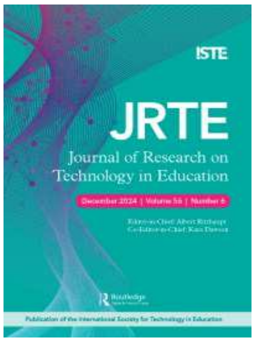

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Causes and consequences of stereotypes: interest stereotypes reduce adolescent girls' motivation to enroll in computer science classes

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ABSTRACT

Motivating girls to enroll in computer science (CS) courses is critically important. Stereotypes that girls are less interested than boys in CS may deter girls. Three preregistered experimental studies ($N = 1{,}053$) examined causal links between gender-interest stereotypes and middle school students' CS motivation. Experiment 1 showed that stereotypes reduced girls' motivation to enroll, mediated by a lower sense of belonging. Experiment 2 showed that underrepresentation is a cue to stereotypes. Experiment 3 demonstrated that providing information about other girls' interest countered stereotypes and promoted motivation. Directly addressing stereotypes may be instrumental in promoting equity for all in CS.

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Motivating girls and young women to enroll in introductory computer science (CS) courses is critically important. Girls represent only 29% of Advanced Placement (AP) CS test-takers and earn only 19% of bachelor's degrees in CS (National Science Foundation, 2019; Code.org Advocacy Coalition et al., 2020). Although women's underrepresentation in CS is a complex problem, psychological factors play a large role in deterring girls from introductory courses (Cheryan et al., 2015). Much research has documented that negative stereotypes about women and girls contribute to gender disparities in STEM, that is, science, technology, engineering, and mathematics (Cvencek et al., 2011; Master et al., 2021a; Spencer et al., 2016). Negative stereotypes affect motivation to pursue CS by reducing women's and girls' sense of belonging and perceptions that they can succeed. When adolescent girls feel that they do not belong in CS classes, they are less interested than boys are in enrolling (Cheryan et al., 2015; Master et al., 2016).

Girls' perceptions of CS often act as barriers that prevent them from selecting opportunities that would promote their motivation for CS. Recent research has identified an understudied type of stereotype that has a particularly large impact on girls' motivation in CS: stereotypes about *interest* in CS (Master, 2021; Master & Meltzoff, 2020). The pervasive societal stereotype that women and girls are less interested in CS, compared to men and boys, can reduce girls' sense of belonging and motivation in CS (Master et al., 2021a). Here we examine cues to these interest stereotypes and their causal consequences for adolescent girls' motivation and academic choices (Figure 1), with the goal of increasing equity for all in CS education.

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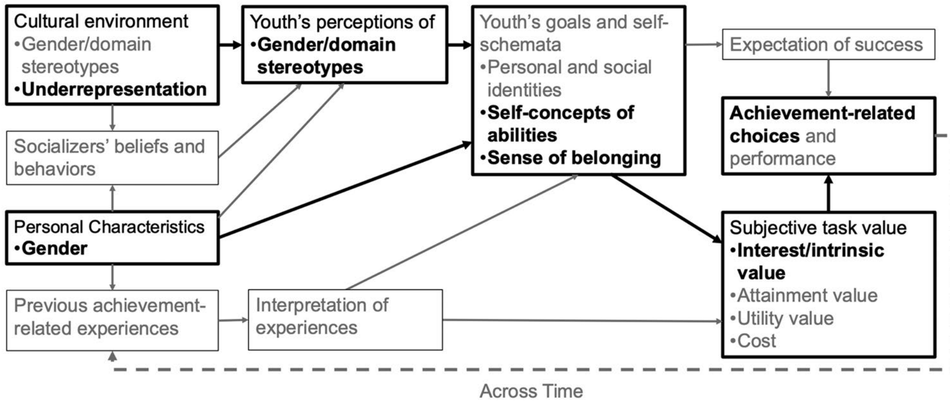

Figure 1. Theoretical Model.

