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# How Children's Media and Teachers Communicate Exclusive and Essentialist Views of Science and Scientists

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**Author Note:** The data, materials, and analyses that support the findings of these studies are openly available on OSF at https://osf.io/smkh6/?view_only=b7caab836b5f4a4bbea8b565003e3e7c (Study 1) and https://osf.io/uc4qm/?view_only=1963eb841a47478d987b1a00178b8adb (Studies 2 and 3). Study 1 was not pre-registered; Study 2's design and hypotheses were pre-registered (see https://osf.io/k84eh/?view_only=9b8e70338140404fbab9654dd60b5c4a); Study 3's design was pre-registered (see https://osf.io/wykre/?view_only=884f1322fcc348e9a56c3f231455f09e and https://osf.io/phn8s/?view_only=6af4deeb57024214a94a7544a4e34c17).

**Acknowledgements**: We are grateful to all the teachers and children who participated in our research. We thank Christine Lott, Maisy Rohrer, Dani Schuler, Daria Troya, and Ashley Winegarden for their help with data collection, transcription, and coding. We also thank Sherry Bai for her programming work in Study 1. Research reported in this publication was supported by the National Science Foundation under Award Number NSF EHR-2000617 (awarded to Marjorie Rhodes) and the National Institutes of Health under Award Number NICHD R01HD087672 (awarded to Marjorie Rhodes and Sarah-Jane Leslie). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Science Foundation or the National Institutes of Health.

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**Abstract**

Language that uses noun labels and generic descriptions to discuss people who do science (e.g., "Let's be scientists! Scientists discover new things") signals to children that *scientists* are a distinctive category. This identity-focused language promotes essentialist beliefs and leads to disengagement from science among young children in experimental contexts. The extent to which these cues shape the development of children's beliefs and behaviors in daily life, however, depends on (a) the availability of identity-focused language in children's environments, and (b) the power of these cues to shape beliefs over time, even in the noisier, more variable contexts in which children are exposed to them. Documenting the availability of this language, linguistic coding of children's media (Study 1) and prekindergarten teachers' language from one science lesson (Study 2; $n$ = 103; 98 female, 1 male, 4 unknown; 66% White, 8% African American, 6% Asian/Asian American, 3% Mixed/Biracial; 21% of the sample, of any race, identified as Hispanic/Latinx), confirmed that identity-focused language was the most common form of science language in these two samples. Further, children (Study 3; $n$ = 83; $M_{age}$ = 4.36 years; 43 female, 40 male; 64% White, 12% Asian/Asian American, 24% Mixed/Biracial; 36% of the sample, of any race, identified as Hispanic/Latinx) who were exposed to lower proportions of identity-focused language from their teachers developed increasingly inclusive science beliefs and greater science engagement over time. These findings suggest that linguistic input is an important mechanism through which exclusive beliefs about science are conveyed to children in daily life.

*Keywords*: noun labels, generic language, science engagement, longitudinal research, cognitive development, linguistic context

## How Children's Media and Teachers Communicate Exclusive and Essentialist Views of Science and Scientists

People often believe that success in science depends not on what one *does*, but on who one *is* – that is, that only certain people are intrinsically able to be "true scientists" (Knobe et al., 2013; Rattan et al., 2012). These beliefs can be maladaptive and exclusionary for children, as they invite children to question whether they themselves belong to this natural and distinct social category – a question that can be particularly demotivating for children who do not view themselves as sharing traits with stereotypic scientists (e.g., girls, children from racial/ethnic groups that have been historically excluded from science). Subtle linguistic cues implying that *scientists* are a special and distinct kind of person – including category labels and generic claims (as in, "Let's be *scientists*! Scientists discover new things") – elicit these problematic representations and their negative consequences in experimental settings (Lei et al., 2019; Rhodes et al., 2019). But whether such linguistic cues shape the development of these beliefs in children's daily lives and contribute to patterns of early disengagement from science depends on (a) the extent of their *availability* in children's contexts, and (b) their power to shape development over time, even in the noisier and more variable contexts in which children are exposed to them.

The primary goal of this paper is to document the linguistic cues concerning science that children hear from children's science media (Study 1) and from their teachers in prekindergarten classrooms (Study 2), to examine whether the specific linguistic cues that can undermine engagement in science are indeed present in children's daily lives. Secondarily, we begin to explore if these everyday cues are powerful enough to shape development over time, by testing

how natural variation in teachers' science language relates to the developmental trajectory of their students' beliefs about science across the school year (Study 3).

**How Linguistic Cues Shape the Development of Category Representations**

Language that includes *noun labels* (e.g., "Let's be scientists!") and *generic descriptions of categories* (e.g., "Scientists discover new things!") often leads children to think that the referenced group (in this case, *scientists*) is a stable, homogeneous, and absolute category in which members share innate, intrinsic properties with each other (Gelman et al., 2010; Gelman & Roberts, 2017; Rhodes et al., 2012). In general, noun labels lead children to expect more commonalities among individuals who share a label and more differences between groups (Bigler & Liben, 2007; Heyman & Gelman, 1999; 2000; Markman, 1989; Waxman, 2010). For example, Waxman (2010) found that 4-year-old children viewed gender and race as marking fundamental similarities across category members and differences between groups when members of those categories were marked with a common noun label, but not otherwise (see also Baron et al., 2014; Diesendruck & Deblinger-Tangi, 2014; Dunham et al., 2011; Gelman & Roberts, 2017).

Noun labels play an important role in guiding category acquisition across multiple conceptual domains (e.g., social categories, objects, animals, etc.; see Waxman, 1999, for review). Further, it is the use of a noun label in particular, and not shared words in other types of language, that increases attention to, learning, and reasoning about categories. For example, toddlers learned a new object category after each object was introduced with the same noun label (e.g., "This is a blicket") but not if they were introduced with a shared adjective (e.g., "This is a blickish one"; Booth & Waxman, 2003). As further illustration, Gelman and Heyman (1999) found that describing a person's behavior in terms of noun labels (e.g., "She is a carrot eater")

instead of simply as behavioral descriptions (e.g., "She eats carrots whenever she can") led children to think that the described behavior was more fundamental to identity and stable over time. Noun labels have even stronger effects on children's beliefs about categories when they are coupled with generic statements (statements that are descriptions of categories as abstract wholes, as in "Scientists care about the truth," or "Girls have long hair"). For example, when children learn about new categories from hearing a series of generic claims, they are more likely to think that the members of the category share an intrinsic "essence" that makes them similar to one another and different from other kinds (Gelman et al., 2010; Rhodes et al., 2012; 2020).

**Linguistic Cues Shape Early Science Beliefs and Behaviors**

Given the powerful role that category labels and generic claims play in communicating beliefs about categories, Rhodes et al. (2019) hypothesized that using these linguistic cues together to introduce science to young children (e.g., "Let's be scientists! Scientists discover new things about the world!") – though intended to be motivating and inclusive – could backfire, leading children to think that one has to be a *particular kind of person* to succeed in science. From this perspective, a kind-based representation of scientists could be problematic for children when they have reason to question if *they themselves* are or have the potential to be a member of this group. Such reasons to question could come from their own experiences of difficulty in science, a lack of role models in their community, or social stereotypes about what scientists are usually or are supposed to be like. Indeed, children develop gender and racial stereotypes of scientists starting from an early age, with the tendency to do so increasing with age (Master, 2021; Miller et al., 2018). For example, the classic Draw-A-Scientist Test (DAST) shows that children often perceive scientists as male and White (Chambers, 1983; Fort & Varney, 1989). Although a recent meta-analysis of this task suggests that children do not consistently associate

scientists with men until around age seven (Miller et al., 2018), such a finding might be due to younger children's difficulty with understanding the task and the lack of detail in their drawings. Indeed, several studies that have administered the DAST along with detailed verbal explanations have found that preschool-aged children also consistently associate scientists with men more often than they do so with women (e.g., Blagdanic et al., 2019; Buldu, 2006). Therefore, identity-focused language about science could be problematic for even preschool-age children from social groups that have been historically excluded from science, as young children are already beginning to develop ideas about whether their own identities are consistent with stereotypic views of scientists or not.

To test this hypothesis, Rhodes et al. (2019) gave children (ages 4-5) a brief introduction to science that used either identity-focused, including both category labels and generic claims about scientists (e.g., "Today we are going to be scientists. Scientists explore the world…"), or more action-focused (e.g., "Today we are going to do science. Doing science means exploring the world…") language. Then, children were asked to engage in a science task that was rigged so that they would have some experiences of difficulty with science. Next, they were invited to continue persisting on the science task for as long as they wished. In these studies, identity-focused language undermined subsequent science persistence relative to action-focused language among girls – presumably because social stereotypes lead girls (more than boys) to have more reasons to question if they are members of the *scientist group*. Using a similar paradigm with elementary-age children from underrepresented racial and ethnic groups in science, Lei et al. (2019) found that children lost interest and a sense of efficacy in their own capacity to "be scientists" over the course of a school year but remained interested and feeling efficacious about their potential to "do science."

In addition, replacing identity-focused language with action-focused descriptions of science increases science engagement within lab settings and beyond (Rhodes et al., 2019; 2020). In a recent field experiment, Rhodes et al. (2020) randomly assigned 130 teachers to watch either an experimental training video, which included many examples of teachers using action-focused descriptions of science, or to a control video that did not provide examples of teacher language. The researchers then recorded the language that teachers used to teach a science lesson in their prekindergarten classrooms. The experimental training video successfully reduced the proportion of identity-focused language that teachers in the experimental condition produced, and critically, children who heard fewer identity cues from their teachers during the lesson also indicated greater interest and engagement in science several days later (Rhodes et al., 2020). Collectively, these studies suggest that subtle language cues can shape children's engagement, persistence, and interest in science.

