DOI: 10.1111/cdev.14007

EMPIRICAL REPORTS

CHILD DEVELOPMENT

Girls are good at STEM: Opening minds and providing evidence reduces boys' stereotyping of girls' STEM ability

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Funding information
Social Sciences and Humanities Research Council of Canada, Grant/Award Number: 895-2017-1025

Abstract

Girls and women face persistent negative stereotyping within STEM (science, technology, engineering, mathematics). This field intervention was designed to improve boys' perceptions of girls' STEM ability. Boys ($N=667$; mostly White and East Asian) aged 9–15 years in Canadian STEM summer camps (2017–2019) had an intervention or control conversation with trained camp staff. The intervention was a multi-stage persuasive appeal: a values affirmation, an illustration of girls' ability in STEM, a personalized anecdote, and reflection. Control participants discussed general camp experiences. Boys who received the intervention (vs. control) had more positive perceptions of girls' STEM ability, $d=0.23$, an effect stronger among younger boys. These findings highlight the importance of engaging elementary-school-aged boys to make STEM climates more inclusive.

> I have had to persevere when told, sometimes subtly but often quite overtly, that women don't belong in science […] I came to recognize that dismissive comments from older male scientists weren't the sign of a personal failure. They were part of a broader pattern—one that other women scientists of my and subsequent generations have encountered.

—Dr. Rita Colwell, "Women Scientists Have the Evidence About Sexism"

(*The Atlantic*, 2020)

As microbiologist Dr. Rita Colwell notes, men's negative perceptions of women's abilities pose a persistent barrier to women's achievement in science, technology, engineering, and mathematics (STEM; Cheryan & Markus, 2020). When do these negative beliefs about women's ability emerge? Some evidence suggests that the stereotypes underlying these perceptions emerge early in life, with boys associating STEM success to a greater extent with men than with women (Hyde et al., 1990) on both explicit and implicit measures (Cvencek et al., 2011; Regner et al., 2014; Steinke et al., 2007). Indeed, these stereotypes tend to strengthen from childhood through early adolescence (Miller et al., 2018), and recent evidence suggests substantial overtime stability in gender–STEM attitudes among adolescents and young adults, more so than for racial and other attitudes (Cai et al., 2021). In the current research, we tested a novel intervention focused on persuading boys to more accurately appraise the STEM ability of girls (whose math/science performance typically aligns with boys'; Hyde & Linn, 2006; Kersey et al., 2018; Martin et al., 2011; Mosatche et al., 2013). In addition, we examined whether this intervention would be more effective in late childhood as opposed to early adolescence, when children have had less reinforcement of societal stereotypes about STEM (Miller et al., 2018) and when attitudes and beliefs about social groups may be more malleable (Aboud, 2005; Degner & Wentura, 2010).

Our intervention to address the gender gap in STEM participation advances theory and practice in several ways. First, past interventions designed to address the STEM participation gap have often focused on girls and women, encouraging them to change their self-views or adapt to male-dominated environments (Kessels, 2015; Liben & Coyle, 2014). Prototypical interventions often yield immediate benefits by empowering girls and women to overcome identity-threatening interactions and environments (Dennehy & Dasgupta, 2017; Logel et al., 2012; O'Brien et al., 2017; Paunesku et al., 2015; Walton & Wilson, 2018). However, exclusive reliance on female-targeted interventions may propagate misconceptions that gender bias is a "female issue" to be fixed by changing the beliefs, attitudes, and behavior of girls and women (Burkinshaw & White, 2017). Other interventions have demonstrated the transmission of teachers' or parents' attitudes regarding girls in STEM to the children in those environments (e.g., Eble & Hu, 2022; Shimwell et al., 2023). Although valuable, these approaches are insufficient to fully address the peer-to-peer cross-gender social interactions—including gender discrimination (Greider et al., 2019; Moss-Racusin et al., 2012)—that undermine girls' and women's sense of STEM "fit" (Schmader & Sedikides, 2018) and hinder their STEM career progress and success (Begeny et al., 2020; Moss-Racusin et al., 2018). Unlike these previous approaches, our intervention instead aimed to change boys' stereotypical perceptions of girls' STEM ability.

In addition, most STEM gender gap interventions focus on higher education (Cheryan et al., 2009; Dennehy & Dasgupta, 2017; Ramsey et al., 2013) or workplaces (Chang et al., 2019; Devine et al., 2017; LaCosse et al., 2020). Although interventions at later career stages are needed, they come after many girls and young women have made educational decisions that might foreclose careers in STEM (National Center for Education Statistics, 2017; National Science Foundation, 2016, 2017; Zheng & Weeden, 2023). Instead, we aimed to improve the STEM climate before girls decide whether to take STEM (vs. non-STEM) courses in high school (Tyson, 2011).

