MIND, BRAIN, AND EDUCATION

Exploring How Teachers' Scientific Questions Differ by Child Gender in a Preschool Classroom

Sona C. Kumar[1], Amanda S. Haber[1], and Kathleen H. Corriveau[1]

ABSTRACT— The current study explores differences in messages that preschool teachers send girls and boys about science, technology, engineering, and math (STEM). Video footage of a preschool classroom (16 hr; $N = 6$ teachers; 20 children) was transcribed. Teachers' questions were coded for question-type and whether the question was directed to a boy or a girl. Teachers directed significantly more scientific questions to boys than to girls. However, boys spent more time than girls in the science areas of the classroom and teachers directed questions to boys and girls at similar rates. These findings highlight how as early as the preschool years, girls and boys may receive different messages about how to approach science.

Many American students leave high school unprepared to meet the national demand for professionals in science, technology, engineering, and math (STEM; NSF, 2021). To address this societal problem, the United States STEM Education Five-Year Strategic Plan (2018) identifies three key objectives to provide all Americans with access to high-quality STEM education: building strong foundations for STEM literacy, increasing diversity and inclusion, and preparing students to enter careers in STEM. We focus on early childhood (preschool through elementary years), which is a critical time for fostering children's critical thinking and engagement in STEM (*Building Blocks of STEM Act*). In 2019, Congress passed the *Building Blocks of STEM Act*, which explicitly encourages broadening representation in STEM in early childhood, with a focus on the role of teachers and parents.

Despite national efforts to increase diversity, female and non-White students remain underrepresented in STEM fields (NSF, 2021; Voyer & Voyer, 2014). Research demonstrates significant disparities in STEM achievement as early kindergarten and first grade, which only widen in K-12 schooling and college (e.g., Curran & Kellogg, 2016; Niu, 2017). The current study explores subtle differences in messages that adults send girls and boys about who belongs in STEM during the preschool years. Such differences may contribute to children's beliefs about their own STEM ability, their performance in STEM activities, and their decision to pursue a career in STEM (Rhodes, Cardarelli, & Leslie, 2020; Rhodes, Leslie, Yee, & Saunders, 2019; Shtulman & Checa, 2012; Valle, Tighe, & Hale, 2009).

To date, research on children's selective learning from others has focused on the role of the adult in fostering children's STEM learning (e.g., Callanan et al., 2020; Fender & Crowley, 2007; Kurkul, Castine, Leech, & Corriveau, 2021; Leech, Haber, Jalkh, & Corriveau, 2020; Tenenbaum & Callanan, 2008). According to the social-interactionist theory of development, conversations between adults and children provide opportunities for children to ask questions, prompting adults to offer scientific explanations that impact children's STEM learning (e.g., Vygotsky, 1978). Although the explanations that adults provide to children's questions are fundamental to children's learning, such high-quality explanations can vary based on child gender (e.g., Crowley, Callanan, Tenenbaum, & Allen, 2001; Tenenbaum & Leaper, 2003). For example, parents are more likely to provide scientific explanations to boys compared with

[1]Boston University Wheelock College of Education and Human Development, Boston University,

Address correspondence to Sona C. Kumar and Amanda S. Haber, Boston University, 621 Commonwealth Avenue, Boston, MA 02215; e-mail: skumar01@bu.edu; haber317@bu.edu

Sona C. Kumar and Amanda S. Haber shared first authorship.

girls in early and middle childhood (Crowley et al., 2001; Tenenbaum & Leaper, 2003).

During early childhood, children rely a great deal on interactions with teachers (e.g., Butler, Ronfard, & Corriveau, 2020; Haber, Leech, Benton, Dashoush, & Corriveau, 2021; Haber, Puttre, Ghossainy, & Corriveau, 2021; Kurkul, Dwyer, & Corriveau, 2022). We extend prior work with caregivers by examining how teacher-initiated questions in a preschool differ depending on whether teachers are engaging with boys versus girls in science learning settings. Utilizing naturalistic classroom data, we explored how often teachers directed scientific fact-based questions (consisting of *what*, *when*, and *where* questions, e.g., "where is my toy?") and causal questions (often marked by *why* or *how* questions, e.g., "why do leaves change color?"; Chouinard, 2007; Kurkul & Corriveau, 2018; Kurkul et al., 2022) to children at the science table and block area of the preschool classroom. Importantly, in the science domain, teachers' causal questions can encourage children to carry out investigations and construct their own explanations about scientific processes (e.g., Haber, Leech, et al., 2021; Haber, Puttre, et al., 2021; Harlen, 2001; Reiser, Brody, Novak, Tipton, & Adams, 2017). In turn, children have the opportunity to engage in foundational scientific practices (e.g., asking questions, constructing explanations, and sharing information with others), which they continue to develop during formal schooling (Next Generation Science Standards, 2013).