**The Language Children Hear in Their Natural Environments**

The negative consequences of identity-focused linguistic cues about science, particularly for children from social groups that are underrepresented in science, raise the possibility that these commonplace features of language could reinforce and perpetuate social disparities in science achievement. For this to be the case, however, these linguistic cues must be *prevalent* in the language children hear about science in their daily lives. Because all prior work in this area has been experimental – designed to test the potential causal effect of this language on science beliefs and behaviors – the extent to which these linguistic cues are prevalent in children's daily environments remains unknown. Therefore, the primary goal of this project was to document the language children hear about science in daily life from two key sources – the media and their teachers in prekindergarten classrooms.

### Overview of Studies

In Study 1, we analyzed the transcripts of 33 children's television shows for references to science to see if identity-focused language is commonly presented to young children via the media. We focused on PBS Kids shows because they are highly accessible to diverse populations of children (as they are available without a cable subscription and freely available on apps) and also because they often have explicit educational aims. In Study 2, we transcribed and analyzed the audio-recordings of one science lesson across 103 prekindergarten teachers to examine their use of identity-focused science language. Furthermore, we measured the teachers' beliefs about science – including their essentialist beliefs about scientists and their explicit gender stereotypes about science – to see if their use of language varied as a function of their science beliefs. In Study 3, we began to explore whether naturally encountered variation in these linguistic cues is powerful enough to predict the development of children's science beliefs and behaviors over time, by testing how teacher science language relates to the developmental trajectories of the science beliefs held by their students. We focused on the prekindergarten year (and PBS shows targeting children in this age range) to document the linguistic cues available as children are first developing their beliefs about the nature of *science* and *scientists* (Chambers, 1983).

## STUDY 1

### Methods

We analyzed the transcripts of PBS Kids shows that were available on tv.ark.com, which indexed all shows that ran on 70 national TV channels (the website contained over 4,961,988 hours of TV programming as of January 2017 when we conducted these analyses). Our decision to choose the tv.ark.com database was purely practical. Our criteria for choosing TV databases were to 1) include as many shows as possible, 2) have complete TV show transcripts that were

downloadable and searchable, and 3) include PBS shows. The tv.ark.com was the database that best met these criteria and included the most PBS shows at the time we conducted these analyses. We chose PBS Kids shows to document the prevalence of identity-focused science language in children's media because of their high viewership – 86% of all U.S. households with televisions and 77% of all kids aged 2-8 watch PBS (U.S. Census, 2015). The goal of Study 1 was to document what proportion of the language used to talk about science is identity-focused *when science is discussed at all* in these shows (not to estimate the overall amount of science language in children's media more generally). To do so, we searched the tv.ark.com database for all series that were listed on the PBS Kids website – a total of 33 TV series. The code used to search the database for science-related content and identify references to our key words ("science," "scientist(s)," and "scientific") is available at https://osf.io/smkh6/?view_only=b7caab836b5f4a4bbea8b565003e3e7c. We excluded hits on our key words that showed up on the transcripts but were not part of the TV scripts proper (e.g., were commercials for another show or activity on the PBS Kids website). The list of series that we searched for and the number of episodes found and coded of each is in Table 1.

Table 1
*All TV programs listed on the PBS Kids' website and the number of episodes of each found in the database on ark.tv.com*

| **Name of TV Series** | **Number of episodes found in database** |
|---|---|
| Between the Lions | 0 |
| Chuck Vanderchuck | 0 |
| DragonflyTV | 0 |
| Fizzy's Lunch Lab | 0 |
| Noah Comprende | 0 |
| Wilson and Ditch | 0 |
| Mister Rogers | 1 |
| Postcards from Buster | 1 |
| SciGirls | 1 |
| Odd Squad | 2 |
| Mama Mirabelle's Home Movies | 8 |

| | |
|---|---|
| Maya & Miguel | 8 |
| Thomas & Friends | 11 |
| Bob the Builder | 14 |
| Peg Plus Cat | 20 |
| Daniel Tiger's Neighborhood | 23 |
| The Cat in the Hat Knows a Lot About That! | 25 |
| ZOOM | 27 |
| Dinosaur Train | 33 |
| Sid the Science Kid | 33 |
| The Electric Company | 37 |
| Cyberchase | 38 |
| Super Why | 40 |
| Wild Kratts | 40 |
| WordGirl | 42 |
| Martha Speaks | 48 |
| WordWorld | 48 |
| Sesame Street | 57 |
| Fetch! With Ruff Ruffman | 63 |
| Clifford the Big Red Dog | 74 |
| Curious George | 83 |
| Caillou | 86 |
| Arthur | 130 |

We outputted all lines of the TV transcripts with reference to one of our key words for more detailed coding. The program outputted a total of 399 matches to a key word; of which 223 (56%) were to "scientist(s)" and 44% were to science ($n$ = 139) or scientific ($n$ = 37). We then had a human coder check each utterance to make sure that the program had worked accurately – that every hit was to an appropriate key word, that no commercials or other text that was not part of the actual script were included, and that there were no duplicates of the same script. This process led to a final sample of 371 utterances from 10 different TV programs, which are the focus of the remaining analyses. All of the text of the matched utterances and coding decisions are available at https://osf.io/smkh6/?view_only=b7caab836b5f4a4bbea8b565003e3e7c. This study was not pre-registered.

## Results and Discussion

In the final sample of science-related utterances, 56% ($n$ = 205) of key word hits were to "scientist(s)" whereas 44% ($n$ = 164) were to "science" or "scientific." A Fisher's exact test confirmed that references to scientists were more common than references to science across the sample, $p$ = .026. There was considerable variation across the different shows, however, as shown in Table 2.

Table 2

*Total number of key word hits for "science," "scientific," or "scientists" for each show in the database that had any matches, and the percentage of these matches that were in the form of the category label (i.e., "scientist/s"; for each show, the remainder were of the form "science"or "scientific")*

| Series | Total number of keyword hits (for "science," "scientific", or "scientist") | % of key wordhits that were of the form "scientist/s" |
|---|---|---|
| Sid the Science Kid | 160 | 83.8% |
| Arthur | 67 | 19.3% |
| Curious George | 41 | 58.5% |
| Fetch! With Ruff Ruffman | 28 | 25% |
| Martha Speaks | 20 | 15% |
| Dinosaur Train | 18 | 88.9% |
| The Electric Company | 15 | 0 |
| Sesame Street | 12 | 16.7% |
| WordGirl | 11 | 27.3% |
| Wild Kratts | 9 | 77.8% |

Next, human coders coded the references to "scientists" into more specialized categories (see Table 3), including (a) using the label to refer to the audience or a combination of the audience and characters (55%; e.g., "All you scientists did a great job!" "My scientists have become muscle experts"), (b) general descriptions of what scientists do, think, or are like (35%; e.g., "A scientist isn't discouraged by a minor setback." "Scientists think that Einiosaurus may have lived in herds." "How do scientists measure a whale?" "Once you think like a scientist,

George, you can solve almost any problem." "It means you're thinking like a real scientist"); (c) references to specific individuals (10%; e.g., "tomorrow is the birthday of this great Italian scientist"). The vast majority (96%) of statements that used "scientist" to refer to the audience came from a single show (*Sid the Science Kid*). In contrast, generic claims about scientists were found across all nine shows that ever used the category label.

The human coders also coded the "science" category into whether the utterances referred to the activity of doing science (e.g., "Now you're doing a scientific investigation", "I love science!" "We are going to see how science is put to work.") or instead used "science" as a modifier of another noun (e.g., "Let's see what is growing in the science center," "Today in my science class we are studying how pendulums work," "Welcome to the science museum."). Discussing the actual activity of science (18.3% of total references) was less common than using the word "science" as a modifier (25.9% of total references; see Table 3).

Table 3

*The percentage of references to science that fit each linguistic code, with identity-focused references broken down into subtypes (in all, identity-focused language comprised 56% of all references to science).*

| Category | Specific Code | Examples | Percent of Total References |
|---|---|---|---|
| Identity-focused science language | Reference to audience | "Hey, you're a scientist." "Ok, scientists, we're going to do the estimation investigation!" | 30.46 |
| | General description | "Well, a scientist isn't discouraged by a minor setback." "A scientist is a person that observes lots of stuff and wants to know about it." | 19.68 |
| | Reference to specific individuals | "That's one cool scientist." "Tomorrow is the birthday of this great Italian scientist." | 5.66 |

| | | | |
|---|---|---|---|
| Action-focused science language | Activity of doing science | "Da Vinci would apply science to art and art to science." "I like science because I like experimenting with stuff." | 18.33 |
| Other | Modifier of noun | "This is the Science Discovery Museum." "Did I hear someone singing my science songs?" | 25.88 |

Overall, these analyses confirmed that identity-focused language about scientists are prevalent in children's science media – in fact, identity-focused cues were overall the *most common* way to discuss science in this sample of episodes. There was considerable variation across the different shows, with six out of the ten showing the reverse pattern; however, as shown in Table 2, identity-focused cues appear particularly common among shows that focus more heavily on science themes and for which science was referenced more commonly overall (e.g., *Sid the Science Kid*; *Wild Kratts*; *Dinosaur Train*). For example, there were 130 episodes of *Arthur* in the database, but only 67 total references to science within all the episodes. In contrast, we had fewer episodes of *Sid the Science Kid* in the database (only 33), but across this much smaller number of episodes, there were many more references to science (160). This simply reflects that science is a bigger focus of the content in *Sid the Science Kid* than in *Arthur*. Indeed, across all of the series, the more total references to science contained in a series, the more likely these references were to be identity-focused ($\beta = .40$, $SE = .11$, $p = .001$).