Note. Situated expectancy-value theory is a theoretical framework that explains how stereotypes impact students' interest and choices through self-schemata including ability self-concepts and sense of belonging, with past experiences and outcomes feeding into current and future beliefs and choices (figure adapted from Eccles & Wigfield, 2020). The key variables and pathways examined in the present experiments are shown in black, and other parts of the broader theoretical framework are shown in gray. The dashed line indicates cyclical processes recurring across time. Underrepresentation is a cue within the cultural environment that can reinforce gender-interest stereotypes that girls are less interested in computer science (CS) than boys. Gender-interest stereotypes can negatively impact girls' beliefs about whether they will succeed and belong in CS, which makes them less interested in pursuing CS, which makes them less likely to enroll in introductory CS courses. The present findings demonstrate that when stereotypes are counteracted through experimental manipulation (Experiment 3), girls may be more likely to believe they would succeed and belong in CS, with increased interest in CS, and thus more motivated to enroll in CS courses.

Gender gaps in motivation for computer science

Evidence suggests that the most likely explanations for women's underrepresentation in CS involve gender differences in preferences and choices, rather than abilities and performance (Ceci & Williams, 2010; Dasgupta & Stout, 2014; Riegle-Crumb et al., 2012). Notably, motivation in CS is malleable and can be shaped by environmental factors such as coding experience, teachers, peers, and perceptions of CS (Cheryan, Meltzoff, et al., 2011; Cheryan et al., 2013; Master et al., 2014, 2016, 2017). We use situated expectancy-value theory as a theoretical framework (Eccles & Wigfield, 2020; Master & Meltzoff, 2020). This theory was developed specifically to provide insights into women's underrepresentation in STEM fields such as CS (Eccles & Wigfield, 2024).

Adolescents' stereotypes are shaped by the cultural surroundings in which they are situated, as well as their personal characteristics such as gender (Cvencek et al., 2024). Many cues in the social environment, such as cues of underrepresentation or the beliefs of parents and teachers, may feed into adolescents' stereotypes. Those stereotypes in turn can shape their "self-schemata" (also called "academic self-perceptions"; Banchefsky et al., 2019), including ability self-concepts and sense of belonging. In turn, those self-schemata can affect expectations of success and subjective task values, including interest (sometimes called "intrinsic value"), which then affect academic choices and outcomes. Importantly, this theoretical model emphasizes that these processes are not linear. Students' past experiences and choices can influence their current and future self-perceptions and interests, with feedback and feedforward loops. Much research has used situated expectancy-value theory to examine causes of women's underrepresentation in STEM fields (Eccles & Wigfield, 2024). Most of this research has focused on the motivational variables in the right-hand side of Figure 1, including self-schemata, expectations of success, and subjective task values (Eccles & Wigfield, 2020). The current experiments were designed to examine how these motivational variables are causally influenced by adolescents' stereotypes, providing novel data to support the "situated," broader portion of this theoretical model. In the following, we review research on three key aspects of motivation within this framework: sense of belonging, ability self-concepts, and interest.

A "sense of belonging" is essential for the motivation of women and students of color in STEM fields such as CS. Gender gaps in sense of belonging in CS begin to emerge late in elementary school and become significant during middle school (Master et al., 2021b). Although not traditionally incorporated into expectancy-value theory, sense of belonging represents a self-schemata or academic self-perception that reflects how students see themselves in connection to an academic subject (Banchefsky et al., 2019; Linnenbrink-Garcia et al., 2018; Master & Meltzoff, 2020). In this case, belonging represents individuals' sense of fit within an academic subject. Pervasive negative stereotypes and common social and environmental cues can signal to members of some groups that they do not belong, which reduces their motivation to pursue these fields (Good et al., 2012; Master et al., 2016; Walton & Cohen, 2007). The ongoing underrepresentation of women can serve as a cue for girls and young women that they will not belong in CS (Cheng et al., 2020; Cowgill et al., 2021). For example, one previous study showed college women a video about a STEM summer program that showed either an unbalanced ratio of men to women or a gender-balanced video (Murphy et al., 2007). Young women who viewed the unbalanced video felt a lower sense of belonging and less desire to participate in the program, compared to women who viewed the gender-balanced video (Murphy et al., 2007). However, to our knowledge, this study has not been replicated among children or adolescents. Moreover, relatively few studies have examined girls' sense of belonging in CS education. A systematic review of belonging in K–12 STEM education found 50 empirical quantitative studies, and only 9 of those studies specifically involved CS (Master et al., 2024).

