation in overall talkativeness. We also included the random intercept of participant and a random slope for activity type (by participant to allow participants to vary with respect to this effect). To address the third research question, interaction effects were added and significant interactions were probed using simple slopes.

Our model building strategy was as follows. In the first model, we simultaneously entered covariates (activity type, child age [in years], and non-science process words) and examined their joint effect on parents' science process language. This model allowed us to examine potential differences in talk by activity type (scale vs. circuit) prior to entering focal predictors. Next, we added the fixed effects of child gender and science capital in separate models to examine their unique effects over and above the covariates. To address the third research question, we added interaction effects in two separate models (Gender × Science Capital and Gender × Activity Type). For each significant predictor variable, we present the incidence rate ratio (IRR) as an effect size measure. IRRs can be interpreted as the magnitude of change in the number of science process words when the predictor variable changes by 1 unit.

Results

Descriptive statistics

On average, parents produced 520 total words per activity, of which 23.41 reflected scientific processes (*SD* = 15.00). There was considerable variation across parents, with some parents using 0 science process words and others using as many as 79 during the 5-min interactions. Talk varied across activity settings, such that parents used more science process language during the scale activity (*M* = 27.66, *SD* = 16.52, range = 1–79) than during the circuit activity (*M* = 19.15, *SD* = 11.99, range = 0–50). Non-science process language and total words also followed this pattern. The quantity of parent and child science process words was significantly and positively correlated, $r = .36$, $p < .01$, 95% confidence interval (CI) = [.21, .50]. Full descriptive statistics for each language variable, by activity setting and child gender, are presented in Tables 3 and 4, respectively.

Before presenting the results of our focal research questions, we report an initial regression model containing only covariates as predictors of parents' science process language (Table 5, Model 1). The results of this model mirror the descriptive data presented above and show a significant effect of activity, such that parents used significantly more science process language when interacting with the scale than when interacting with the circuit, $p < .001$, IRR = 1.69, 95% CI = [1.45, 1.96]. Child age was not a significant predictor of parents' science process language ($p = .67$).

Research Question 1: Differences in parent talk by child gender

The first research question examined whether parents' science process language varied as a function of child gender. Table 5 (Model 2) shows that the effect of child gender was significant, such that parents used significantly more science process language with boys than with girls, $p = .003$, IRR = 0.81, 95% CI = [0.70, 0.93]. This IRR suggests that there is a 20% decrease in the expected count of science process words to girls versus boys. The model's predicted values showed that parents used, on average, 21.61 science words with boys and 17.48 science words with girls.

We conducted two follow-up analyses to probe potential reasons for gender differences in parental talk. First, parents may use more science language with boys because they simply talk more to boys. To empirically test this possibility, we built a similar regression model predicting parents' non-science process language from the predictors in Model 2 (Table 5). Results indicated that there was no difference in parents' non-science process language when conversing with boys (*M* = 508.50, *SD* = 217.37) versus girls (*M* = 486.34, *SD* = 227.20), $B = -0.03$, $SE = 0.04$, $z = -0.79$, $p = .43$. A second possibility is that parents use more science language with boys because they are attuned to gender differences in children's science process talk. To examine this, we compared boys' and girls' use of science process language. Overall, and as expected, children used fewer science process words than their parents (*M* = 3.89 words, *SD* = 3.98, range = 0–20). However, there was no statistically significant difference in science process words between boys (*M* = 3.90, *SD* = 3.64) and girls (*M* = 3.93, *SD* = 4.36), $B = -0.17$, $SE = 0.16$, $z = -1.04$, $p = .30$.