The database that we chose contained a convenience sample of scripts with certain limitations (e.g., PBS is local, so the database contained scripts from only select stations and might not fully represent what aired in all regions across the United States). Nevertheless, this database provided a good starting point for examining our research questions because the shows we were able to examine here are highly popular across broad audiences of children and were

designed with educational goals. For example, according to Parrot Analytics (a viewership analytics website), as of January 2022, *Sid the Science Kid* has an audience demand that is 3.4 times that of the average TV series in the U.S. and is in the top 15.2% of TV shows in terms of demand; *Curious George* has an audience demand that is 9.5 times that of the average TV series in the U.S. and is in the top 5.7% of TV shows in terms of demand; and *Dinosaur Train* has an audience demand that is 3.3 times that of the average TV series in the U.S. and is in the top 14.8% of TV shows in terms of demand (see Table S1 in the online supplementary materials for further information on viewership data for all television series included in Study 1).

The broad availability and exceptionally high viewership of these shows, along with the finding that identity-focused descriptions of science are particularly common in shows with more science content in this sample of popular shows, supports the conclusion that children are indeed likely to encounter the linguistic cues implicated in the disengagement of young children from science in science media they might access in daily life.

## STUDY 2

The goal of Study 2 was to document the science language children hear in another salient context – from their prekindergarten teachers. The field experiment conducted by Rhodes et al. (2020) found that prekindergarten children were sensitive to subtle features of their teachers' science language in classroom contexts; thus, it is important to document the language that teachers spontaneously use in their science teaching without any prior training or modeling. To do so, we extrapolated prekindergarten teachers' science language use in one standardized science lesson to serve as a proxy measure of their usual way of describing science to children in an everyday learning context. Previous research on child-directed natural language in semi-structured contexts supports the validity of interpreting teacher's identity-focused science

language use during this one lesson as a proxy for the science language that children hear in their everyday learning contexts. For example, parents' generic language production during semi-structured laboratory tasks with their children correlates with their production of generics in conversations with their children during unstructured activities at home (Gelman & Tardiff, 1998). Also, individual differences in parents' use of generics in conversations with their children are consistent across time and different laboratory tasks (Gelman et al., 2014) and correlate with individual differences in their children's beliefs over time (Gelman et al., 2004; Segall et al., 2015). This prior work supports our interpretation that the variation we capture in teacher language during the lesson that we record serves as a reasonable proxy for the science language they might hear from their teachers over time.

In Study 2, we also began to probe why teachers might speak the way they do – in particular, whether they are more likely to produce identity-focused linguistic cues if they themselves hold more essentialist beliefs about scientists. Our hypothesis that essentialist beliefs about scientists would predict increased proportions of identity-focused language use was based on past studies that show parents who hold more essentialist representations of categories produce higher levels of generic language to describe categories (Rhodes et al., 2012; Segall et al., 2015). Indeed, prior theoretical work has suggested that generic language serves as a covert cue by which essentialist beliefs are passed on across generations – that when adults hold essentialist beliefs about a category, they are more likely to generate generics to describe it, and that when children then hear those generics, they interpret the language as a cue to apply essentialist beliefs to the category they are learning about (Foster-Hanson & Rhodes, 2020; Gelman & Roberts, 2017). Therefore, we aimed to examine if such a relationship would also appear in the specific context of science education. In addition, we also measured teachers'

explicit gender stereotypes about science and brilliance beliefs about science. We included these two measures as additional exploratory measures given that they are also highly correlated with essentialism and each other (e.g., see Bastian & Haslam, 2006 and Leslie et al., 2015).

## Methods

### Participants

One hundred and seventy-two prekindergarten teachers (163 female, 1 male, 8 unknown) participated in our research. Of those who provided racial and ethnic demographic information ($n$ = 155), 66% self-identified as White, 8% as African American, 6% as Asian/Asian American, and 3% as Mixed/Biracial; 21% of the sample, across race, identified as Hispanic/Latinx. All teachers in participating schools were invited to participate. Each teacher participant taught a different class within 56 public prekindergarten schools across 13 districts in New York City. All teachers were recruited from the same prekindergarten program that follows a set curriculum structure for the year. Although teachers have freedom in their lesson planning (i.e., some variation across teachers and classrooms is to be expected), all teachers in the sample generally followed the same science curriculum across the year. The lesson in which we collected the samples of teacher language introduced an additional science activity (for all classrooms). We designed this lesson in consultation with a working group of teachers and science specialists from the prekindergarten program, so that it would fit in well with teachers' overall science curriculum.

Teachers were recruited by email during January 2020 to participate in a two-part science study: 1) an online survey on their beliefs about science and 2) a science lesson for them to implement and audio-record. Although we invited all teachers to participate in both the survey and the lesson, a subset of teachers only completed the survey ($n$ = 69) or only completed the

lesson ($n$ = 2), resulting in 103 teachers who participated in both. All participants were included in our analyses when appropriate. We tried to recruit as many teachers as possible from participating prekindergarten schools. We did not conduct an a priori power analysis (which determines the sample size needed for a desired level of power) since our goal was to include as many teachers as possible. Instead, we recruited the maximum sample we could, and then conducted a sensitivity analysis (which assesses the level of power that the analyses will have to detect a meaningful effect given our obtained sample size). Our sensitivity analyses revealed that the obtained sample ($n$ = 103) was sufficient to detect developmentally significant effects of teachers' language relating to their underlying belief system (a predicted .20 increase in the proportion of identity-focused science language used when brilliance beliefs about science, essentialist beliefs about science, and explicit gender stereotypes about science were high versus low) at 89% power (effect sizes informed by Gelman et al., 2004; Segall et al., 2015).

All methods and procedures were reviewed and approved by the Institutional Review Boards of New York University (IRB # FY2016-760 "Conceptual Development and Social Cognition") and the New York City Department of Education. The study was pre-registered, and all registrations, hypotheses, materials, data, and analyses are available in the project's Open Science Framework repository (see https://osf.io/uc4qm/?view_only=1963eb841a47478d987b1a00178b8adb and https://osf.io/k84eh/?view_only=9b8e70338140404fbab9654dd60b5c4a).

**Materials & Procedure**

The present study measured: 1) prekindergarten teachers' science beliefs, and 2) prekindergarten teachers' use of language when teaching science. Teachers completed the science beliefs survey between January and March 2020 via a Qualtrics survey linked to a

recruitment email. All participants provided informed consent at the beginning of the survey. They taught the science lesson in-person to their students between January and March 2020. Prior to teaching and audio-recording the science lesson, they received a lesson plan, lesson materials, and an audio recorder.

### *Teachers' Science Beliefs Survey*

**Essentialist Beliefs about Science.** Using a seven-point scale (1 = Strongly disagree, 7 = Strongly agree), teachers completed six items (see Appendix A for full list of items) that measured their essentialist beliefs about the category *scientists* (e.g., "Scientists share an underlying property that causes them to have many similarities with one another"; "Knowing that someone is a scientist tells you a lot about who they are as a person"; $\alpha = .73$; adapted from Haslam et al., 2000; Rhodes & Gelman, 2009). Higher scores reflected a more essentialist conception of scientists. The order of the six items was randomized across participants.

**Explicit Gender Stereotypes about Science.** Using a seven-point scale (1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree nor disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree), teachers completed four items (see Appendix A for full list of items) that measured their explicit gender stereotypes about science (e.g., "When they are young, boys are often naturally more talented in science than girls"; "One reason why more men than women go into careers in science is because they have more natural talent in these fields"; $\alpha = .87$). Higher scores reflected more explicit gender stereotypes about science. The order of the four items was randomized across participants.

**Brilliance Beliefs about Science.** Teachers rated how much brilliance they thought a typical scientist and a top scientist required, respectively, by indicating how much they agreed (1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree nor disagree, 5 =

Somewhat agree, 6 = Agree, 7 = Strongly agree) with four statements (see Appendix A for full list of items) about innate brilliance (e.g., "If you want to become a typical/top scientist, hard work alone just won't cut it; you need to have an innate gift or talent"; adapted from Leslie et al., 2015; $\alpha = .79$). Items were coded (i.e., two items were reverse-coded) so that higher scores reflected greater brilliance that was required. Whether items pertaining to the typical scientist or the top scientist appeared first was randomized across participants.

***Teachers' Language Use in Science Lessons***

The goal of the science lesson that we asked teachers to implement was to teach children the scientific method (i.e., observing, predicting, checking) by using texturized mystery capsules (see Figure 1; Lakeshore Learning Materials, 2021). In the science lesson plan, we told teachers to introduce the activity to students as they normally would for a science lesson and to use the three steps of science (observing, predicting, checking) to explore the mystery capsules (the full science lesson plan and the letter that accompanied the lesson plan are available on the study OSF page). Crucially, we did not provide explicit instructions on what kind of language to use (e.g., action-focused or identity-focused) and only provided one set of examples on how to introduce the activity (in which we listed one action-focused and one identity-focused example). Because the lesson plan only provided general explanations of the mystery capsules and basic instructions for how to use them for a science lesson (but no specific language directives for teachers to use while teaching), we do not anticipate that the lesson plans would have significantly altered teachers' language patterns from their usual science lessons.

*Figure 1*. Example of the texturized mystery capsules used in the science lessons. Children were able to observe the texture on the top, make predictions about what the texture was from, and twist the capsule to check their predictions. Images reproduced with permission from Lakeshore Learning Materials (2021).