Based on the research showing that parents provided more scientific explanations to boys than to girls, we predicted that teachers would direct more scientific questions to boys compared with girls. Our approach is drawn from prior research examining how children learn from others, primarily their use of questions and explanations in formal and informal learning contexts (Haber, Leech, et al., 2021; Haber, Puttre, et al., 2021; Kurkul et al., 2022; Kurkul & Corriveau, 2018).

METHOD

We collected video footage in a mixed-age classroom (ranging from 2.9 to 5 years old) at the science table and block area (16 hr; $N = 6$ teachers; 20 children; 277 questions). The majority of children in the preschool classroom were from White middle-class backgrounds. On average, 7 boys (range 4–11) and 6 girls (range 2–9) per video visited the science areas of the classroom. Approximately, 10% of children did attend the preschool through scholarships. Although there is some sociodemographic diversity, the exact demographic information is not available for the children in this school.

Because this preschool is part of a teacher preparation program for preservice teachers, there are several microphones and cameras embedded in the ceiling of the classroom. Thus, we were able to unobtrusively record teacher–child naturalistic conversations as they engaged in scientific inquiry. The block and science areas of the classroom were recorded for about 60 min twice a week in the spring and fall of 2018. The study was approved by the Institutional Review Board at Boston University.

The videos were first searched for teacher-initiated questions (often starting with *what*, *why*, *who*, *when*, *how*, *can* and *did*; Chouinard, 2007; Kurkul & Corriveau, 2018; Kurkul et al., 2022). This resulted in 277 teacher-initiated information-seeking scientific questions. Questions were coded as either causal or fact-based (see Table 1). An additional 31 questions were excluded from these data because teachers directed the questions to a mixed-gender group, and thus, it was unclear whether teachers were addressing boys or girls in the classroom.

Causal questions (often marked by a *why* or *how* question, e.g., "how do germs spread?") demand a more complex response, whereas fact-based questions (often consist of *what*, *when* and *where* questions, e.g., "where is the crab?") can be answered with a simple response (e.g., Kurkul et al., 2022). We then coded for whether the question was directed to a boy or a girl. Second, after coding the teachers' information-seeking questions and child gender, we also examined whether boys were more likely than girls to choose to engage in free play in the science areas of the classroom. Accordingly, we tallied the number of boys and girls who visited the science table and block area in 90-s intervals. Finally, we also coded how many questions were asked to a given child and divided that number by the amount of time (in minutes) spent in the science areas and then examined whether that rate differed by child gender: 45 questions asked to 8 children were excluded from this analysis because it was difficult to determine which child was asked the question.

RESULTS

We first investigated whether teachers posed scientific questions differently based on child gender, finding that teachers overwhelmingly direct these questions to boys over girls. Teachers asked more fact-based questions than causal questions (239 vs. 38), a finding consistent with previous research (Butler et al., 2020; Chouinard, 2007; Kurkul & Corriveau, 2018). Inspection of Figure 1 indicates that teachers direct a significantly larger proportion of fact-based (71% vs. 29%, $z = -9.06$, $p < .001$) and causal questions (82% vs. 18%, $z = -5.51$, $p < .001$) to boys than girls.

Next, we explored whether boys were visiting the science areas more frequently than girls. To quantify frequency of children visiting the science area by gender, we counted the number of boys and girls at the science area every 90 s. There

Table 1
Coding Scheme for Teachers' Scientific Questions

Information-seeking question code	*Definition*	*Example*
Fact-based questions	Questions were coded as fact-based when a teacher directed a question at a child that could often be answered with a one-word factual response. These questions primarily included *what*, *when*, *where*, and *who* questions (as defined by Chouinard, 2007; Kurkul & Corriveau, 2018).	• When do you think the eggs with hatch? • What kind of water does the crab need? • Which block will you start with?
Causal questions	Questions were coded as causal when a teacher directed a question at a child that demanded a more complex response. These questions primarily included *why* and *how* questions (as defined by Chouinard, 2007; Kurkul & Corriveau, 2018).	• How do you take care of your fish? • Why do you need lights? • How will you get the marble out?