Table 3
Raw means (and standard deviations) and ranges of parent and child talk during the scale and circuit activities

	Circuit		Scale	
	Mean (*SD*)	Range	Mean (*SD*)	Range
Parent				
Science process words	19.15 (11.99)	0–50	27.66 (16.52)	1–79
Non-science process words	527.51 (212.90)	53–1000	464.35 (225.19)	64–1022
Total words	546.66 (221.13)	54–1047	492.01 (238.00)	65–1064
Child				
Science process words	3.42 (3.20)	0–15	4.37 (4.60)	0–20
Non-science process words	75.75 (52.26)	0–238	94.77 (54.12)	1–266
Total words	79.17 (54.37)	0–253	99.14 (56.99)	1–273

Table 4
Raw means (and standard deviations) and ranges of parent and child talk by child gender

	Boy		Girl	
	Mean (*SD*)	Range	Mean (*SD*)	Range
Parent				
Science process words	26.06 (15.72)	3–79	20.87 (14.09)	0–64
Non-science process words	508.50 (217.37)	112–1022	486.34 (227.20)	53–914
Total words	534.56 (228.44)	118–1064	507.21 (235.91)	54–1011
Child				
Science process words	3.90 (3.64)	0–15	3.93 (4.36)	0–20
Non-science process words	79.53 (50.44)	5–266	90.73 (57.57)	0–233
Total words	83.43 (52.83)	5–273	94.66 (60.33)	0–240

Note. Data are aggregated by activity setting (circuit or scale)

Table 5
Regressions displaying main effects of child gender and science capital on parents' science process language

Model 1: Covariates only	*B*	*SE*	*z*	*p*
Fixed effects				
Intercept	2.65	0.34	8.16	<.001
Child age (years)	−0.04	0.08	−0.47	.63
Activity (scale)	0.48	0.07	6.52	<.001
Non-science process words	0.46	0.04	12.08	<.001
Child science process words	0.03	0.01	3.88	<.001
Random effects (participant)	Variance (σ^2)	*SD* (σ)		
Intercept	0.16	0.40		
Activity	0.24	0.49		
Model 2: Child gender	*B*	*SE*	*z*	*p*
Fixed effects				
Intercept	2.76	0.32	8.70	<.001
Child age (years)	−0.01	0.07	−0.17	.86
Activity (scale)	0.47	0.07	6.46	<.001
Non-science process words	0.46	0.04	12.64	<.001
Child science process words	0.03	0.01	3.92	<.001
Child gender (female)	−0.21	0.07	−2.95	.003
Random effects (participant)	Variance (σ^2)	*SD* (σ)		
Intercept	0.13	0.35		
Activity	0.24	0.49		
Model 3: Science capital	*B*	*SE*	*z*	*p*
Fixed effects				
Intercept	2.68	0.31	8.52	<.001
Child age (years)	0.01	0.07	0.08	.94
Activity (scale)	0.49	0.07	6.52	<.001
Non-science process words	0.44	0.04	12.31	<.001
Child science process words	0.03	0.01	3.86	<.001
Child gender (female)	−0.21	0.07	−2.91	.003
Science capital	0.07	0.03	2.05	.04
Random effects (participant)	Variance (σ^2)	*SD* (σ)		
Intercept	0.13	0.36		
Activity	0.24	0.49		

Research Question 2: Differences in parent talk by science capital

Turning to our second question, we examined whether science capital was associated with parents' use of science process language. Model 3 (Table 5) revealed a significant and positive association between science capital and parents' language use, $p = .04$, IRR = 1.07, 95% CI = [1.00, 1.15]. For each standard deviation increase in science capital, the quantity of parents' science process language increases by 8.4%. Again, this model includes the above-specified covariates, suggesting that science capital explains unique variance in language use above and beyond the covariates.

Research Question 3: Moderators of child gender effects on parent talk

Our third research question had two parts focused on whether hypothesized gender differences in science process language were conditional on (a) activity type and (b) families' science capital. We addressed this question by examining whether child gender significantly interacted with activity type and science capital using a negative binomial regression framework. The model output for each interaction effect is presented in Table 6. A significant Gender × Activity Type interaction emerged, $p = .03$, IRR = 1.36, 95% CI = [1.11, 1.49] (Model 1, Fig. 1). Simple slope analyses indicated that parents used significantly more science process language with boys than with girls during the circuit activity, $B = -0.40$, $SE = 0.11$, $z = -3.57$, $p < .001$. In contrast, there were no gender differences in science process language during the scale activity, $B = -0.09$, $SE = 0.10$, $z = -0.93$, $p = .35$.