Finally, by intervening with boys to reduce barriers for girls, our approach builds on calls to consider broader contextual factors when addressing inequality in STEM (Murphy et al., 2018). For example, peers' gender stereotypic attitudes in adolescence negatively affect girls' predictions they will enter STEM majors (Riegle-Crumb & Morton, 2017), as well as their actual entry into STEM majors (van der Vleuten et al., 2018). These patterns start early: Among youth aged 5–11, boys—more than girls—tend to believe boys are better at STEM than girls, and these negative perceptions of girls' STEM ability then predict seeking science advice from male over female peers (McGuire et al., 2022). Girls and women frequently experience gender bias in STEM settings (e.g., negative comments about their ability), predominately from male peers. This bias often corrodes girls' and women's STEM self-concept, although having a supportive network of non-biased peers buffers against negative identity-related outcomes (Robnett, 2016). Such evidence linking early gender bias from peers (especially male peers) to negative outcomes for girls in STEM domains highlights the potential impact of improving boys' beliefs on girls' ultimate representation in these fields.

We therefore believe that focused efforts to change boys' perceptions of girls' STEM ability represent a critical step toward creating STEM environments in which girls can more easily reach their full potential, without the burdens of gender stereotypes (Leslie et al., 2015; Schmader & Sedikides, 2018; Spencer et al., 2016). Such interventions could also provide immediate benefits to girls by reducing gender stereotypes "in the air" in childhood STEM settings, thus boosting girls' sense of belonging (both of which predict intended career trajectories; Master, 2021). Thus, we aimed to alter the stereotypic perceptions of girls' STEM ability held by boys in late childhood to early adolescence, using a multi-step persuasive intervention.

Multi-step model of persuasion

Our intervention provided evidence to boys in late childhood through early adolescence that girls' STEM abilities are generally stronger than they initially appear (Walton & Spencer, 2009). However, given the salience and centrality of gender throughout childhood (Arthur et al., 2008; Shutts, 2013, 2015), we anticipated that boys might feel defensive at the suggestion that girls' STEM potential is underestimated (e.g., Sherman & Cohen, 2006). To counteract this defensiveness and to facilitate open-minded processing of our persuasive appeal (McQueen & Klein, 2006; Sherman & Cohen, 2006), we used a multi-step model of persuasion developed for adults (see Pilot 1 in the Supplement) that, to our knowledge, has not been previously used with children.

The first step was designed to facilitate open mindedness. Building on extensive research with adults demonstrating that self-affirmation interventions reduce psychological threats and facilitate objectivity (e.g., Correll et al., 2004; see Sherman & Cohen, 2006 for a review), boys in our intervention condition first had their top-rated value affirmed by a male role model in STEM (see the Supplemental Methods for details, and Pilot 2 regarding the importance of this step, using adult data). In a second step, that same role model presented strong evidence that girls' and women's true STEM ability is commonly underestimated and underappreciated. Importantly, these men argued against their apparent group interest—resulting in an expectancy violation that, according to previous research with adults, increases the perceived credibility of the evidence (Petty et al., 2001; Walster et al., 1966). In a third step, the persuasive appeal was interactively strengthened and personalized by asking boys to identify and describe a female peer whose STEM ability they had possibly underestimated (Jenni & Loewenstein, 1997). We anticipated that this novel multi-step intervention would reduce boys' stereotypic perceptions of girls' STEM ability.

The present study

The goal of the present study was to examine whether this multi-step model of persuasion, which had been developed for adults, would improve boys' perceptions of girls' ability in STEM, as well as attenuate their ingroup bias favoring boys. We expected that boys in the intervention condition would report more positive perceptions of their female peers' STEM ability than boys in the control condition. In addition, we examined whether the intervention would be more effective in late childhood, when boys have had fewer years of exposure to gender stereotypes in STEM, as opposed to in early adolescence. We also examined possible covariates and moderators. To address concerns about possible experimental demand, we then leveraged sociometric data from these boys' female peers to examine whether boys' (improved) perceptions of girls' STEM ability were reflected in more cross-gender friendships, as reported by the *girls* in their social environment.

METHOD

Participants

We recruited 829 boys from week-long co-ed STEM summer day camps at three large Canadian universities. The camps included students entering Grades 5–9. Recruitment spanned 3 years (2017–2019), with 2017 recruitment at one site and 2018–2019 recruitment at three sites (see Table S1 for cell sizes). We aimed to recruit as many participants as possible. Approximately half of all eligible boys received parental permission to participate, from a total of 133 camp classes, with 2–21 boys per class taking part. Although these camps were co-ed, only boys were recruited into this study; girls were recruited into a separate study. Notably, we asked the girls ($N = 610$), who were peers of our male participants, to report which boys at camp they saw as friends.