Ability self-concepts are another academic self-perception and represent a key motivational outcome for girls in STEM. These refer to students' perceptions of their ability in an academic domain, related to their expectations for success on tasks in that domain (Eccles & Wigfield, 2020). Gender gaps in ability self-concepts in CS begin to emerge late in elementary school and become significant in middle school (Master et al., 2021b). When gender stereotypes are salient (as is common in STEM fields), stereotypes can affect students' ability self-concepts (Cvencek et al., 2015; Martinot & Désert, 2007), with higher ability self-concepts for boys and lower for girls. These self-concepts play an important role in students' STEM motivation and academic outcomes (Jansen et al., 2015; Simpkins et al., 2006). Previous research indicates that adolescent boys have higher ability self-concepts related to computers and CS compared to girls (Tellhed et al., 2017), and these self-concepts predict interest and intentions to pursue these careers (Sáinz & Eccles, 2012). Gender stereotypes about CS may make girls feel that they do not have what it takes to succeed in this field, thereby reducing their motivation to pursue CS.

When students perceive that they will not belong or be successful in CS, they are less interested in pursuing this field. Interest is defined as "the state of engaging or predisposition to reengage" over time (Hidi & Renninger, 2006, p. 112). Gender differences in interest in CS emerge around late elementary or middle school (Master et al., 2021b). Understanding the factors that explain girls' lower interest is crucial to mitigating current gender disparities in CS (Ceci et al., 2014). Research suggests that there are two main phases of interest development: situational interest (immediate and spontaneous engagement in a topic), and individual interest (a relatively stable, dispositional interest in a particular domain; Hidi & Renninger, 2006). Within situated expectancy-value theory, interest represents one of several subjective task values that directly affect academic choices like enrollment. Enrollment interest is similar to situational interest, because cues in the current environment (such as decorations in the classroom) may increase immediate interest in enrolling in a course (Master et al., 2016). Because enrollment interest is a powerful predictor of actual subsequent course enrollment (Eagan et al., 2013), actual course enrollment can help to transform situational interest into well-developed individual interest (Harackiewicz et al., 2008). Creating environmental conditions that trigger situational interest and sway girls to enroll in CS courses is a critical part of the process of developing deep interest in this subject (Hidi & Renninger, 2006). The idea is to "catch" girls' interest in a way that prompts them to enroll in courses, at which point educators can "hold" their interest to retain girls in CS educational pathways.

How stereotypes impact students' motivation

Although most research using situated expectancy-value theory has focused on motivation rather than on the cultural environment or youths' perceptions of stereotypes, previous research has shown the importance of stereotypes for STEM motivation (Master & Meltzoff, 2020). Most of this research has focused on stereotypes about ability, with stereotypes about interest only recently being examined (Master et al., 2021a; Tang et al., 2024). Gender-interest stereotypes are beliefs that one gender group has lower liking or interest in a particular topic than another group has (Master et al., 2021a). Girls may infer, "If others like me don't like CS, then I won't like CS" (Cvencek et al., 2011; Meltzoff, 2013). These perceptions may be even more influential on girls' motivation to pursue CS than their expectations of success (Master et al., 2021a; Master & Meltzoff, 2020). Many young women are academically successful in STEM in school but choose to enter other fields, a motivational pattern that can be summarized as "I can, but I don't want to" (American Association of University Women, 2000).