Consistent with our hypothesis, a significant interaction effect between science capital and child gender also emerged (Table 6, Model 2), $p = .001$, IRR = 1.28, 95% CI = [1.10, 1.49]. We probed the nature of the interaction by testing the conditional effect of child gender at three levels of science capital: 1 standard deviation below the mean (science capital composite = −1.00), at the mean (composite = 0.00), and 1 standard deviation above the mean (composite = 1.00) (Fig. 2). Parents whose science capital was 1 standard deviation below the mean used significantly more science process language with boys than with girls, $B = -0.50$, $SE = 0.11$, $z = -4.51$, $p < .001$. Similar findings emerged for parents at the mean level of science capital, $B = -0.25$, $SE = 0.07$, $z = -3.36$, $p < .001$. At high levels of science capital, science process language did not differ between parents of sons and parents of daughters, $B = 0.00$, $SE = 0.10$, $z = 0.05$, $p = .96$.[1]

Discussion

Providing opportunities for parents and children to talk about science as a process of inquiry, experimentation, and observation has been shown to promote engagement and learning (Haden, 2010; Haden et al., 2014; Tenenbaum et al., 2005) and prepare children for the demands of science in K–12 settings (Abd-El-Khalick & Lederman, 2000). Yet, research also indicates that parents vary in how much they reference scientific processes within conversations. The current study investigated factors that explain variation in parent–child conversations about scientific processes. Specifically, we found that parents' science process language was most prevalent in conversations between parents and boys, among parents with more science-related capital, and while playing with the balance scale versus circuit activity. Moreover, our findings add nuance to research on early science conversations by showing that gender differences in parental language were most pronounced at lower levels of science capital and during certain activities, namely, circuits. Together, these findings suggest that it is necessary to examine both the unique and combined effects of family-, context-, and child-level characteristics when investigating variation in parent–child conversations about science.

[1] In response to a reviewer's comment, we verified that the interaction between child gender and science capital held if the 9 items pertaining to scientific knowledge were removed from the science capital composite. Both the interaction effect and the nature of the interaction remained significant and in the same direction.

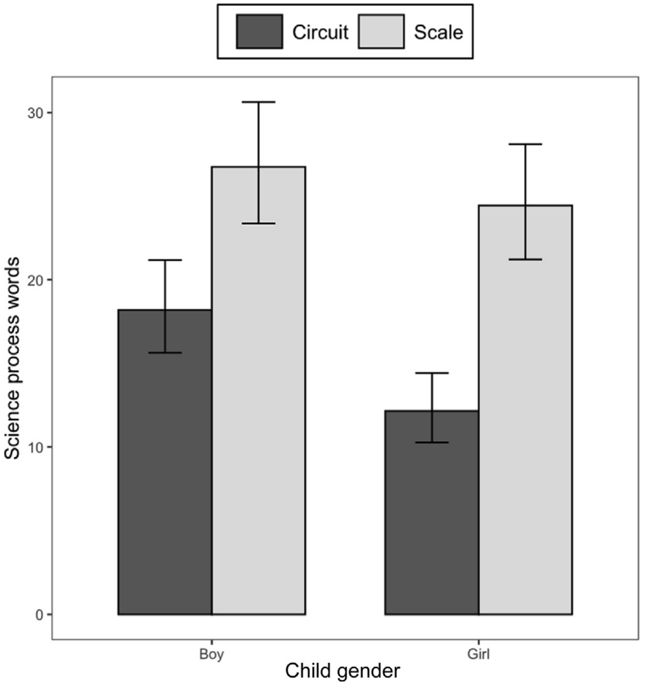

Fig. 1. Gender differences in science process talk are moderated by activity type. Gender differences in parents' talk were evident during the circuit activity but not during the scale activity. Overall, parents used more science process language during the scale activity than during the circuit activity. The y-axis indicates the number of parents' science process words. Error bars reflect 95% confidence intervals.