Participants received $5 in gift cards and an entry into a raffle for a science museum family membership. Analyses excluded campers who did not complete their assigned intervention or control conversation ($n = 103$) or the main dependent measure ($n = 41$), or had low protocol adherence (e.g., major external distractions/disengagement, $n = 18$). Our analyses included 667 boys (median age: 12 years; range: 9–15 years). Broadly mirroring the demographics of the collection cities (Waterloo, Vancouver), most boys self-identified as White or European (42%) or East Asian (37%); the remainder identified as South Asian, Middle Eastern, Latino/a or Hispanic, Black, and Indigenous, or another background. Participants (and staff) reported their gender, so all associated terms (nouns: *boys/girls*; adjectives; *male/female*) indicate gender identity, not sex.

Materials and procedure

After receiving parental consent, our male participants completed three components: the Intake Survey on Day 1, the intervention (or control) conversation on Day 2 or 3, and the Exit Survey on Day 5. To minimize the influence of socially desirable responding or experimental demand, the Intake (Day 1) and Exit (Day 5) Surveys were collected concurrently in large group settings (with each participant on a separate computer). Additionally, we collected and analyzed a social network measure of friendship ties collected from these boys' female peers on Day 5. This study received clearance from research ethics boards at the University of Waterloo, the University of British Columbia, and Simon Fraser University. Full materials are available at osf.io/xk4ga/?view_only=8a9786a53d2c471d9ef3f9467a3f78cc (for item wording, see Table S2).

Intake survey (day 1)

The Intake Survey began with child assents and included the value rankings used to tailor the self-affirmation component of the intervention (Fein & Spencer, 1997). Participants ranked a list of eight values (e.g., family, friends) from *the most important to you* to *the least important to you*. Starting in Year 2, the Intake Survey also probed their current sense of fit in current STEM classes, using four items (e.g., "How much do you feel you belong (fit) in [Science] classes?"; $\alpha = .81$) rated from 1 (*not at all*) to 5 (*extremely*). A parallel set of eight items tapped their sense of future fit in potential STEM university classes (e.g., "How much do you feel like you *will* belong (fit) in [Engineering] classes?"; $\alpha = .87$).

Intervention or control conversation (Day 2 or 3)

Boys who completed the Intake Survey were randomly assigned to either the intervention ($n = 309$) or control ($n = 358$) condition. Both conditions included a semi-structured one-on-one conversation between the participant and typically a male camp staff member. (When male staff were unavailable, a female staff member completed the conversation—intervention <3%; control 18%—however, staff gender did not moderate results; see Supplement.) All conversations were with an undergraduate or graduate student in STEM who was involved with the camp and had received study procedure and camp training. (As girls from these co-ed camps also participated in surveys and one-on-one conversations for a parallel project, participants were not visibly segregated by gender in any aspects of this research.) Conversations took place on Day 2 (47%) or Day 3 (27%) whenever possible. Due to a variety of logistical constraints, some took place on Day 1 (17%) or on Day 4 or 5 (9%), always between the Intake and Exit Surveys.

Control conversations

Control conversations included introductions (i.e., their STEM major and interest in STEM), icebreakers (e.g., "If you could have any superpower, what would it be?"), and a discussion of the boy's camp experiences (e.g., most enjoyable activity).

Intervention conversations

The intervention condition built upon the control conversation with additions between the icebreakers and discussion of camp experiences. In the self-affirmation step, staff told a genuine personal story connecting the reason they personally chose to major in STEM to the participant's top-rated value. For instance, a staff member told a participant who had ranked family as his most important value about how his older sibling's chemistry project inspired his interest in science (see Supplement for more details). During this retelling of the value-affirming anecdote, the staff member encouraged the participant to consider their own related experiences—enabling an active (if assisted) reflection upon the participant's top value.

Participants then watched a video (Years 2 and 3) or listened to the staff member talk (Year 1) about how stereotypes can impede the recognition of others' abilities and therefore bias perceptions, using an analogy of ankle weights masking a runner's true speed (see https://osf.io/xgjny for the full video and the Supplement for more information). Finally, the staff member told a personal story highlighting the true ability of a female peer/mentor in STEM and asked the participant to consider a female peer whose STEM ability they had possibly underestimated (personalizing the message and fostering deeper elaboration).

Exit Survey (Day 5) and Mid-Week Survey

Boys completed an Exit Survey on the final day of camp (Years 1–3) and a Mid-Week Survey right after the intervention with our main dependent measure (Year 3 only; mirrors Exit Survey results, see Supplement for analyses).

Perceptions of Girls' STEM ability

Participants reported their perceptions of girls' STEM ability by responding to three items ("In general, girls my age are good at [math/science/computers]"; $\alpha = .88$) on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*). This composite was our main dependent measure.