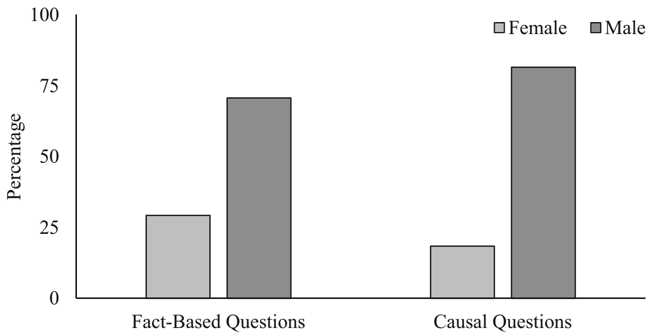

Fig. 1. Differences in teacher-initiated questions by child gender.

were 671 90-s intervals. Because the distribution of the number of boys and number of girls visiting the science area was not normal, we conducted a Mann–Whitney U test to compare the difference in children visiting the science area by gender. Analysis showed that significantly more boys visited the science area of the classroom than girls ($U = 160{,}460$, $p < 0.001$, *effect size* $= 0.26$). Additionally, we found that at least one boy was present at the science and block areas for 75% of the 90-s intervals and that at least one girl was present at those areas for 59% of the 90-s intervals. We then conducted a binary logistic regression with the proportion of boys to girls in each 90-s interval as the predictor and the likelihood of asking a scientific question as the dependent variable. The analysis indicated that the proportion of boys to girls in the science area does not significantly predict whether the teacher directed a science question to a child ($B = 0.09$, $SE = 0.08$, $p = .26$).

In our final analysis, we coded how many questions were asked to a given child and the amount of time spent by that child in the science area. We found that 170 questions were asked to boys across 990 min spent in the science areas and 62 questions were asked to girls across 394 min. This yielded the finding that the rate of questions asked to boys was 0.17 questions per minute (95% CI [0.15, 0.20]) and the rate of questions asked to girls was 0.16 per minute (95% CI [0.12, 0.20]). These rates did not differ significantly, suggesting that teachers were asking questions to boys and girls at the same rates.

DISCUSSION

Taken together, our findings demonstrate that although teachers in this preschool directed more scientific questions to boys than to girls overall, they directed scientific questions to boys and girls at similar rates. Prior work has shown gender bias in parents' scientific explanations to boys compared to girls (Crowley et al., 2001). In the context of the elementary school classroom, prior work has also shown that boys receive more teacher attention than girls (Sadker & Sadker, 1986). By contrast, this work indicates that early childhood teachers did not display bias in the rates at which they directed scientific questions to boys and girls. Future work should consider what factors, such as professional training or beliefs about gender equality, may have led teachers in this early childhood educational setting to provide similar rates of scientific questions to boys and girls.

Why did teachers in this preschool direct science questions at a greater frequency to boys than to girls? One possible explanation is that more boys visited the block and science table areas than girls in the preschool classroom, providing more opportunities for teachers to engage boys in scientific conversations than girls. Indeed, we found that boys visited the block and science areas more frequently than girls. However, it was not the case that girls were never present in the science areas; the majority of the 90-s time intervals included at least 1 girl. Additionally, given that we did not have data on the total number of boys and girls in the classroom, it is difficult to meaningfully interpret this finding (e.g., if there were more boys than girls, boys may simply have been more present at all areas of the classroom).

The exploratory nature of this study allows us to identify patterns in teachers' scientific questions. In future work, we aim to empirically test such patterns by further investigating the direct relation between teachers' messages related to science and children's learning in STEM activities. Of particular interest is the finding that, although teachers appear to be asking boys and girls questions at similar rates in the classroom, it seems possible that girls may still receive different messages than boys about how to approach science as early as the preschool years. Thus, it may be important to consider ways to encourage young girls to participate in science activities in the classroom, such as by introducing female role models in science (consider Baker, 2013; Gladstone & Cimpian, 2021).