Scientific conversation is associated with child gender and science capital

In this sample, girls received fewer opportunities to engage in conversations about scientific processes than boys. Although it is possible that differences in parents' input reflect gender differences in children's own language production, our exploratory follow-up analysis did not reveal evidence for this possibility. This aligns with prior work reporting gender differences in parental science talk but not in children's own contributions to the conversation or interaction (Crowley, Callanan, Tenenbaum, et al., 2001; Tenenbaum et al., 2005). Similarly, our data indicated that variation in science process language by child gender was not simply a byproduct of the overall quantity of parental language. Instead, our data implicate possible alternative explanations rooted in family characteristics. We found that parents with more science-specific resources and social capital—*science capital*—engaged in more scientific conversations with children. This finding is in line with prior showing that dimensions of family science capital are associated with variations in science conversation within museum settings (e.g., Callanan et al., 2020). This study extends extant work by showing relations between science capital and science conversations in a sample of families recruited outside a museum setting who may represent a wider range of science capital.

Why is science capital related to scientific conversation? Parents with greater scientific capital are more likely to possess greater knowledge of the scientific process, potentially resulting in more scientific process language when interacting with their children. Moreover, scientific capital is a multidimensional construct that includes not only scientific literacy but also individuals' identification with science, their level of interest, and the frequency of engagement in scientific activities (DeWitt et al., 2016). Thus, it is unlikely that the effects of science capital on parental input can be attributed solely to knowledge of science. Bourdieu's (1984, 1986) theory of cultural capital suggests that parents

Table 6
Regressions displaying moderators of child gender on parents' science process language

Model 1: Activity type interaction	*B*	*SE*	*z*	*p*
Fixed effects				
Intercept	2.57	0.35	7.38	<.001
Child age (years)	0.07	0.08	0.93	.35
Activity (scale)	0.39	0.10	3.86	<.001
Non-science process words	0.46	0.04	11.74	<.001
Child gender (female)	−0.40	0.11	−3.56	<.001
Science capital	0.08	0.04	2.15	.03
Gender × Activity	0.31	.15	2.14	.03
Random effects (participant)	Variance (σ^2)	*SD* (σ)		
Intercept	0.15	0.38		
Activity	0.24	0.49		
Model 2: Science capital interaction	*B*	*SE*	*z*	*p*
Fixed effects				
Intercept	2.56	0.32	8.07	<.001
Child age (years)	0.06	0.07	0.80	.42
Activity (scale)	0.53	0.08	6.90	<.001
Non-science process words	0.44	0.04	12.08	<.001
Child gender (female)	−0.24	0.07	−3.36	.001
Science capital	−0.01	0.04	−0.06	.95
Gender × Science Capital	0.25	0.08	3.33	.001
Random effects (participant)	Variance (σ^2)	*SD* (σ)		
Intercept	0.12	0.36		
Activity	0.27	0.52		

with greater access to scientific capital may have developed a "scientific habitus," or a set of dispositions and attitudes that shape their own engagement with science and, in turn, their scientific interactions with their children. For example, parents with greater science capital are more likely to place greater value on science and are likely more comfortable in engaging in scientific interactions. Although the idea of a scientific habitus has been discussed concerning older students (Archer et al., 2015; DeWitt et al., 2016), it has not, to our knowledge, been examined in the context of parental conversations with young children beyond individual dimensions of capital (e.g., attitudes toward science/scientists). Thus, this study provides a novel application of Bourdieu's (1984, 1986) theory, extending it to the domain of early childhood science education and the important role that family factors and adult input play in shaping children's scientific understanding.