After teachers finished the lesson and returned their audio recorders to us, two trained research assistants transcribed the audio recordings ($M$ = 10.17 minutes; $SD$ = 5.42) and coded teachers' use of science language into four categories: 1) action-focused descriptions of doing science (e.g., "doing science is fun"; "science is easy"), 2) use of science as part of a noun rather than an activity (e.g., "science time"; "science center"), 3) generic statements about scientists (e.g., "scientists observe"; "scientists work hard and solve problems"), and 4) noun labels of scientists (e.g., "we are scientists"; "put on your scientist hat"). We summed codes for the latter two categories for a composite measure of identity-focused science language, as they were highly correlated, $r$ = .56, $p$ < .001, and doing so was consistent with past experimental studies in which these linguistic cues were presented together (e.g., Lei et al., 2019; Rhodes et al., 2020)[1]. Inter-rater reliability was high (Cohen's kappa = .89), and all discrepancies were resolved by a third senior researcher. The coding scheme changed slightly across Studies 1 and 2 (i.e., we no longer included the codes "Reference to audience" and "Reference to specific individuals") due

[1] In Study 3, we also ran additional analyses to examine how generic statements about scientists and noun labels of scientists may have shaped children's science beliefs and engagement differently. These exploratory analyses are reported in the online supplementary materials.

to the difference in context. For TV shows, we coded the language of all agents/characters, whose speech was often directed at different targets (e.g., other characters vs. the audience). In comparison, for teacher language, the speech was always produced by the teacher and directed towards the students. Therefore, the differentiation between whom the identity-focused language was referencing was no longer relevant in Study 2, as it was in Study 1.

### Analysis Plan

We first descriptively examined the language that teachers produced when teaching the science lesson. We then examined the effects of teachers' beliefs about science on their language when teaching science by using a generalized linear mixed-effects model with a binomial distribution. Using the "glmer" function in the *lme4* package (Bates et al., 2015), we conducted a generalized linear mixed-effects model with a binomial distribution (for the proportion of identity-focused language)[2] with teachers' essentialist beliefs about science, explicit gender stereotypes about science, and brilliance beliefs about science as predictors; and teacher participant ID, school, and district as random intercepts.

## Results and Discussion

### Teachers' Science Language

Overall, teachers used identity-focused science language cues ($M$ = 3.58, $SD$ = 5.21) more often than they used action-focused science language cues ($M$ = 1.39, $SD$ = 1.45), $t(118) = 4.12$, $p < .001$, or used science as part of a noun phrase ($M$ = 1.58, $SD$ = 2.61), $t(150) = 3.48$, $p < .001$ (Figure 2). We summed codes for teachers' identity-focused and action-focused science

[2] We also ran additional negative binomial generalized linear mixed-effects models with the *prevalence* of identity-focused and action-focused science language as the dependent variables, respectively, but given that 1) their results were largely redundant with those that used the *proportion* of identity-focused science language as the dependent variable, 2) the proportion measure could better control for the total amount of relevant science language used, and 3) past studies with a similar design most often examined the proportion of identity-focused science language teachers produced (e.g., Rhodes et al., 2020), we focused on the proportion measure here but report model outputs from the prevalence measure in the online supplementary materials.

language cues for a measure of total relevant science language cues and computed the proportion of identity-focused science language cues out of total relevant science language cues for each teacher participant (the proportion of action-focused science language cues would be redundant, since their sum would always equate 1). On average, out of the relevant identity-focused or action-focused language, 57% (*SD* = 39%) of teachers' relevant science language cues were identity-focused. Out of the *total* science language (which also included the less relevant statements that used science as part of a noun phrase), 46% (*SD* = 38%) of teachers' total science language cues were identity-focused.

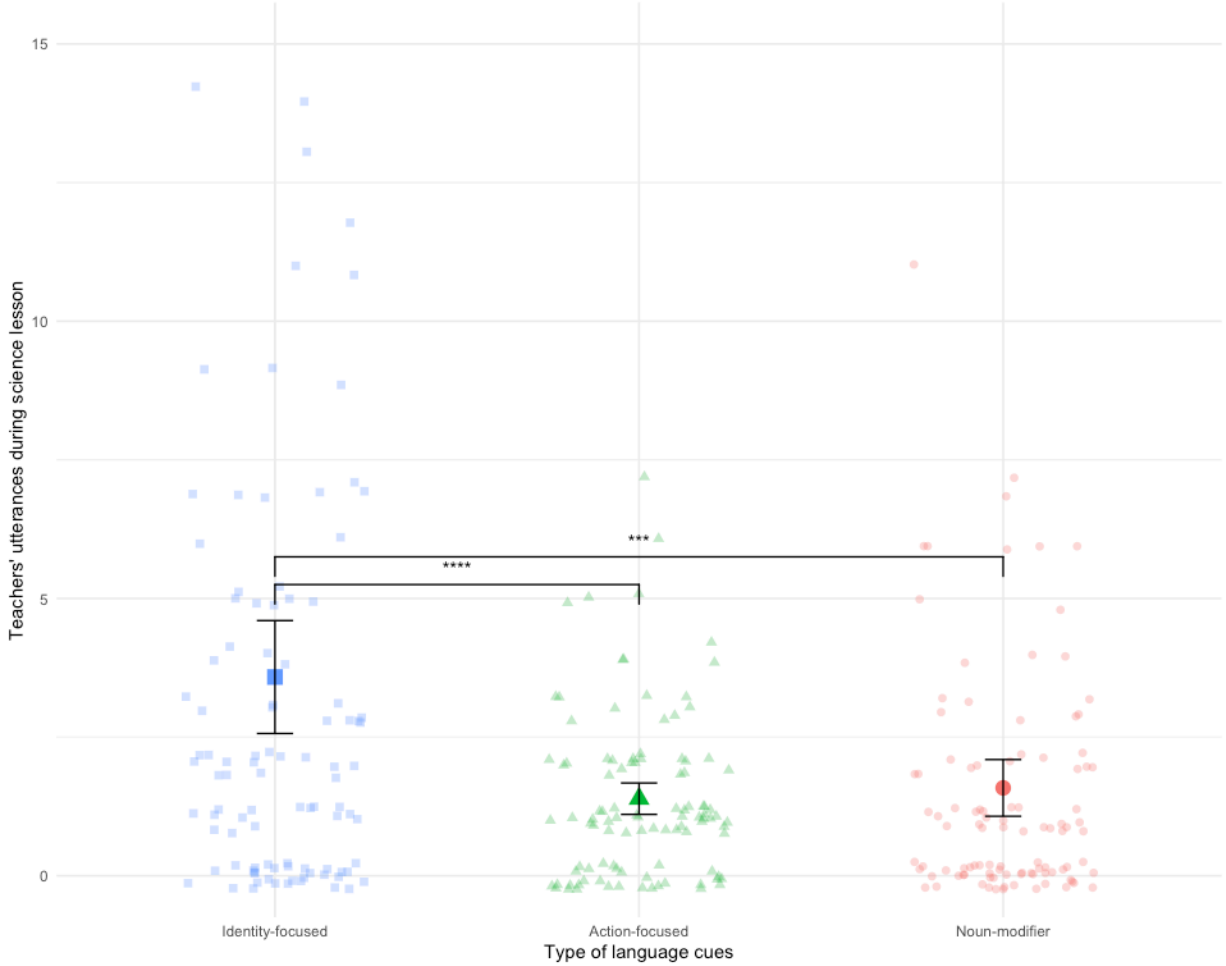


*Figure 2*. Teachers' use of science language during their science lesson, coded by type (identity-focused, action-focused, and as a noun modifier). Larger shapes represent group means and smaller shapes represent individual responses (the current graph limits the y-axis from 0 to 15

although four individual responses in the identity-focused column and one individual response in the noun-modifier column exceeded this range). Error bars represent 95% confidence intervals.

**Teachers' Science Beliefs and Language**

Overall, teachers held essentialist beliefs about the social category *scientists* as indicated by their average responses on the science essentialism scale ($M = 4.29$, $SD = .90$), which was significantly greater than the midpoint (i.e., 4), $t(163) = 4.16$, $p < .001$. However, overall, they did not endorse explicit gender stereotypes about science, as indicated by their average responses on the explicit gender stereotypes scale ($M = 2.56$, $SD = 1.25$), which was significantly below the midpoint (i.e., 4), $t(162) = -14.76$, $p < .001$. They also indicated that top scientists ($M = 3.24$, $SD = 1.08$) require greater brilliance than typical scientists ($M = 2.97$, $SD = .95$), $t(324) = -2.67$, $p = .008$, but overall, their brilliance responses about scientists (averaged across top and typical scientists) were below the midpoint ($M = 3.08$, $SD = .93$), $t(162) = -12.674$, $p < .001$.

Teachers who held stronger essentialist beliefs about scientists (i.e., believed that scientists are a natural category in which members hold stable, intrinsic, objective similarities with each other) were also more likely to endorse explicit gender stereotypes about science (i.e., believe that boys and men are more interested and talented in science than girls and women; positive correlation between science essentialism and explicit gender stereotypes, $r(159) = .39$, $p < .001$). Teachers' brilliance beliefs about scientists did not correlate with their science essentialism scores or explicit gender stereotypes ($p$s > .30).

Contrary to our hypotheses, the proportion of teachers' identity-focused science language was not significantly predicted by any of the teachers' belief measures ($p$s > .20). In other words, in the context of teachers' representations of scientists and use of identity-focused science language, we did not find that essentialism – or other related beliefs measured here – predicted

increased use of generic statements and noun labels to describe categories. We will return to this finding in the General Discussion.