Several experimental studies that attempted to broaden the stereotypic view about who is interested in STEM have successfully increased young women's motivation, supporting a causal link between stereotypes and motivation (Cheryan, Siy, et al., 2011; Master et al., 2016; Murphy et al., 2007; Stout et al., 2011). This was recently tested in two experiments that experimentally manipulated the information that elementary-school girls heard about two CS activities: one that "girls were much less interested in than boys" (stereotyped activity) and one that "girls and boys were equally interested in" (non-stereotyped). In both experiments, which involved random assignment of children to these experimental interventions, girls were found to be significantly less interested in the stereotyped activity and were significantly less likely to behaviorally choose to do that activity (Master et al., 2021a). The stereotype created a gender gap in motivation that was eliminated when the activity was not stereotyped. This effect was mediated by girls' lower sense of belonging for the stereotyped task—when they believed other girls were less interested in it, they felt that they would not belong with other children doing that task, which led to their lower motivation. In this way, stereotypes create self-fulfilling prophecies: If girls believe that other girls are less interested in CS, they become less interested themselves.

However, to our knowledge, no experimental studies have yet examined whether cues of interest stereotypes might causally reduce *middle-school* girls' interest in CS *classes*. This matters because effects of interest stereotypes may be more powerful for adolescents than children. Adolescents have more advanced cognitive capacities to make inferences from their groups' characteristics to themselves and may be strongly motivated to conform with perceived gender norms (Master, 2021; Patterson & Bigler, 2018; Steinberg & Monahan, 2007). If so, secondary-school CS teachers may benefit from placing additional attention on this type of stereotype, which may be particularly influential on enrollment interest and choices. Past research has often called for role models in STEM to combat negative stereotypes (Happe et al., 2021). However, these STEM role models are typically encouraged to share messages about their success and ability (Boston & Cimpian, 2018). If countering interest stereotypes is more critical for supporting girls' interest than countering ability stereotypes, then these role models may be sharing messages that are less effective. Therefore, the current studies have the potential to improve CS education beyond existing practices by placing greater focus on combating interest stereotypes, rather than on ability stereotypes. Furthermore, countering CS stereotypes may be more challenging in adolescence than in childhood. As students get older, stereotypes may become reinforced in ways that make them difficult to effectively counter (Tang et al., 2024).

When to address gender gaps in computer science interest

The *recruitment* of young women into a variety of STEM fields, including CS, is a fundamental problem in terms of gender equity in these fields, which must be solved prior to efforts to subsequently *retain* women (Miller & Wai, 2015). Thus, it is critically important to focus on recruiting girls to enroll in introductory CS courses. Research points to middle school (early adolescence) as a particularly important stage at which to intervene. Gender gaps in interest, sense of belonging, and self-efficacy in CS are evident by middle school (Master et al., 2021b). Recent cross-sectional survey data from Grades 1–12 showed a significant drop in girls' interest in CS around Grade 7, which created a gender gap in interest in CS (Master et al., 2021b). Students in middle school are learning about academic fields and beginning to choose career paths, making middle school an ideal stage to influence their interest in pursuing CS before they begin to choose high-school elective courses (Maltese & Tai, 2010).

Rationale for this article

This article examines how gender-interest stereotypes impact middle-school girls' motivation to enroll in CS. Experiment 1 examined whether gender-interest stereotypes have *causal consequences* for girls' motivation to enroll in CS classes. This experiment aimed to extend previous studies with young girls to assess whether these stereotypes also have consequences for CS course enrollment for girls in early adolescence. Experiment 2 was designed to examine a potential *cue* that communicates gender-interest stereotypes to students: the numerical underrepresentation of girls in CS classes. When girls represent only 20% of students in an elective course, students may infer that girls have lower interest in that subject compared to boys. Experiment 3 examined whether providing additional counter-stereotypical information about girls' interest in a CS course could reduce the impact of gender-interest stereotypes on girls' motivation in CS.

All three studies used experimental designs in which students rated two computer science courses. Although experimental studies may have less ecological validity compared to field studies or quasi-experimental studies, an experimental design was purposely selected to give precise indications of how stereotypes, underrepresentation, and counter-stereotypical information may have causal impacts on students' enrollment interest in computer science classes. This is analogous to some real-world changes in CS education, when new versions of CS courses are offered with the goal of encouraging greater equity in enrollment, such as the AP CS Principles course (Ganelin & Dee, 2024). This situation also occurs in informal learning settings when students are choosing between afterschool programs or summer camps, and in choosing between higher education courses (Belanger et al., 2017; Kizilcec & Kambhampaty, 2020). We chose to have students compare two CS classes rather than one CS class and one non-CS class because students may vary widely in their interest in non-CS classes, which would prevent us from measuring precisely how the experimental manipulation affected interest in a CS class.