A novel finding from this study was that gender effects on parents' science process language varied as a function of family scientific capital. That is, the quantity of parents' science process language—favoring boys—disappeared at higher levels of scientific capital. In families with greater scientific capital, traditional gender stereotypes around scientific engagement may be less influential, and scientific capital may encourage parents to actively work against stereotypical expectations that tend to favor boys in scientific discussions. This interaction effect raises the possibility that equivocal results regarding child gender from prior literature might stem from variations in science capital among participating families. Thus, future research may benefit from measuring the science capital of participants to better understand its role in shaping scientific discourse and potentially other measures of dyadic interaction beyond verbal communication.

Our data point to opportunities to design interventions focused on building family science capital as a means to address gender disparities in parent–child scientific conversation. Science capital is more malleable than socioeconomic variables such as household income and formal education. Thus, a potentially effective strategy to reduce gender differences in parent–child scientific conversations might involve providing parents with opportunities to construct positive attitudes about science or building their scientific literacy. Such an approach might include highlighting the relevance of science in everyday life and connecting it to experiences that families already value (Yosso, 2005).

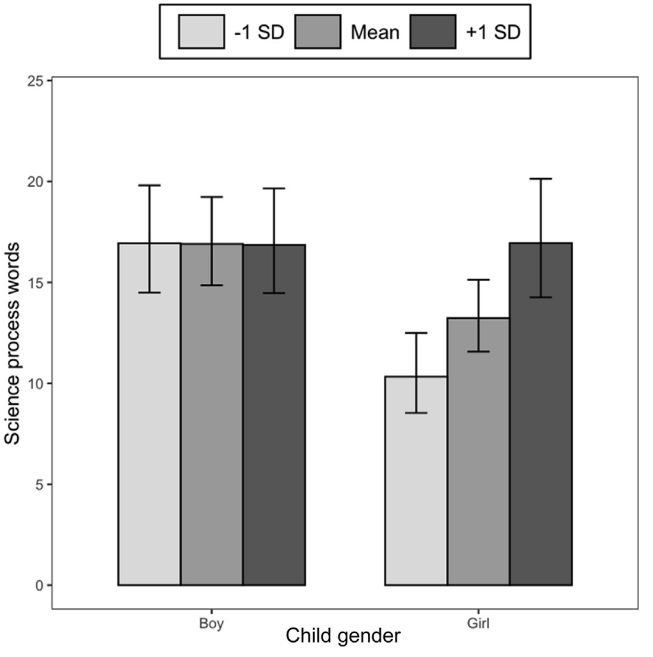

Fig. 2. Gender differences in science process talk are moderated by science capital. Gender differences in parents' talk were strongest among families with low science capital (−1 standard deviation below the mean). At the sample mean, gender differences were weaker but still statistically significant. For families +1 standard deviation above the sample mean, there were no gender differences in parents' talk. The y-axis indicates the number of parents' science process words. Error bars reflect 95% confidence intervals.

In addition to changes in parent–child conversation, these interventions may have positive effects on children. We argue that parent–child conversations during early childhood are a potentially powerful mechanism for cultivating interest and engagement in science. As early as kindergarten, children are aware of gender stereotypes about who can and cannot be scientists, and such awareness is likely amplified by language from adults (Bian et al., 2017; Rhodes et al., 2019). Thus, providing children with more opportunities to engage in scientific conversations may contribute to their positive science identity development, which may have a cascading effect on the likelihood of pursuing scientific activities and coursework. Our findings suggest that directing these efforts specifically toward parents of girls and within families with less access to science capital may be particularly beneficial.