Overall, these analyses revealed that identity-focused linguistic cues about science are prevalent in the language children hear about science from their teachers in classroom contexts. Thus, together, Studies 1 and 2 confirmed that linguistic cues that have been experimentally found to interfere with science engagement among children from social groups that are underrepresented in science are prevalent in at least two key sources that children might encounter in their daily lives – from some children's television shows and from their teachers.

Yet, although these linguistic cues are available in children's daily lives, the input that children receive in daily life is considerably more variable than the input that has been found to shape their beliefs and behaviors in prior experiments (see Figure 2). For example, in Rhodes et al. (2019), children were randomly assigned to receive either action-focused or identity-focused language, and in each condition, heard 19 examples of the assigned linguistic cue. This manipulation was then found to immediately influence their behavior. It is an open question whether linguistic cues presented in daily life – when children might hear a mix of different linguistic forms across different contexts (and when many distractions might interfere with their attention to these subtle features of language) – are powerful enough to shape their science beliefs and behaviors as they develop over time. Thus, the aim of Study 3 was to begin to probe if this might be the case, by examining the developmental trajectories of children's science beliefs as a function of naturally occurring variation in their teachers' language.

## STUDY 3

In Study 3, we tested how teachers' beliefs and language each contribute to the development of children's beliefs about who can succeed in science, and how they relate to

children's own interest and engagement in science. For example, do children who hear less identity-focused language develop a more *inclusive* view about science, thus preventing disengagement in science? In addition, we tested the development of children's science beliefs and interest *over time* as they were gradually exposed to the type of language their teachers naturally used, by drawing on longitudinal data on children's science beliefs and interest near the beginning of the prekindergarten year and again in the middle, after four months of additional language exposure.

For these analyses, we drew from data that were being collected from children attending a subset of the teachers' classrooms from Study 2. The data for these analyses were originally intended to be part of a separate project, examining the development of children's beliefs and attitudes about "being a scientist" vs. "doing science" across the prekindergarten year (similar to Lei et al., 2019, which conducted a similar longitudinal analysis with older children). Due to interruptions to the school year caused by the onset of the global pandemic of Covid-19, that project could not be completed as originally designed and the data that were collected at the time that schools were closed were not sufficient to test the hypotheses that motivated the original design of that study.

We realized, however, that because the children participating in that project were in classrooms from which we had also collected data regarding teacher language and beliefs as part of Study 2, we could use the data that were collected as part of the interrupted study for a different purpose – to explore how teacher language and beliefs relate to the development of children's science beliefs, attitudes, and behaviors across the subset of the child sample for which two time points of data were collected already at the time of the school closures (the

original design had called for three time points with 150 children; at the time of the closure, we had two time points from approximately 80 students).

Because the study was originally designed to examine developmental trajectories of children's beliefs about "doing science" vs. "being a scientist", half of the children in this sample (and half the children in any given classroom) heard the study questions introduced with action-focused phrasing (e.g., "How much do you like doing science?") whereas the other half heard the study questions with identity-focused phrasing (e.g., "How much do you like being a scientist?"). Because the planned data collection was not completed, however, and we are now re-purposing them, the collected data do not provide sufficient power to test for effects of this between-subjects variable in our analyses. Instead, the goal of the present analyses is to focus on the role of teacher language and beliefs on the development of children's beliefs and behaviors more generally (not based on momentary changes in language). Therefore, the present analyses do not consider the between-condition differences in wording (i.e., whether the study questions were introduced with action-focused or identity-focused phrasing); instead focusing on how the developmental trajectory of children's responses over time relate to their teachers' language and beliefs (measured on a separate occasion). We confirmed as part of preliminary analyses that adjusting for the between-subjects condition variable does not change any of the patterns presented here, so we do not consider this variable further[3].

[3] Although effects of momentary wording in study questions were found in Lei et al. (2019), that study drew from a student population that was predominantly from groups under-represented in science based on race and ethnicity (who are likely more sensitive than children from over-represented groups in science to subtle linguistic cues implying that one has to be a special kind of person). In contrast, 64% of children in the present sample for Study 3 were White (to clarify, over 80% of children taught by all the teachers in Study 2 were from racial and ethnic minority groups, consistent with the demographic composition of the city overall, see Rhodes et al., 2020; but Study 3 included only children from particular schools who were participating in additional research with children, and those particular schools included children who were primarily White). In the original research plan, we planned to test whether the effects of language in this sample varied by participant gender (since girls are also under-represented in science across race and ethnicity groups). Due to the data collection interruptions, the present study

Because the idea to use the present data for these analyses (though not the hypothesis that motivated them) was conceived after these child data were collected and we realized their originally intended goal could not be met due to the interruption of in-person schooling, all of the analyses in Study 3 are exploratory.

## Methods

### Participants

Among the prekindergarten teachers recruited from Study 2, we recruited the students ($n$ = 83; $M_{age}$ = 4.36 years; 43 female, 40 male) of seven of them for whom we had received permission to conduct individual research with children. Child participants, and their seven teachers, were from four prekindergarten schools across two districts. Of those children whose parents provided racial and ethnic demographic information for them ($n$ = 67), 64% of their parents identified them as White, 12% as Asian/Asian American, and 24% as Mixed/Biracial; 36% of the sample, across race, identified as Hispanic/Latinx. Again, because our sample size was determined by the number of parents who agreed to participate (and then data collection was curtailed by the onset of the global pandemic of Covid-19), we conducted a post-hoc sensitivity analysis based on our obtained sample size of instead an a priori power analysis. Our analyses confirmed that the obtained sample ($n$ = 83) was sufficient to detect developmentally significant changes in children's inclusivity beliefs about science (a predicted increase of 1 unit for children with teachers who produced low levels of identity-focused science language and a predicted decrease of 1 unit for children with teachers who produced high levels of identity-focused

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was under-powered to test for language effects by participant gender (there would be less than 20 children per cell if we undertook these analyses as originally planned). Therefore, we view these data as uninformative regarding the possible consequences of momentary language exposure in the study questions, and instead, focused analyses on the relation of individual variation in teacher language to the trajectory of children's beliefs. For descriptive means by language condition, see the online supplementary materials.

science language) at 99% power (effect sizes informed by Gelman et al., 2004; Segall et al., 2015). Children were recruited in September 2019 through letters that were sent to parents and an in-person recruitment event. Participating children's parents indicated consent and provided demographic information for their children via a form returned in envelopes to children's teachers.

All methods and procedures were reviewed and approved by the Institutional Review Boards of New York University (IRB # FY2016-760 "Conceptual Development and Social Cognition") and the New York City Department of Education. All materials, data, and analyses are available in the project's Open Science Framework repository (see https://osf.io/uc4qm/?view_only=1963eb841a47478d987b1a00178b8adb; also see https://osf.io/wykre/?view_only=884f1322fcc348e9a56c3f231455f09e and https://osf.io/phn8s/?view_only=6af4deeb57024214a94a7544a4e34c17 for the study's original pre-registration).

**Materials & Procedure**

In addition to the 1) science beliefs and 2) use of language measures we collected from the seven teachers from Study 2, we also measured children's 3) science interests and beliefs at two time points during the prekindergarten year from children from these teachers' classes. Child participants were tested independently in quiet spaces in the hallway or empty classrooms in their schools by trained researchers, and materials were presented on Microsoft Surface Go computers via the Qualtrics Offline Surveys App. All children provided verbal assent before beginning the study.

***Teachers' Science Language and Beliefs***

These measures were identical to those in Study 2.

### *Children's Science Interest and Beliefs*

Children's science interest and beliefs were measured twice at two time points during the prekindergarten year (November 2019 and February 2020). Most children completed both sessions, although a small subset of children only completed the first session ($n$ = 10) or only the second session ($n$ = 1) due to unavailability (e.g., sick or transferred schools). All participants were included in our analyses when appropriate. Researchers visited prekindergarten classrooms and presented the measures to individual children via touchscreen tablet computers. Children watched a brief video introducing the concept of science and then completed a series of measures examining their inclusivity beliefs about science, choice to engage with science, gender stereotypes about science (i.e., their associations of boy and girl targets with science versus art), and inclusivity stereotypes about science (i.e., their associations of small and large groups of people with science versus art). The present analyses focused on the first two measures; there were no effects of teacher language or beliefs on the other measures, and these measures and the full models examining children's responses to them are presented in the online supplementary materials.

**Inclusivity Beliefs about Science.** To measure how exclusive/common children believed science to be, we showed them a scale containing four different-sized groups of stick-figure people and asked them 1) "Who do you think can be a scientist?" or "Who do you think can do science?" (see Note 3 and the online supplementary materials for discussion of these wording differences; descriptively, means did not differ by wording in the present data) and 2) "Who do you think can use their senses to observe?" Responses were scored from 1 to 4 (1 = "Only one person", 2 = "Only a few people", 3 = "Only some people", 4 = "A lot of people") and averaged

across these two questions ($\alpha = .55$)[4]. Prior to responding, children completed a comprehension check question for each option choice (e.g., "Can you point to the picture that means only one person?"; overall success rate = 97.6%). If children responded incorrectly to an attention check question, they heard the correct response option repeated again before moving on.

**Choice to Engage with Science.** To measure children's choice to engage with science, we presented children with two pictures of a book (one with a magnifying glass on its cover and one with an art palette on its cover) and asked them to choose one ("Would you rather choose a book about science or a book about art?"). Responses were scored as 1 or 0 (1 = "Book about science", 0 = "Book about art").