Perceptions of Boys' STEM ability and Girls' English ability

As a matched control variable, participants responded to the same perceived STEM ability items about boys ("In general, boys my age are good at [math/science/computers]"; $\alpha = .80$) on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*). Starting in Year 2, participants also reported perceptions of girls' English ability ("In general, girls my age are good at writing"; a parallel item about boys' English ability is not analyzed here).

Demographics and community
Participants reported the gender ratio of their closest friends (excluding camp friends) from 1 (*all of my best friends are girls*) to 5 (*all of my best friends are boys*). They reported their age and which, if any, family members worked in STEM (only female relatives were analyzed).

Female Peers' friendships with male participants
We collected sociometric data about campers' friendships during the Exit Survey, asking "Which of your fellow campers do you see as your friend?". Girls then categorized each boy in their camp as a best friend, a friend (but not a best friend), not really a friend, or "I don't know [this person]". Although boys also reported friendship ties, girls' data are focal for our friendship hypotheses. Girls were unaware of condition assignments among the boys, isolating this friendship nomination measure from potential expectancy effects among our male participants.

To enable computation of standard network metrics reliant on binary ties (Scott, 2017), we counted a friendship tie as present for "friend" (16%) and "best friend" (10%) nominations and absent for "not friend" (24%) or unknown (51%) responses. We then summed the friendship nominations each boy received from their female peers, as a proportion of all possible nominations. The resulting cross-gender social indegree metric (Cyr et al., 2021) indexes boys' network centrality within the girls participating in their camp.

RESULTS

Analytic approach

Multi-level random intercept models accounted for clustering of participants within camp classes, given a very small but non-negligible intraclass correlation coefficient, $ICC=.06$, $p=.050$ (Lorah, 2018). Condition was effects coded (control = −1, intervention = 1), and continuous predictors were winsorized to ±3 *SD*s (the highest winsorization rate was 1.67%) then mean-centered (see Table 1 for means and Table S3 for correlations). Effect sizes are approximated Cohen's *d*s (Rosenthal & Rubin, 2003, Equation 3).

Boys' perceptions of girls' STEM ability

Our main goal was to determine whether our intervention would increase boys' perceptions of girls' STEM ability. As hypothesized, boys in the intervention condition reported more positive perceptions of girls' STEM ability than did boys in the control condition, $t(652.07)=2.95$, $p=.003$, $d=0.23$ (see Figure 1).

This condition effect held even when controlling for geographic and temporal variation in data collection. There was significant variation across sites (a factor) and, to a lesser extent, years (a linear term), but these variables did not moderate the intervention effect (see Supplement). The subsequent "core" models retain site and year as covariates.

Covariates

We next added a predetermined series of covariates to our core model: perceptions of boys' STEM and girls' English ability, plus baseline (i.e., Intake Survey) sense of current and future STEM fit. These are theoretical confounds related to socially desirable responding (e.g., artificially inflating all ability appraisals) or domain identification (e.g., possibly inflating assumptions about girls' STEM interest or aptitude via projection).

No covariates changed the finding that the intervention led to improved perceptions of girls' STEM ability (see Table 2 and Figure 2). The conditioning effect persisted when controlling for boys' ratings of

TABLE 1 Means by condition.

	Control ($ns=315$–358) *M* (SD)	Intervention ($ns=272$–309) *M* (SD)	Condition Difference *t*
1. Perceptions of Girls' STEM Ability	**4.43 (1.23)**	**4.70 (1.20)**	**2.88****
2. Perceptions of Boys' STEM Ability	5.08 (1.12)	5.05 (1.07)	0.34
3. Perceptions of Girls' English Ability	5.24 (1.27)	5.39 (1.22)	1.43
4. Current STEM Fit (Intake)	3.91 (0.75)	3.85 (0.76)	1.00
5. Future STEM Fit (Intake)	3.87 (0.67)	3.79 (0.67)	1.46
6. Proportion female friends	4.04 (0.79)	4.00 (0.82)	0.52
7. Age in years	11.92 (1.23)	12.01 (1.26)	0.94
8. Female family members in STEM	0.41 (0.63)	0.47 (0.68)	1.13

Note: Boldface indicates the focal effect.
**$p<.01$.