Contextual differences in scientific conversation

In addition to the effects of child gender and science capital, parents' patterns of conversation differed across the two activity settings used in this study. Although both activities provide opportunities for hands-on engagement and to talk about scientific mechanisms (i.e., balance and weight, electricity), parents used nearly twice as much science process language while engaging with the balance scale than with the circuit activity. This finding is in line with previous work in other STEM domains, such as math, showing the nature of parent–child communication changes as a function of the materials available (e.g., Chan et al., 2020). It is possible that parents were more familiar with the scale toy and the concepts of balance and weight. Indeed, the concept of balance is more visible and intuitive than more abstract concepts such as electricity. Visible features of the balance scale may have afforded parents more opportunities for scaffolding—evident in their guidance through hypothesis generation (e.g., "Okay, so how do we balance it out?") and encouraging explanations (e.g., "Do you know why that side was heavier?"). These findings suggest that in the absence of providing explicit guidance to parents, selecting activities and materials that have more visible scientific mechanisms may be a way to increase scientific conversation between parents and preschool-aged children. Nevertheless, it is worth noting that we did not offer parents any instructional guidance on how to interact with the activities; had such support been provided, it is possible that activities with less overt mechanisms, such as the circuit activity, might have yielded greater quantities of scientific conversation.

The effect of activity setting was qualified by an interaction with child gender, such that differences in science talk emerged during the circuit activity but not during the scale activity. Specifically, we found that parents used science process language more often with boys than with girls only while engaging with the circuit. We posit that gender stereotypes within science subfields may be, in part, responsible for this interaction effect. Compared with electricity, weight and balance are considered more fundamental science concepts that are introduced to children at an early age (e.g., NGSS Lead States, 2013). Fields such as physics and electrical engineering, which heavily feature electrical concepts, have historically seen lower female participation (Cimpian et al., 2020; National Center for Science and Engineering Statistics, 2023), potentially reflecting and perpetuating societal stereotypes that deem these fields as traditionally masculine. These gendered perceptions may lead parents to subconsciously associate electrical activities with boys, prompting more talk about science with boys than with girls. The finding that non-science-related talk did not differ by gender further supports this argument. Notably, prior research shows that toys packaged for boys lead parents to engage in more scientific interactions with children (e.g., engaging in building) than toys packaged for girls (Coyle & Liben, 2020). Our findings are in line with this work, suggesting that activities perceived as gender-typed, such as the circuit, may activate gendered stereotypes and influence scientific conversation. Of course, the scale and circuit toys used in this study are only two examples of STEM-related toys, and future work should further consider how parents' perceptions of toys may shape how they interact with children and potentially what children learn.

Implications

The effects of gender and science capital on parent–child scientific conversation hold implications for both researchers and practitioners interested in promoting girls' engagement in science during early childhood. As argued above, variations in how parents communicate with their sons versus daughters and across science capital backgrounds provide targets for future interventions aimed at supporting children's early engagement and interest in STEM. Rather than interpreting these findings through a deficit lens—which can unintentionally perpetuate harmful stereotypes—we argue that these data provide an opportunity to use a strengths-based approach toward intervention. Science process language occurs within families across all socioeconomic backgrounds (Pattison & Dierking, 2019). For example, Tenenbaum et al. (2005) found that science process language made up approximately 7% of parents' input in an entirely lower-income sample in the United States, a percentage similar to other studies with mid- to higher-income populations (e.g., Leech et al., 2020). Families have been found to engage in scientific conversation especially when topics align with existing values and strengths (Castañeda et al., 2022).

In addition to interventions that focus on building science capital, it is possible that science capital may serve as a moderator of intervention efficacy. For instance, there is considerable evidence within the field of informal science learning that providing parents with prompts (e.g., conversation cards, instructions from researchers or experts) before interacting with science-related materials increases scientific talk and child learning (e.g., Benjamin et al., 2010; Chandler-Campbell et al., 2020; Haden et al., 2014). However, the efficacy of such interventions may vary based on the family's science capital, such that the impact of guided prompts could be moderated by preexisting science capital.