**Analysis Plan**

We tested the effects of teachers' language on children's beliefs in separate linear mixed effects models. Using the "lmer" function in the *lme4* package (Bates et al., 2015), we conducted linear mixed effects models (one for each child measure) with time (wave 1 or wave 2), teachers' language, and their interactions as predictors; child age and gender as covariates; and child ID, teacher ID (i.e., classroom), school (i.e., site), and district as random intercepts. Similar analyses were conducted on children's book choice measure, but with binomial models (as these were composed of 0 or 1 responses across trials). For teachers' language, we examined the *proportion* of identity-focused science language out of total relevant science language (the sum of their action-focused and identity-focused science language).

We tested the effects of teachers' beliefs about science on children's beliefs in separate linear mixed effects models. The models we ran were identical to the ones described above,

[4] By convention, a Cronbach's alpha that is $\geq 0.70$ is considered as evidence of acceptable reliability (Taber, 2017); the Cronbach's alpha for children's inclusivity beliefs about science is below this range, but also note that Cronbach's alpha often underestimates true reliability for two-item scales (Eisinga et al., 2013).

except we used teachers' beliefs (one for each model; teachers' brilliance beliefs, essentialist beliefs about science, or explicit gender stereotypes about science) rather than teachers' language as predictors.

## Results and Discussion

### Teachers' Science Language on Child Measures

#### *Children's Inclusivity Beliefs about Science*

Teachers' proportion of identity-focused language related to the development of children's inclusivity beliefs about science over time. Specifically, our analyses revealed a significant main effect of time ($\beta$ = .56, *SE* = .27, $p$ = .04), and an interaction between time and teachers' proportion of identity-focused science language cues ($\beta$ = -1.01, *SE* = .46, $p$ = .03). To illustrate this interaction, we plotted children's inclusivity beliefs about science across the two study sessions for those with teachers with high proportions of identity-focused science language use and low proportions of identity-focused science language use (based on a median split), respectively (see Figure 3). Simple slope analyses revealed that inclusive beliefs about science increased over time for children who heard low proportions of identity cues ($\beta$ = .50, *SE* = .34, $p$ = .15) and decreased for those who heard high proportions ($\beta$ = -.09, *SE* = .14, $p$ = .54), though neither slope on its own significantly differed from 0, and unexpectedly, children who heard low proportions of identity-focused language appeared to view science as more exclusive (and then developed more inclusive views over time) earlier in the school year (at the first time point of data collection).

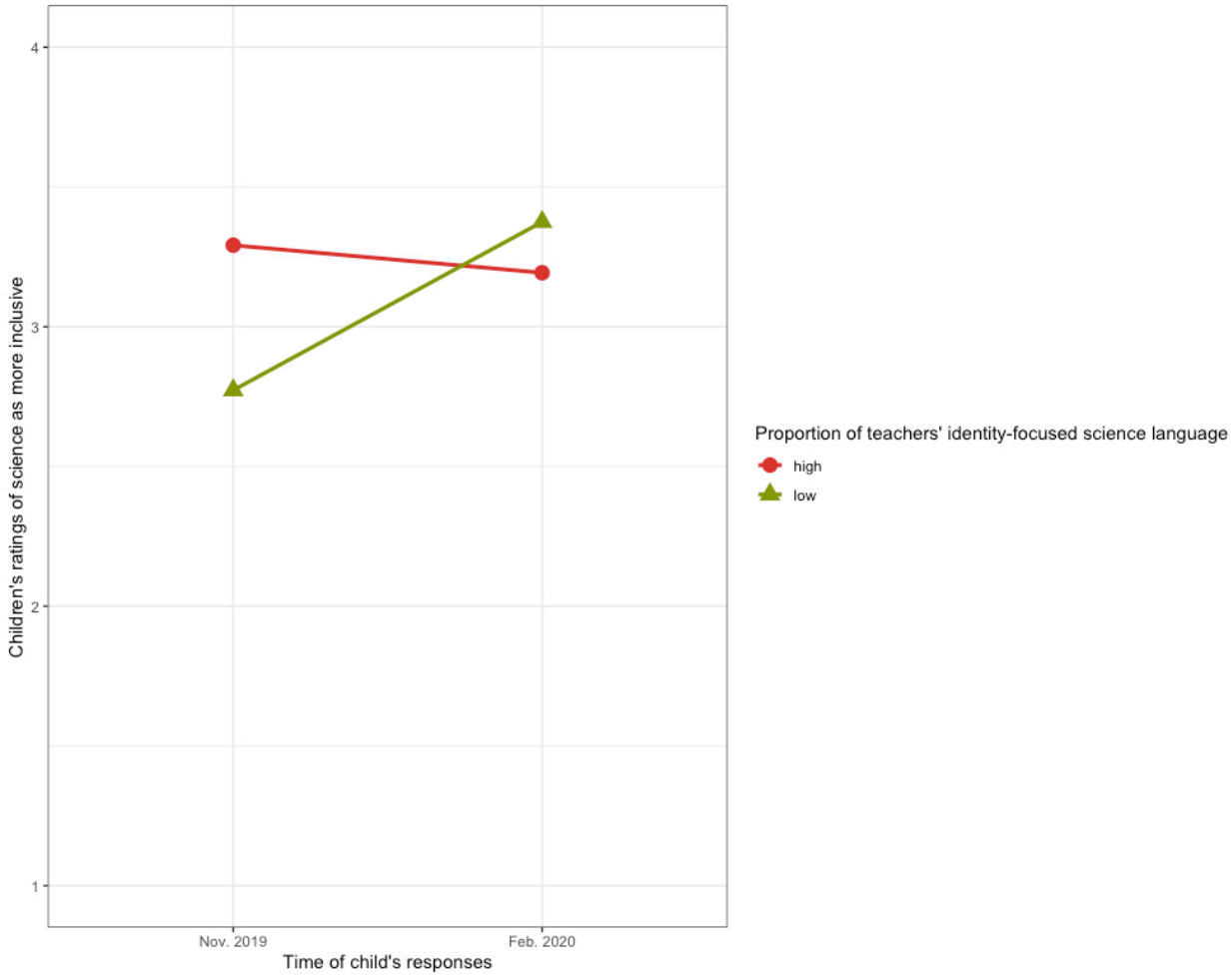


*Figure 3*. Children's inclusivity beliefs about science (average score across two items; range = 1-4; higher score indicates more inclusive beliefs about science) by study session and teachers' proportion of identity-focused science language cues (median split).

### *Children's Choice to Engage with Science*

Considering the effects of teacher language on children's choice to engage with science revealed main effects of time ($\beta$ = 2.04, *SE* = .97, *p* = .04) and child gender ($\beta$ = 2.60, *SE* = .79, *p* = .001). Overall, boys (*M* = .49, *SD* = .50) picked the science book more than girls did (*M* = .16, *SD* = .36), and children picked the science book more often across time (wave 1: *M* = .27, *SD* = .45; wave 2: *M* = .40, *SD* = .49). Although the interaction between time and teachers' proportion of identity-focused science language cues was not significant ($\beta$ = -2.50, *SE* = 1.72, *p* = .14), we explored the slopes associated with time for children who heard high or low

proportions of identity-focused language (to see if a similar pattern emerged as was found for children's inclusivity beliefs). To do so, we plotted children's choice of the science book across the two study sessions for those with teachers with high proportions of identity-focused science language use and low proportions of identity-focused science language use (based on a median split), respectively (see Figure 4). Indeed, simple slope analyses indicated that the likelihood of selecting the science book increased over time for children who heard low proportions of identity-focused language ($\beta = 18.47$, $SE = 5.40$, $p < .001$), but did not increase for children who heard high proportions of identity-focused language ($\beta = .55$, $SE = .50$, $p = .27$).