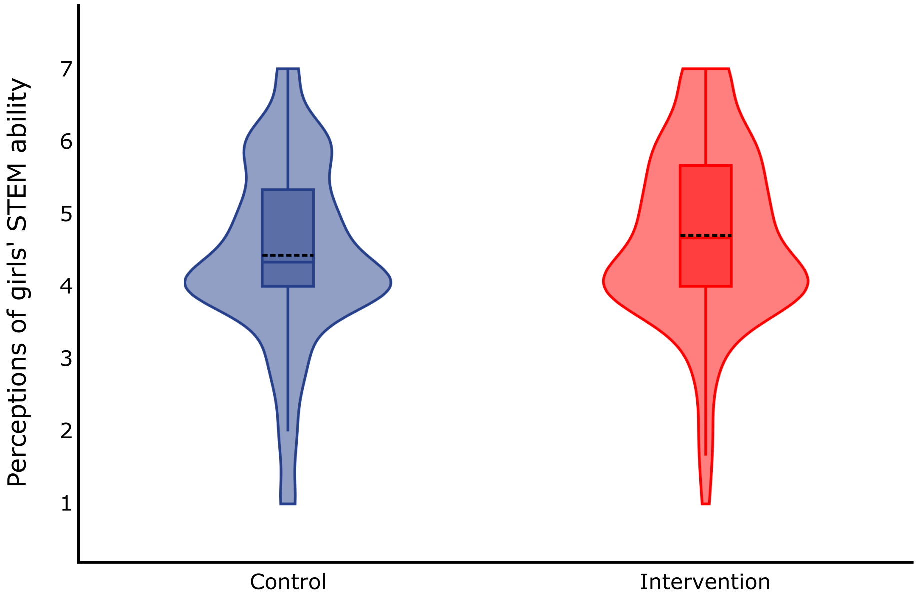

FIGURE 1 Boys' perceptions of girls' STEM ability by condition. *Note*: Medians and interquartile ranges are indicated with solid horizontal lines. Means are indicated by dashed horizontal lines.

TABLE 2 Core and additional covariate models of boys' perceptions of girls' STEM ability.

	Core model		Covariate							
			Perceptions of boys' STEM ability		Perceptions of girls' English ability		Current fit in STEM		Future fit in STEM	
Parameter	*B*	*t*	*B*	*t*	*B*	*t*	*B*	*t*	*B*	*t*
Condition[a]	0.13	**2.77****	0.14	**3.18****	0.09	**2.09***	0.13	**2.61****	0.14	**2.76****
Covariate	—	—	0.41	10.42***	0.51	14.96***	0.23	3.48***	0.29	3.92***
Site	0.16	1.84[†]	0.14	1.77[†]	0.33	3.81***	0.36	3.26**	0.36	3.31**
Year (*F*)	4.78*		4.55*		1.39		3.33*		3.75*	
Random intercept	0.08[†]		0.05		0.01		0.06		0.06	
Condition (*d*)	0.22		0.25		0.17		0.22		0.23	

Note: Boldface indicates the key condition effect on boys' perceptions of girls' STEM ability (df = 574.5–646.2). Site is a three-level categorical predictor, tested with an F ratio. For each model's random intercept (representing clustering of participants within camp classes), variance estimates are provided.

[a]Control = −1, Intervention = 1.

[†]$p < .10$.

*$p < .05$; **$p < .01$; ***$p < .001$.

girls' English ability, suggesting that the intervention improved boys' ratings of girls' *STEM* ability independent of their perceptions of girls' non-STEM ability. Including participants' perceptions of boys' STEM ability further clarified that the intervention selectively improved perceptions of *girls*' STEM ability. Finally, participants' baseline sense of (current or future) fit in STEM did not overwhelm the effectiveness of the intervention.

Boys' ingroup bias

We also tested whether the intervention reduced boys' ingroup bias by comparing participants' ratings of boys' STEM ability to their ratings of girls' STEM ability (stacking these ratings in a "long" file and specifying target gender as a within-participants factor). Ingroup bias varied by intervention condition. As expected, boys displayed less ingroup bias in the intervention versus the control condition (see Table 3). Ingroup bias in gender-based STEM ability was roughly halved from a medium effect (d = 0.50) in the control condition to a small effect (d = 0.27) in the intervention condition.

Moderators

We also examined whether three predetermined variables moderated the intervention effect on perceptions