Our experimental design fills a much-needed gap in the CS education literature. A recent review of K–12 CS education studies found that only one out of 76 papers used a design with a randomized control group (McGill & Decker, 2020). Similarly, a review of interventions designed to increase STEM motivation among adolescents found few studies focused on technology (only 6 out of 53), among which most studies used quasi-experimental designs rather than randomized control groups (Rosenzweig & Wigfield, 2016). The current experimental work is needed to lay the foundation for future interventions to broaden participation in CS that can effectively harness causal mechanisms for motivation. Educational programs that are offered to girls are often focused on solutions to improve gender equity without careful attention to the root causes (Happe et al., 2021). The current studies are valuable in bringing greater attention to causes of gender gaps in computing.

Data and preregistrations (including methods, hypotheses, and analysis plans) for all three experiments are available at https://osf.io/syqn3/. Taken together, these three studies provide valuable insights into why and how to address gender-interest stereotypes to promote greater equity for all in CS.

Experiment 1: Consequences of gender-interest stereotypes

The overall goal of Experiment 1 was to provide a test of the causal relation between gender-interest stereotypes and girls' motivation to enroll in CS courses. Previous research showed that gender-interest stereotypes had a negative impact on 8- to 9-year-old girls' motivation for CS activities (Master et al., 2021a). However, it is important to extend this work to students in early adolescence (around age 13 years) and their motivation for CS courses, because these are the students who will soon have opportunities to choose to enroll in CS classes in high school and beyond. The presence of a gender-interest stereotype about CS may lead girls to infer that, like other girls, they would also be less motivated to take a CS course. We hypothesized, however, that if girls receive specific information that other girls were just as interested in boys in the content of the course, they may become more motivated to take that course.

This study experimentally investigated the negative effects of gender-interest stereotypes on girls' motivation and choice of elective courses. Using a within-subjects experimental design, participants rated their motivation for two courses that were identical in all respects except for the experimental manipulation—the association of a gender-interest stereotype with one class or the other (counterbalanced). The use of a controlled, random-assignment experiment allowed for every variable to be held constant except the manipulation of the gender-interest stereotype, to test whether stereotypes can *cause* lower motivation for adolescent girls. Follow-up mediation analyses further examined effects in two ways: first, whether condition effects on enrollment interest for girls were mediated by lower sense of belonging and ability self-concepts for the stereotyped class; and second, whether gender differences in enrollment interest in the stereotyped class were mediated by girls' lower sense of belonging and ability self-concepts compared to boys.

Methods

In January 2022, students watched a brief video through Qualtrics survey software in which they learned about two CS courses that their high school would offer next year; see Supplementary Material Section 1.1 for more details. All studies were completed during class time. In one course, girls were reported to be less interested in the course than boys were (stereotyped), and in the other course, girls and boys were reported to be equally interested (nonstereotyped). Students were told that girls and boys performed equally well in both courses. The order of the stereotyped and nonstereotyped courses was counterbalanced across participants; so were the names of the courses ("Introduction to Computer Science" and "Foundations of Computer Science"). These names were selected based on pilot feedback from adolescent students. We used different names for the courses to reinforce the idea that they represented different courses. See Supplementary Material Sections 1.2 and 2 for analyses of order and name effects for all studies. We measured motivation by assessing enrollment interest, sense of belonging, and ability self-concepts on a scale from 1 to 6. Participants also made a behavioral choice as to which class they themselves would choose to take.

Participants

Table 1 gives full demographic information about participants. Participants were 208 eighth-grade students (84 girls, 99 boys; M_{age} = 13.49, $SD = 0.50$) in a school district selected by the Character Lab Research Network (CLRN). See Supplementary Material Section 1.1 for more details about CLRN. CLRN was a network that sought to help researchers conduct research with a diverse population of public middle- and high-school students in the United States. To facilitate research and recruitment, the population of U.S. public schools was divided into strata using k-means cluster analysis (Tipton, 2014). Character Lab then recruited schools and students

Table 1. Demographic Information for Participants in Experiments 1–3.