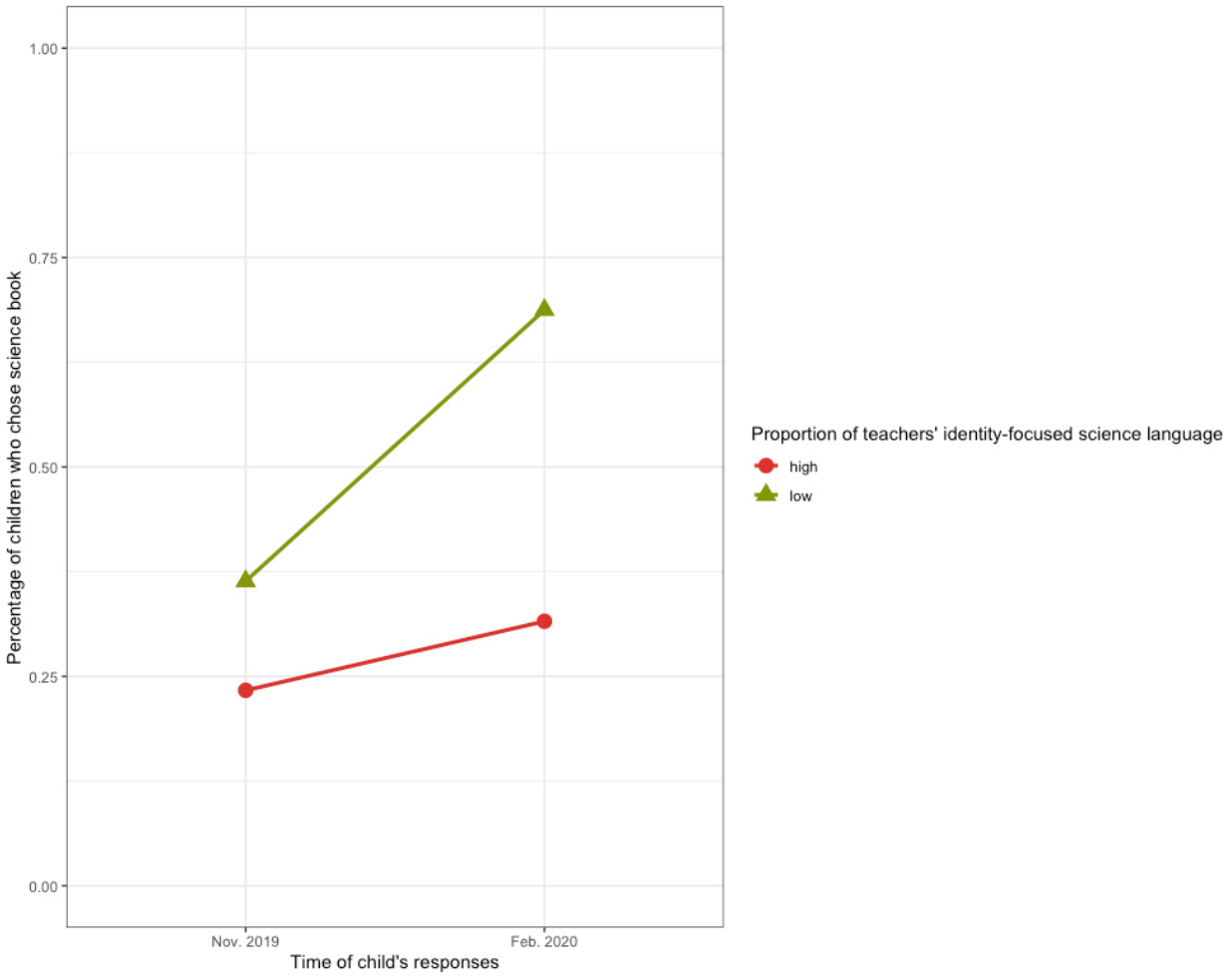


*Figure 4*. Children's book choice (1 = science, 0 = art) by study session and teachers' proportion of identity-focused science language cues (median split).

**Teacher Beliefs on Child Measures**

Although we did not find in Study 2 that teachers' language and beliefs were related to one another, it is possible that teacher beliefs shape the development of children's beliefs through other mechanisms. Indeed, teachers' gender stereotypes related to the development of children's inclusivity beliefs about science over time. There was a main effect of time ($\beta$ = 1.44, *SE* = .45, *p* = .002), and an interaction between time and teachers' explicit gender stereotypes about science ($\beta$ = -.58, *SE* = .18, *p* = .002; with no main or interactive effects of child gender; girls: *M* = 3.15, *SD* = 1.06; boys: *M* = 3.24, *SD* = .91). To illustrate the interaction between time and teacher beliefs, we plotted children's inclusivity beliefs about science across time for those with teachers with high explicit gender stereotypes and low explicit gender stereotypes (based on a median split), respectively (see Figure 5). Simple slope analyses indicated that children whose teachers had low gender stereotypes developed more inclusive beliefs across the year ($\beta$ = .30, *SE* = .19, *p* = .13), whereas those whose teachers had high stereotypes did not ($\beta$ = -.17, *SE* = .20, *p* = .39), though neither slope on its own differed from 0. Children's inclusivity beliefs about science were not predicted by any other aspect of teachers' beliefs (*p*s > .2) and children's choice of the science book was not predicted by any measured components of teachers' beliefs (*p*s > .4).

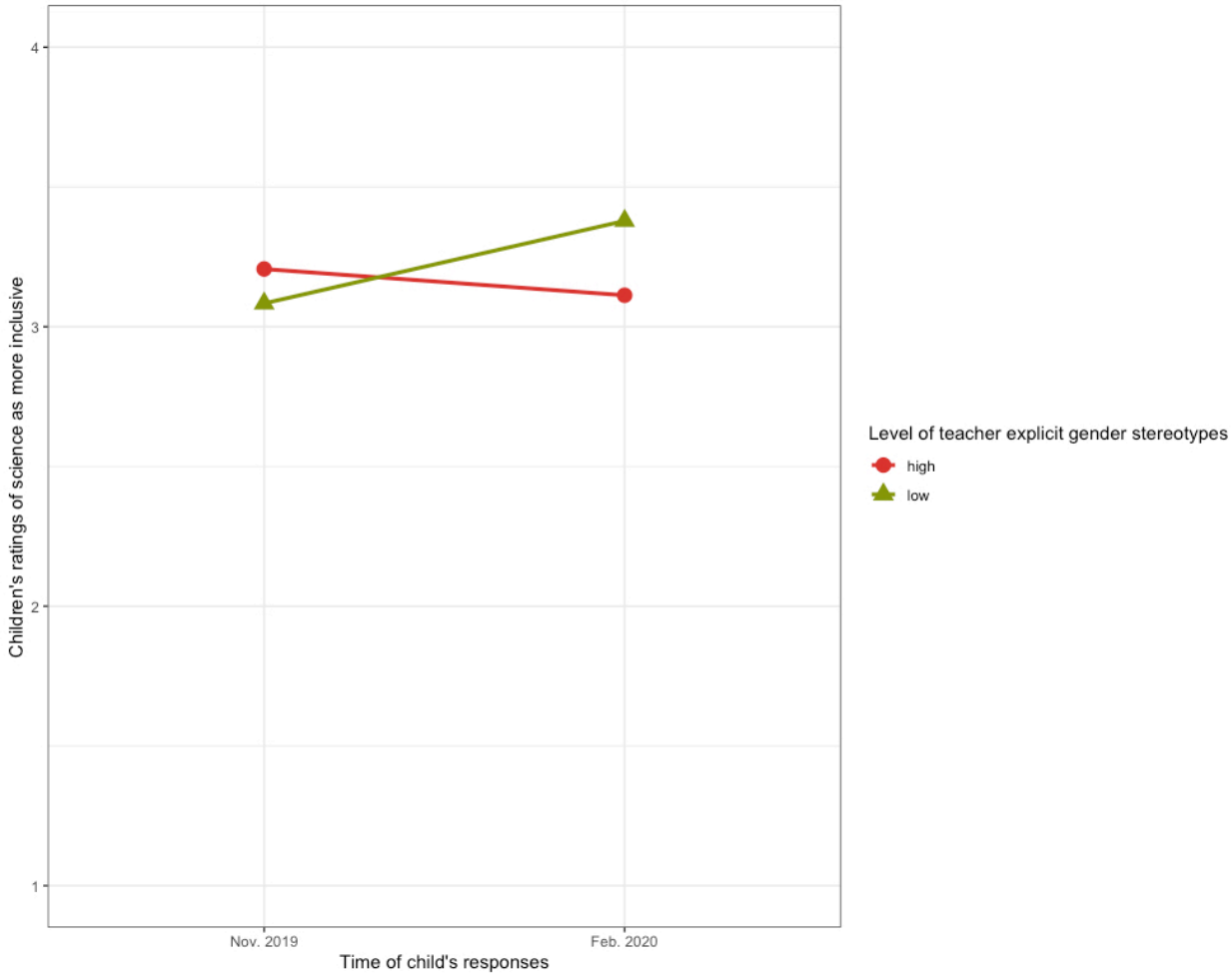


*Figure 5*. Children's inclusivity beliefs about science (average score across two items; range = 1-4; higher score indicates more inclusive beliefs about science) by study session and teachers' explicit gender stereotypes about science (median split).

**Discussion**

Overall, in Study 3, we found preliminary evidence that young children are sensitive to naturally encountered variations in linguistic cues related to science. Specifically, children who received lower proportions of identity-focused input developed increasingly inclusive beliefs about science and more science engagement over time, whereas children who received *higher* proportions of identity-focused input did not (although, unexpectedly, children with teachers who produced higher proportions of identity-focused language also had more inclusive beliefs about science to begin with). We propose that the beneficial effects of action-focused science

language may speak to the prevalence of identity-focused science language in children's daily contexts – if children are commonly and regularly exposed to identity-focused science language (as shown in Studies 1 and 2 and Rhodes et al., 2020), then perhaps those who received high proportions of identity-focused science language may be more like a "control" or "baseline" group (i.e., not receiving or receiving minimal levels of action-focused science language is more of a norm). In comparison, those who received low proportions of identity-focused science language (i.e., high proportions of action-focused science language) may have had a more unusual exposure to science, which thus had a stronger effect on changing the developmental trajectory of their science inclusivity beliefs and choice to engage with science.

Furthermore, we also found that although teacher beliefs did not directly relate to the components of teacher language that we coded here, children's inclusivity beliefs did relate to their teachers' explicit gender stereotypes – those with teachers who indicated lower levels of explicit gender stereotypes about science also developed increasingly inclusive beliefs about science over time. We will return to this finding in the General Discussion. Although the present study was exploratory in nature and the measures were pulled from a larger study that included two independent measures and four dependent measures measured at two points (thus introducing the possibility of false positive results), Study 3 provides preliminary evidence that even in the noisier and more variable contexts in which children are exposed to different types of linguistic input, these cues seem to be powerful enough to relate to variation in the development of children's science beliefs and behavior over time.

## General Discussion

In the present studies, we documented the prevalence of identity-focused language cues – specifically, those that use noun labels or generic statements to describe science (e.g., "Let's be

scientists! Scientists discover new things") – in children's natural environments, as such cues signal to children that only people of a certain and special kind can be scientists. We found that identity-focused language cues are prevalent in two important contexts in children's daily lives – children's media and classrooms. Based on our samples of popular children's television shows and teacher language, we found more references to scientists as a kind of person than science as an activity that people do. These findings suggest that language that promotes essentialist beliefs – noun labels and generic descriptions of categories – may be frequently available in young children's experiences with science.