Importantly, adult language surrounding children's science engagement has been shown to impact girls' science learning (Rhodes et al., 2019). For example, girls (aged 5–7) persist longer during a science activity when they are told they are "doing science" versus "being scientists," whereas boys' persistence did not change based on this language. Young children are sensitive to the messages that adults send about who should engage and participate in science (Bian, Leslie, Murphy, & Cimpian, 2018). Such messages and opportunities to respond to teachers' scientific questions may impact children's engagement in science during the preschool years and contribute to their later interest and motivation in STEM during formal schooling, potentially contributing to the gender gap in the STEM workforce (NSF, 2021).

Limitations and Future Directions

Because we examined naturalistic classroom talk, we cannot draw conclusions about the nature of the relation between teachers' scientific talk and children's engagement with STEM. Similarly, we did not include formal measures to assess children's science learning. Future work should explore potential causal relations between engaging in scientific conversations with teachers and children's subsequent understanding of scientific concepts. In addition, although the children included represent a range of racial and ethnic backgrounds, the sample consisted of predominantly highly educated early childhood educators and children from mid-socioeconomic status backgrounds (e.g., Haber, Leech, et al., 2021; Haber, Puttre, et al., 2021). Thus, future work should explore to what extent teachers' scientific questions may differ by child gender, age, and racial and ethnic background in schools serving children from lower-SES backgrounds (Kurkul et al., 2022). Another rich area for future exploration is to examine individual child-level differences in teachers' scientific questions by following a select number of children in the preschool classroom.

From an early age, children's science education is centered on asking questions, constructing explanations, evaluating knowledge, and communicating information effectively (Edson, 2013). Thus, the child's teacher plays a fundamental role in facilitating children's scientific learning. Indeed, the *Next Generation Science Standards* (NGSS, 2013) and *the Framework K-12 Science Education* (NRC, 2012) emphasize that STEM learning should be integrated in K-12 science education to prepare students for careers in STEM. These findings are a critical first step in developing future classroom interventions that could increase girls' participation in STEM before the onset of formal schooling.

CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

ACKNOWLEDGMENTS—The work was supported by the National Science Foundation to Kathleen H. Corriveau (grant #1652224).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding authors.

REFERENCES

Baker, D. (2013). What works: Using curriculum and pedagogy to increase girls' interest and participation in science. *Theory Into Practice*, *52*(1), 14–20.

Bian, L., Leslie, S.-J., Murphy, M. C., & Cimpian, A. (2018). Messages about brilliance undermine women's interest in educational and professional opportunities. *Journal of Experimental Social Psychology*, *76*, 404–420. https://doi.org/10.1016/j.jesp.2017.11.006

Butler, L. P., Ronfard, S., & Corriveau, K. H. (Eds.) (2020) *The questioning child: Insights from psychology and education*. (1st ed.). Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108553803

Callanan, M. A., Legare, C. H., Sobel, D. M., Jaeger, G. J., Letourneau, S., McHugh, S. R., … Watson, J. (2020). Exploration, explanation, and parent–child interaction in museums. *Monographs of the Society for Research in Child Development*, *85*(1), 7–137. https://doi.org/10.1111/mono.12412

Chouinard, M. M. (2007). Children's questions: A mechanism for cognitive development. *Monographs of the Society for Research in Child Development*, *72*(1), 1–129. https://doi.org/10.1111/j.1540-5834.2007.00412.x

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science*, *12*(3), 258–261. https://doi.org/10.1111/1467-9280.00347

Curran, F. C., & Kellogg, A. T. (2016). Understanding science achievement gaps by race/ethnicity and gender in kindergarten and first grade. *Educational Researcher*, *45*(5), 273–282. https://doi.org/10.3102/0013189X16656611

Edson, M. T. (2013) *Starting with science: Strategies for introducing young children to inquiry*. Grandview Heights, OH: Stenhouse Publishers.

Fender, J. G., & Crowley, K. (2007). How parent explanation changes what children learn from everyday scientific thinking. *Journal of Applied Developmental Psychology*, *28*(3), 189–210. https://doi.org/10.1016/j.appdev.2007.02.007

Gladstone, J. R., & Cimpian, A. (2021). Which role models are effective for which students? A systematic review and four recommendations for maximizing the effectiveness of role models in STEM. *International Journal of STEM Education*, *8*(1), 1–20.