Finally, our methodology also holds implications for researchers who work with language data and on topics related to parent–child interaction. We conducted this study entirely remotely because COVID-19 lockdowns were still in effect and because 4- and 5-year-old children in the United States did not yet have access to vaccinations. This remote approach inadvertently provided a methodological advantage by broadening participant diversity beyond our university town, which typically exhibits higher-than-average scientific capital. This approach mitigates the risk of a restricted range bias that often limits studies constrained by local recruitment. Remote research is increasingly common (e.g., Sheskin & Keil, 2018), including the development of infrastructure to support fully unmoderated studies in which families participate without interacting with the research team (e.g., Rhodes et al., 2020). Similar to others, we see these remote methodologies as a significant opportunity to conduct research that can better generalize to the population and thus produce actionable targets for intervention.

Limitations and future directions

Although this study provides insight into factors that are associated with parent–child scientific conversation, we acknowledge several limitations that offer potential directions for future research. First, this study was cross-sectional; thus, we cannot speak to how conversations change over time or determine cause-and-effect relationships between key constructs. Thus, an important direction for future research is to collect longitudinal data to test the hypothesis that gender and science capital have longer-term effects on how parents talk about science with children. In addition, longitudinal designs can address questions about how gendered conversations affect children's scientific learning and interest. Longitudinal designs may also be integrated with interventions aimed at building scientific capital in parents and evaluating their impact on child outcomes.

Second, despite the benefits of dictionary-based approaches to measuring science process language (e.g., efficiency, consistency), we also acknowledge their limitations. Namely, this approach might not capture the full range of science process language as comprehensively as manual line-by-line coding. This limitation was partially addressed using a two-step validation process that showed a high degree of reliability when compared with manual coding. Furthermore, in line with sociocultural theories that emphasize how different social contexts lead to variation in parental language input (Bruner, 1983; Vygotsky, 1978), we tailored our dictionary by analyzing the language present in our specific corpus. Therefore, it is important for future studies to refine the dictionary to align with each study's unique context.

Third, we measured scientific conversation within two informal, relatively open-ended activities, and the patterns observed here might not generalize to other learning settings. We chose two play activities given the constraints of remote research (i.e., we could mail the materials to families easily) because they were likely to be familiar to families from different backgrounds and are well-established settings where children learn about science from adults. However, these results should not be generalized to other settings such as mealtimes, outside play, and contexts outside the home (e.g., museums). Although prior research has shown gender differences in museum contexts (Crowley, Callanan, Tenenbaum, et al., 2001), other contexts may yield additional differences. For example, cooking and meals may elicit more talk about physical science, whereas museums may offer opportunities to talk about biological or earth/space concepts, depending on the exhibit. Moreover, because certain subfields of science such as physical science are more male-stereotyped, whereas others are less stereotyped (e.g., biological science), gender differences in talk may become more or less apparent. A context that may lessen gender differences in scientific conversation is book reading. Book reading constitutes a high proportion of children's daily linguistic input (Montag et al., 2015) and has been shown to promote science process language when parents read the text and through conversations during reading, known as extratextual talk (e.g., Haden et al., 2023). Recent work has shown that gender differences are less apparent during book reading, and in some cases parents have been found to use more science talk with girls than with boys (Shirefley & Leaper, 2022). Moreover, book reading provides an opportunity for dyads to discuss scientific concepts across subfields and choose books that are interesting and relevant to their family and community.

Conclusion

The current study provides novel insights into explanations for individual differences in parent–child scientific conversations. Parents are often considered children's first teachers, and their interactions are known to shape children's learning and future interest in science. Thus, understanding the factors associated with variation in parent–child interactions provides important information regarding the contexts that can foster positive engagement with science during early childhood.

CRediT authorship contribution statement

Kathryn A. Leech: Writing – original draft, Funding acquisition, Formal analysis, Conceptualization.

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Data availability

The data that support the findings of this study are available via the Open Science Framework repository (LINK).

Data availability

The data that support the findings of this study are available from the corresponding author via the Open Science Framework repository (https://osf.io/v4h75/?view_only=86a06a5df6164da caa2686e795a26b9a).

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.jecp.2024.106020.

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