	Experiment 1 ($N=208$)		Experiment 2 ($N=287$)		Experiment 3 ($N=558$)	
	n	%	*n*	%	*n*	%
Gender						
Girls	84	40.4	125	43.6	249	44.6
Boys	99	47.6	140	48.8	281	50.4
Another	0	0	0	0	14	2.5
Prefer not to say	13	6.3	12	4.2	13	2.3
Missing	12	5.8	10	3.5	1	0.2
Race						
White	127	61.1	210	73.5	349	62.5
Asian/Asian American	43	20.7	33	11.5	94	16.8
Multiracial	13	6.3	15	5.2	30	5.4
Black/African American	12	5.8	12	4.2	47	8.4
Native American/Native Indian	2	1.0	0	0	1	0.2
Missing	11	5.3	17	5.9	37	6.6
Ethnicity (of any race)						
Hispanic/Latine	8	3.8	14	4.9	28	5.0
Free/reduced price lunch	9	4.3	15	5.2	54	9.7

Note. Gender was self-identified. Race, ethnicity, and free/reduced price lunch status were obtained from district records for almost all participants. Hispanic/Latine students could be from any racial group.

within each of these strata and matched researchers and studies to specific strata. Although our research team requested the opportunity to run all three studies with students at schools in a stratum defined as "large, diverse, urban/suburban school," Character Lab was not able to recruit enough participants from these schools for Experiments 2 and 3, resulting in final samples in which White and Asian students were overrepresented compared to U.S. public schools overall (National Center for Education Statistics, 2024). In accord with our preregistration, students who did not report their gender as girl or boy were excluded from analyses involving gender. Race, ethnicity, and free/reduced price lunch status were obtained from district records. See Supplementary Material Section 1.3 for information about preregistered power analyses for all studies.

Measures

Table 2 lists the full set of items in each scale in Experiments 1–3 and evidence of reliability and validity. All scales showed excellent reliability for both courses in all studies, with Cronbach's $\alpha > .90$. Each participant rated their enrollment interest in both classes. Interest was assessed with three items (e.g., *How interested are you in taking this class?*) on a 1 (*really not*) to 6 (*really*) Likert scale. Sense of belonging for both classes was assessed with three items (e.g., *How much would you feel like you belong in this class?*) on a 1 (*really not*) to 6 (*really*) scale. Ability self-concept was assessed with three items (e.g., *How good would you be at this class?*) on a 1 (*really not*) to 6 (*really*) scale. For the behavioral choice measure, students were also asked, *If you had to choose one computer science class to take next year, which class would you choose?*

Results

Table 3 presents the means, standard deviations, effect sizes, and *p* values for simple effects, and Table 4 gives the correlations, separated by participant gender and stereotype condition.

Enrollment interest

As predicted in our preregistration, gender-interest stereotypes reduced enrollment interest for girls, but not boys (Figure 2A). A 2 × 2 (participant gender × stereotype condition [stereotyped vs. nonstereotyped]) mixed-model analysis of variance (ANOVA) revealed a significant interaction

Table 2. Complete List of Measures.