Haber, A. S., Leech, K. A., Benton, D. T., Dashoush, N., & Corriveau, K. H. (2021). Questions and explanations in the classroom: Examining variation in early childhood teachers' responses to children's scientific questions. *Early Childhood Research Quarterly*, *57*, 121–132. https://doi.org/10.1016/j.ecresq.2021.05.008

Haber, A. S., Puttre, H., Ghossainy, M. E., & Corriveau, K. H. (2021). "How will you construct a pathway system?": Microanalysis of teacher-child scientific conversations. *Journal of Childhood, Education & Society*, *2*(3), 338–363. https://doi.org/10.37291/2717638X.202123117

Harlen, W. (2001) *Primary science: Taking the plunge*. (2nd ed.). Portsmouth, NH: Heinemann.

Kurkul, K. E., Castine, E., Leech, K., & Corriveau, K. H. (2021). How does a switch work? The relation between adult mechanistic language and children's learning. *Journal of Applied Developmental Psychology*, *72*, 101221. https://doi.org/10.1016/j.appdev.2020.101221

Kurkul, K. E., & Corriveau, K. H. (2018). Question, explanation, follow-up: A mechanism for learning from others? *Child Development*, *89*(1), 280–294. https://doi.org/10.1111/cdev.12726

Kurkul, K. E., Dwyer, J., & Corriveau, K. H. (2022). 'What do YOU think?': Children's questions, teacher's responses and children's follow-up across diverse preschool settings. *Early Childhood Research Quarterly*, *58*, 231–241. https://doi.org/10.1016/j.ecresq.2021.09.010

Leech, K. A., Haber, A. S., Jalkh, Y., & Corriveau, K. H. (2020). Embedding scientific explanations into storybooks impacts children's scientific discourse and learning. *Frontiers in Psychology*, *11*, 12. https://doi.org/10.3389/fpsyg.2020.01016

National Research Council (2012) *A framework for K-12 science education: Practices, crosscutting concepts, and core idea*. Washington, DC: The National Academic Press.

National Research Council (2013) *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18290

National Science Foundation, National Center for Science and Engineering Statistics. (2021). *Women, minorities, and persons with disabilities in science and engineering*. https://ncses.nsf.gov/pubs/nsf21321/report.

Niu, L. (2017). Family socioeconomic status and choice of STEM major in college: An analysis of a national sample. *College Student Journal*, *51*, 298–312.

Reiser, B. J., Brody, L., Novak, M., Tipton, K., & Adams, L. (2017). Asking questions. In C. V. Schwarz, C. Passmore & B. J. Reiser (Eds.), *Helping students make sense of the world using next generation science and engineering practices*. (pp. 87–108). Richmond, VA: NSTA.

Rhodes, M., Cardarelli, A., & Leslie, S.-J. (2020). Asking young children to "do science" instead of "be scientists" increases science engagement in a randomized field experiment. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(18), 9808–9814. https://doi.org/10.1073/pnas.1919646117

Rhodes, M., Leslie, S.-J., Yee, K. M., & Saunders, K. (2019). Subtle linguistic cues increase girls' engagement in science. *Psychological Science*, *30*(3), 455–466. https://doi.org/10.1177/0956797618823670

Sadker, M., & Sadker, D. (1986). Sexism in the classroom: From grade school to graduate school. *The Phi Delta Kappan*, *67*(7), 512–515.

Shtulman, A., & Checa, I. (2012). Parent-child conversations about evolution in the context of an interactive museum display. *International Electronic Journal of Elementary Education*, *5*(1), 27–46.

Tenenbaum, H., & Leaper, C. (2003). Parent-child conversations about science: The socialization of gender inequities? *Developmental Psychology*, *39*, 34–47. https://doi.org/10.1037/0012-1649.39.1.34

Tenenbaum, H. R., & Callanan, M. A. (2008). Parents' science talk to their children in Mexican-descent families residing in the USA. *International Journal of Behavioral Development*, *32*(1), 1–12. https://doi.org/10.1177/0165025407084046

Valle A, Tighe E, & Hale J (2009). *Domain-related patterns in epistemological understanding: Evidence from questionnaire and parent–child conversation data*. Poster session presented at the annual meeting of the Society for Research in Child Development, Denver, CO.

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin*, *140*(4), 1174–1204.

Vygotsky, L. S. (1978) *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.