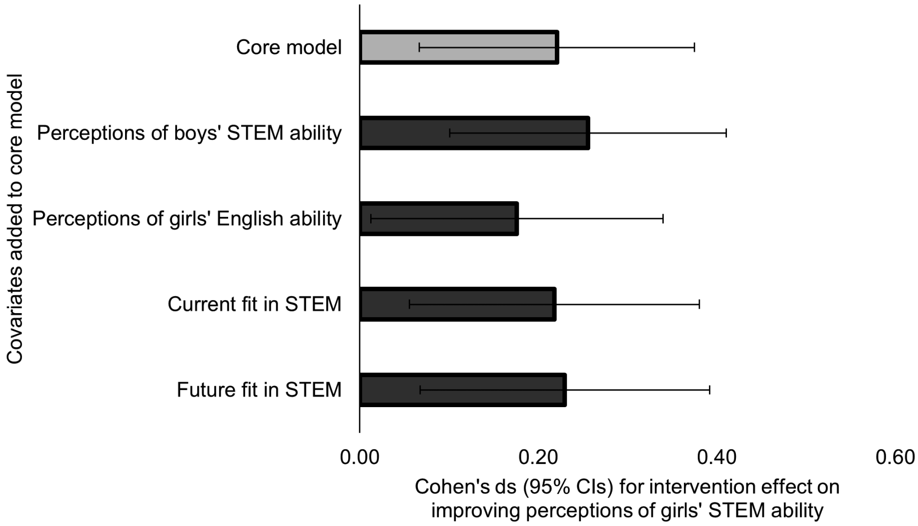

FIGURE 2 Intervention effect sizes: core model and models with additional covariates. *Note*. Error bars indicate 95% confidence intervals.

TABLE 3 Ingroup bias model: comparing boys' perceptions of boys' and girls' STEM ability.

Predictor	*B*	*t* or *F* [a]	*df*	*d*
Site	—	2.71†	90.1	
Year	0.10	1.40	108.3	
Condition[b]	0.05	1.38	647.3	
Target gender for STEM ability	0.25	9.93***	658.0	0.39
Target gender *within* Control	**0.33**	**9.48*** **	**658.0**	**0.50**
Target gender *within* Intervention	**0.17**	**4.73*** **	**658.0**	**0.27**
Condition × Target gender	−0.08	−3.01**	658.0	

Note: Intervention condition effects are estimated averaging across perceptions of boys' and girls' STEM ability. Boldface indicates the focal effect.

[a]Site is a three-level categorical predictor, so its *F* ratio is reported.

[b]Control = −1, Intervention = 1.

†$p < .10$.

**$p < .01$; ***$p < .001$.

of girls' STEM ability (see Table 4). Greater exposure to girls' STEM ability, indexed as the number of female family members in STEM and the proportion of friends (outside of camp) who are girls, might make the intervention more effective, insofar as boys with higher exposure could better relate to the persuasive appeal in the intervention condition. Conversely, higher ages could be associated with lower malleability of beliefs regarding girls' STEM ability, reducing the effect of the intervention. We tested whether female family members in STEM, proportion of friends who are girls, and age moderated the condition effect.

Unexpectedly, number of female family members in STEM was not linked to boys' perceptions of girls' STEM ability, nor did it moderate the effect of the intervention. Having a higher proportion of female friends was generally associated with more positive perceptions, but also did not moderate the effect of the intervention.

Age moderated intervention condition effects (see Figure 3), $p = .019$. Condition effects were minimal among older boys (+1 *SD,* point estimate just over 13 years old; $t < 1$), but clearly present among younger boys (−1 *SD*, point estimate just under 11 years old), $b = 0.25$, $t(617.73) = 3.61$, $p < .001$. Testing simple slopes of age found more negative beliefs about girls' STEM ability among younger (vs. older) boys in the control condition, $b = 0.14$, $t(577.64) = 2.31$, $p = .021$, but not the intervention condition ($p = .469$). These results point to the value of early interventions.

Female peers' friendships with male participants

Finally, to address concerns regarding potential experimental demand (rather than authentic attitude change), we turned to data from these boys' female peers: girls' friendship nominations of the male participants. These sociometric data provide an initial test of whether boys' perceptions of girls' STEM ability are reflected in their social relationships with their female peers. Logically, if boys were simply repeating claims they heard from staff (without believing them), there would be no reason to expect boys' ratings of girls' STEM ability to predict whether girls saw these boys as friends.

Boys' positive ratings of girls' STEM ability predicted more of their female peers seeing these boys as friends ($b = 0.02$, Wald $\chi^2 = 5.69$, $p = .017$; see the Supplement for analysis details and robustness checks). Despite condition differences in perceptions of girls' STEM ability, condition did not directly affect friendship nominations ($b = -0.002$, Wald $\chi^2 = 0.04$, $p = .833$).

TABLE 4 Moderation models of boys' perceptions of girls' STEM ability.

	Potential moderator					
	Female family in STEM		Proportion female friends		Age	
Predictor	*b*	*t*	*b*	*t*	*b*	*t*
Condition[a]	0.13	**2.58***	0.12	**2.37***	0.13	**2.80****
Moderator	−0.13	−1.67†	−0.21	−3.48***	0.05	0.99
Condition × Moderator	−0.10	**−1.32**	0.02	**0.30**	−0.09	**−2.36***
Year	0.38	3.25**	0.36	3.26**	0.17	1.92†
Site (*F*)	4.30*		3.30*		4.35*	
Condition (*d*)	0.22		0.20		0.22	

Note: Boldface indicates key condition effect (*df*s = 572.1–645.7) and tests of moderation (*df*s = 570.1–643.0). Site is a three-level categorical predictor, so its *F* ratio is reported.