In addition, preliminary evidence from Study 3 suggests that young children are sensitive to naturally encountered variation in these linguistic cues. Specifically, we found that prekindergarten children who heard lower proportions of identity-focused language (relative to action-focused language) from teachers in their classrooms developed more inclusive beliefs about science and greater engagement in science over time whereas those who heard higher proportions of identity-focused language did not. These findings are the first, to our knowledge, to document how even in the noisier and more variable contexts in which children are exposed to various types of linguistic input, these cues are powerful enough to predict variation in the development of children's science beliefs and engagement over time.

More work in the future, however, is needed to systematically examine the direct effects of teacher language use on children's beliefs and behaviors in classroom environments. For example, due to logistical restrictions, we were not able to recruit a larger sample of teachers in whose classrooms we could also conduct individual research with children (so that we could include a larger sample of teachers and children in our teacher-child analyses), include more detailed measures of children's beliefs and behaviors (such as those documenting their

essentialist beliefs about science), or track the developmental trajectory of our child participants' responses over a longer period of time. These limitations offer directions for future research, which we believe will shed light on the specific processes by which natural variation in linguistic input affects children's science inclusivity beliefs and choice to engage with science.

The present studies contribute to the current literature in several ways. First, they complement previous experimental work (e.g., Lei et al., 2019; Rhodes et al., 2019) that have documented the short-term consequences of brief, consistent exposure to action-focused or identity-focused language cues. Although these previous studies suggested that linguistic cues shape children's science engagement from an early age, the extent to which children's beliefs and behaviors are *actually* influenced by variation in linguistic cues across early childhood development remains largely unknown. The present studies bolstered the possibility that this could be a plausible mechanism in children's natural environments by (a) revealing the prevalence of noun labels and generic statements to describe science in children's media and classroom contexts, (b) providing preliminary evidence that young children are sensitive to the noisier and more variable linguistic input from their natural environments, and (c) tracking the developmental trajectory of children's science beliefs and behaviors from exposure to such linguistic cues across several months. In sum, the present studies complement past experimental, cross-sectional research, by suggesting that the effects of language on children's early engagement with science might operate in children's daily lives, prompted by the television shows they watch and the language they hear in classrooms.

Identity-focused language, such as "A scientist isn't discouraged by a minor setback" or "Scientists think about problems and get ideas to solve them", often sound like accurate, positive, and possibly even inspirational descriptions of scientists, as well as a pragmatically

appropriate way to refer to a professional category. Why does such language lead children to disengage from science? We propose that by describing scientists as a *kind of person*, such language leads children to believe that scientists are a distinct, natural category, and that whether one can be a scientist or not is absolute, determined by birth, fundamental to identity, and stable (Gelman, 2003; Gelman et al., 2007; Rhodes & Mandalaywala, 2017). Therefore, even though children are not expected to be scientists in the professional sense, identity-focused language nevertheless invites children to think of whether one can succeed in science in categorical terms. Furthermore, once children form such a categorical representation of science, they may actively search for information to determine *which* kind of person can become a scientist, thus laying the foundation for the acquisition of social stereotypes (e.g., that scientists are male and White). Therefore, if children doubt that they are the right kind of person that "fits" the category scientists – such as if they come from a traditionally underrepresented group in science, including gender, racial, ethnic, and socioeconomic groups – they may further disengage from science early on in development. These beliefs might prove to be particularly maladaptive once children encounter setbacks (an inevitable part of science). Importantly, because beliefs that success requires intrinsic qualities (e.g., innate talent) are especially problematic for girls and people from racial and ethnic backgrounds that are underrepresented in relevant fields (Bian et al., 2017; Dweck, 2006; Leslie et al., 2015), the language described here – even though it does not convey explicit social stereotypes – could be especially detrimental for children from groups that are underrepresented in science.

Indeed, as indicated by our exploratory analyses in Study 3, children who were exposed to lower proportions of identity-focused language cues developed increasingly inclusive beliefs about who can do science and increased science engagement over time, whereas those who heard

higher proportions of identity-focused language did not. This lends support to the possibility that children who heard higher proportions of identity-focused language held more stereotypic and essentialist beliefs about scientists, which may deter their own interest and engagement in science. Future work is needed to directly test this possibility within a larger sample, which would also allow for testing how these processes interact with participants' own group memberships (e.g., gender, race).

In the present study, we focused on early childhood, to consider the role of language, and the implications of action-based or identity-based representations, when children are *first* learning about science. We propose that thinking about science learning as something everyone does (much like everyone is expected to learn to read and to do math) rather than something that is only "for" a particular kind of person, is particularly helpful when science learning is just getting off the ground (and that adopting a categorical or identity-based way of thinking could be particularly harmful at these ages because it could contribute to disengagement before science learning even starts). The implications of language, and of more action-based or identity-based representations of science and scientists, may indeed change across development, however. For example, later in adolescence and adulthood, people may need to integrate science into their identity and view it as possible for themselves to become scientists, if they are ultimately going to continue in the field (Estrada et al., 2011; Hernandez et al., 2013; Robinson et al., 2018). Further, this type of identity development – viewing academic goals as compatible and integrated with other components of gender, racial, and ethnic identity has been found to be particularly important for groups historically excluded from science (Arroyo & Zigler, 1995). Here, by focusing on early childhood, we think one positive approach is to focus on the *process* of science

learning, rather than the *identity* of scientists. But how to incorporate the idea of being a scientist into one's identity across development is an important subject for future research.

In the present set of studies, we found an unexpected null relationship between teachers' beliefs about science and their use of language when teaching science. In light of previous findings that parents with higher essentialist beliefs about a certain category produce more generic language – a kind of identity-focused language – about that category when talking to children (Gelman et al., 2004; Rhodes et al., 2012; Segall et al., 2015), this finding was rather surprising (although one key difference is that these previous studies examined the relation of adult essentialist beliefs to generic language in particular, whereas in the present studies, we considered a broader category of identity-focused language). One possibility is that the prevalence of identity-focused language (especially in relation to action-focused language) in the environment more generally contributed to this null relationship. For example, given the prevalence of identity-focused language about science across contexts, one possibility is that teacher's own language use is cued more by the science language they encounter in their own environment (e.g., media, children's curricular materials) rather than by their own underlying beliefs. Indeed, people produce more generic statements themselves when they are exposed to higher levels of generic language from others (Gelman et al., 2004). Future work is needed to test this possibility, as well as to explore other mechanisms by which teachers' beliefs might be transmitted to children to shape children's science beliefs and behaviors. For instance, in Study 3, children who had teachers with higher levels of explicit gender stereotypes developed increasingly exclusive beliefs about science over time. As the relation appeared to be independent of identity-focused teacher language as we measured it here, it will be important to explore other mechanisms by which teachers might have communicated these beliefs, such as

through their choices of example scientists to present in class as role models, and so on. If it is indeed the case that the effects of identity-focused teacher language and stereotyped and essentialist beliefs operate independently, this has important implications for future intervention studies – perhaps modifying teacher language by replacing their identity-focused language with action-focused descriptions is effective on its own (Rhodes et al., 2020) *because* teachers' use of language is highly sensitive to contextual cues and does not reflect their deeper-held beliefs – thus making it a straightforward cue to directly modify.

Relatedly, future research should also aim to identify what accounts for variation in identity-focused science language use in children's media. In the present research, popular science educational shows varied considerably in terms of the proportion of identity-focused science language they used (see Table 2). Given the constraints of the current design (e.g., we only had access to audio transcripts of the television shows but not video clips), we were not able to test whether features of media content correlated with increased use of identity-focused science language across shows (e.g., gender of the protagonist, gender of the individual referenced, stereotypicality of the individual referenced, etc.). Future research that explores such questions would provide a more nuanced documentation of *how* children are exposed to identity-focused science language in the media, and the effects of such exposure on children's science beliefs and engagement.

In conclusion, the present studies documented the powerful role of language in children's natural environments. Specifically, within the media and classroom contexts we examined in Studies 1 and 2, we found that identity-focused science language was highly accessible and prevalent, thus complementing past experimental research by bolstering the plausibility that this is a mechanism that shapes children's science beliefs and engagement. We also provide

preliminary evidence that, starting from a young age, children are sensitive to the noisier and more variable ways in which linguistic cues are presented in their natural environments, and that they are powerful enough – even within these natural contexts – to predict children's beliefs about who can do science and their own engagement in science over time. Future work should test how similar processes may unfold in other domains, such as math or reading, and other mechanisms in which teachers' – or other agents' – beliefs are transmitted to children. Building on the current studies, such work would have important implications for educational interventions that would encourage engagement from underrepresented groups and populations, starting from an early age.

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## Appendix A

Items for Teachers' Science Beliefs Measures

**Essentialist Beliefs about Science**

1) If someone is a scientist, then their profession is an important part of what makes them who they are.

2) Scientists have many things in common with each other.

3) Knowing that someone is a scientist tells you a lot about who they are as a person.

4) Scientists are a natural category.

5) Scientists share an underlying property that causes them to have many similarities with one another.

6) Some people are naturally better at science whereas others are naturally better at other subjects.

**Explicit Gender Stereotypes about Science**

1) When they are young, boys are often naturally more interested in science than girls.

2) When they are young, boys are often naturally more talented in science than girls.

3) One reason why more men than women go into careers in science is because they have more natural talent in these fields.

4) One reason why more men than women go into careers in science is because they are more interested in these fields.

**Brilliance Beliefs about Science**

1) Being a typical/very, very top scientist requires a special aptitude that just can't be taught.

2) If you want to become a typical/very, very top scientist, hard work alone just won't cut it; you need to have an innate gift or talent.

3) With the right amount of effort and dedication, anyone can become a typical/very, very top scientist.

4) When it comes to becoming a typical/very, very top scientist, the most important factors for success are motivation and sustained effort; raw ability is secondary.