[a]Control = −1, Intervention = 1.

†$p < .10$.

*$p < .05$; **$p < .01$; ***$p < .001$.

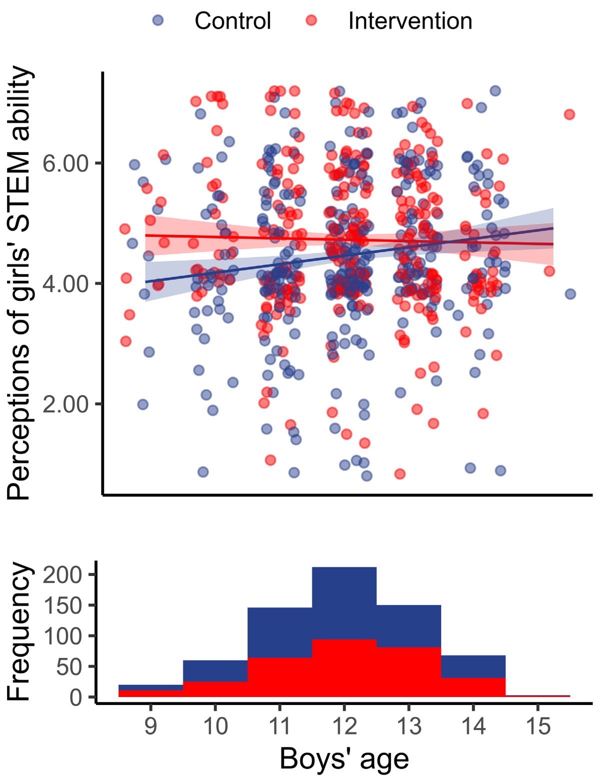

FIGURE 3 Boys' perceptions of girls' STEM ability by condition and age. *Note*. The upper panel presents raw data, jittered to avoid overplotting. The lower panel depicts boys' age distribution by condition.

If experimental demand (or indeed, even reactance) had led some boys in the intervention condition to artificially misreport their perceptions of girls' STEM ability, this additional noise would have presumably attenuated the relation between boys' perceptions of girls' STEM ability and girls' friendship nominations. However, the association between boys' perceptions of girls' STEM ability and girls' friendship nominations did not vary by condition, ($b = 0.001$, Wald $\chi^2 = 0.04$, $p = .842$). These results suggest that boys' appreciation of girls' STEM ability may foster cross-gender friendships.

DISCUSSION

We found support for our core hypothesis that our intervention could change boys' perceptions of girls' STEM ability: Boys' awareness of girls' ability in STEM was higher in the intervention (vs. control) condition. This intervention specifically improved boys' perceptions of girls' STEM ability, beyond their perceptions of boys' STEM ability or girls' ability in other domains. Additionally, the intervention effect on boys' perceptions of girls' STEM ability remained robust across individual differences in their own sense of fit in STEM (current or future), proportion of female friends, and number of female family members in STEM. In addition, sociometric data on girls' friendships with our male participants demonstrate a link from boys having more positive perceptions of girls' STEM ability to their female peers being more likely to name them as best friends or friends. These results advance the literature by demonstrating that a value affirmation followed by a persuasive appeal can meaningfully shift boys' perceptions of girls' STEM ability. Moreover, we demonstrate that girls may be responding positively to boys' perceptions of girls' STEM ability: boys with less stereotypical beliefs were more likely to be seen as friends by their female peers.

The intervention effect on boys' perceptions of girls' STEM ability was stronger for younger boys; boys in late childhood (under 11) were more persuaded by the message that girls possess latent STEM ability than boys in early adolescence. This finding aligns with theories from the developmental literature postulating that late childhood is characterized by a unique combination of cognitive flexibility and limited stereotype exposure (Gonzalez et al., 2017; Steele et al., 2018). Indeed, evidence from this research area shows that as children age, attitudes become more resistant to change (Krosnick & Alwin, 1989) and cultural exposure to gender stereotypes increases (Master, 2021). From an applied perspective, this prior work, combined with our current findings, suggests that late childhood might be an optimal developmental period for persuasion-based bias reduction interventions. Further work with seventh graders (aged approximately 12–13 years) also demonstrates the effectiveness of a minimalist value affirmation paradigm at reducing identity threat (Cohen et al., 2006), reinforcing the potential utility of a value affirmation before delivering potentially identity-threatening information to youth. For those in early adolescence (vs. late childhood), additional work is needed to determine how to best strengthen the effect of the intervention. For example, repetition and reinforcement may more effectively persuade adolescent or older populations. Alternatively, leveraging norm interventions that emphasize their male peers who have more positive perceptions of girls' STEM ability might be an effective future approach.

Constraints on generalizability

Notably, the intervention effect lasted for at least the duration of this multi-day camp (as well as immediately following the conversation; see Supplement). Future work should test how long the intervention effect persists, and whether repeated interventions are needed to sustain lasting change to stereotypic perceptions. Also, although this experiment demonstrates a robust intervention effect using a practical method, we did not isolate psychological mechanisms. Several best-practice persuasive techniques were employed to shift boys' perceptions of girls' STEM ability (e.g., value affirmation, information provided by an expert, male STEM role model, and reflection on a female peer's ability). Additional work should assess which aspects of this intervention are most essential or could be conducted more efficiently (e.g., Zoom conversations and video-watching in groups). Furthermore, identifying behavioral outcomes of the intervention—like choosing to work with female peers on STEM projects—is a critical next step. Despite these caveats, the results demonstrate the feasibility of positively shifting boy's perceptions of girls' STEM ability through a notably "light touch" persuasive intervention.

CONCLUSIONS

The present work demonstrates that a persuasive intervention can change the gender perceptions held by boys, particularly those in late childhood, in ways that move us closer to creating more inclusive early STEM environments. These findings are nicely situated in a growing literature showing that interpersonal climates affect women's experiences in STEM. For example, men's sexist attitudes and gender stereotypes are associated with decreased STEM test performance (Logel et al., 2009) and reduced social inclusion of women (Cyr et al., 2021), which, in turn, predict women's reduced STEM workplace engagement. The present research critically extends earlier in development: intervening early to change boys' perceptions of girls' STEM ability. In demonstrating a method for changing gendered perceptions, these findings raise the possibility of fostering spaces where girls and women are less burdened by gender bias, more welcomed and supported by their male peers, and freer to showcase their STEM talents.

AUTHOR CONTRIBUTIONS

ENC, HBB, CL, TCD, RAK, SLR, AL, CBL, CT, ALF, MZ, SSF, MW, TS, SCW, and SJS designed research; ENC, HBB, TCD, RAK, WTH, PS, ODS, AL, TB, and HN performed research; ENC, KMK, HBB, and RAK analyzed data; ENC, KMK, HBB, CL, JRS, and SJS wrote the paper; all authors approved the submission.

ACKNOWLEDGMENTS

We thank Brian Mulvany, Brittany Dennett, Claire Samii, Craig Bonamis, Ehsaan Elhagehassan, Grace Denney, Harleen Gill, Jacob Pavicic, Jeevanjot Sethi, Jessie Shen, Jo Hernanto, Jonathan Mendel, Kavana Ramesh, Kirsten Fraser, Kirsten Suhner, Nicholas Rahming, Rachel Wang, Seth Mahon, William Tyler Hartwig, Yingchi Guo, Yingfan (Viola) Zhang, and Zane Zheng for their research assistance. We also thank organizational liaisons Alicia Ward, Caity Dyck, Emily Ritz, Jakob Manning, Jess Crawford-Brown, Leanne Predote, Soundous Ettayebi, and Virginia Hall.

FUNDING INFORMATION

This research was supported by a Partnership Grant (#895-2017-1025) from the Social Sciences and Humanities Research Council of Canada, as well as the President's Postdoctoral Scholars Program at The Ohio State University, the International Work Learn Award at the University of British Columbia, the Faculty of Arts and Social Sciences at Simon Fraser University, the Faculty of Arts and Provost at the University of Waterloo, and the Faculties of Science and Applied Science at the University of British Columbia.

OPEN SCIENCE

Our materials (and semi-structured intervention details) are provided in the Supplement. Although this study was not preregistered, its experimental design was reviewed by an SSHRC committee prior to funding. The materials are publicly accessible at: osf.io/xk4ga/?view_only=8a9786a53d2c471d9ef-3f9467a3f78cc.

DATA AVAILABILITY STATEMENT

The data and syntax necessary to reproduce the analyses presented here are publicly accessible at: https://osf.io/mt25q/?view_only=e820d1c59dea4dffa868c5de057c196d.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Cyr, E. N., Kroeper, K. M., Bergsieker, H. B., Dennehy, T. C., Logel, C., Steele, J. R., Knasel, R. A., Hartwig, W. T., Shum, P., Reeves, S. L., Dys-Steenbergen, O., Litt, A., Lok, C. B., Ballinger, T., Nam, H., Tse, C., Forest, A. L., Zanna, M., Staub-French, S. … Spencer, S. J. (2024). Girls are good at STEM: Opening minds and providing evidence reduces boys' stereotyping of girls' STEM ability. *Child Development*, *95*, 636–647. https://doi.org/10.1111/cdev.14007