Scale			Reliability (Cronbach's α)		
			Exp. 1	Exp. 2	Exp. 3
Enrollment interest	Items	Source and prior validity/reliability			
	How interested are you in taking this class?	Adapted from two-item scale in Master et al. (2021a)	.96—97	.97	.96
	How much do you want to take this class?	Prior reliability: *rs* = .70–.85			
	How much would you enjoy taking this class?	Prior predictive validity: correlated with girls' CS belonging, *rs* = .21–.40, *ps* < .001			
Sense of belonging					
	How much would you feel like you belong in this class?	Master et al. (2021a)	.95	.93–.94	.93
	How comfortable would you be in this class?	Prior reliability with 8- to 10-year-old children: αs = .65–.76			
	How similar would you be to other kids taking this class?	Prior predictive validity: predicted girls' interest in CS activity, *B* = .79, *p* < .001			
Ability self-concept					
	How good would you be at this class?	Sriutaisuk (2022)	.95–.96	.94–.95	.93–.94
	How well would you understand the material in this class?	Prior reliability: α = .91			
	How well would you expect to do in this class?	Prior predictive validity: correlated with girls' interest, *rs* = .70–.78, *p* < .001			
Behavioral choice					
	If you had to choose one computer science class to take next year, which class would you choose?	Master et al. (2016) Prior concurrent validity: gender difference based on stereotype manipulation, *p* = .012	N/A	N/A	N/A
Gender-interest stereotypes					
How interested in taking this class would most girls at your school be?		Adapted from Sriutaisuk (2022)	N/A	.92–.93	.91–.93
How interested in taking this class would most boys at your school be?		Prior reliability: αs = .94–.95			
How much would most girls at your school like this class?		Prior predictive validity: ingroup stereotypes correlated with personal interest, *rs* = .39–.42, *ps* < .011			
How much would most boys at your school like this class?					
How much would most girls at your school enjoy this class?					
How much would most boys at your school enjoy this class?					

Note. All items were measured on a 1 (*really not*) to 6 (*really*) Likert scale, except for behavioral choice. Exp. = Experiment.

between gender and stereotype condition on enrollment interest, $F(1, 179) = 5.56$, $p = .019$, $\eta_p^2 = .03$. Looking at the simple effects, as predicted, girls were significantly less interested in the stereotyped class than in the nonstereotyped class, but there was no condition effect for boys. Although we predicted a gender difference for the stereotyped but not nonstereotyped class, the gender difference in enrollment interest was significant in both conditions but smaller for the nonstereotyped class.

Sense of belonging

As predicted, gender-interest stereotypes reduced sense of belonging for girls, but not boys. A 2 × 2 (participant gender × stereotype condition) mixed-model ANOVA revealed a significant interaction between gender and stereotype condition, $F(1, 177) = 17.02$, $p < .001$, $\eta_p^2 = .09$. As predicted, girls felt a significantly lower sense of belonging in the stereotyped class than in the nonstereotyped class, but there was no condition effect for boys. Although we predicted

Table 3. Descriptive Statistics and Effect Sizes for Experiments 1–3.

	Girls					Boys					Gender diff.		
	M	*SD*	*F*	*p*	d_z	*M*	*SD*	*F*	*p*	d_z	*F*	*p*	*d*
Experiment 1													
Interest													
Stereotyped	2.43	1.40	14.25	<.001	0.45	3.64	1.48	0.39	.54	0.06	31.42	<.001	0.84
Nonstereotyped	2.71	1.48				3.68	1.39				20.50	<.001	0.67
Belonging													
Stereotyped	3.02	1.47	33.11	<.001	0.66	4.14	1.44	0.03	.87	0.02	26.24	<.001	0.77
Nonstereotyped	3.55	1.47				4.15	1.33				8.26	.005	0.43
Self-concept													
Stereotyped	3.54	1.57	22.34	<.001	0.44	4.20	1.29	1.17	.28	0.13	9.44	.002	0.46
Nonstereotyped	3.92	1.57				4.27	1.28				2.86	.093	0.25
Behavioral choice													
Stereotyped	21%					51%							
Nonstereotyped	79%					49%							
Experiment 2													
Gender-interest ster.													
Unequal	1.13	1.09	21.20	<.001	0.47	1.42	1.40	69.81	<.001	0.64	3.60	.059	0.24
Equal	0.68	0.94				0.65	1.09				0.03	.86	0.02
Interest													
Unequal	2.53	1.36	12.63	<.001	0.36	3.40	1.59	1.12	.29	0.08	22.34	<.001	0.59
Equal	2.76	1.48				3.47	1.57				13.93	<.001	0.46
Belonging													
Unequal	3.03	1.32	100.98	<.001	0.78	4.04	1.38	1.34	.25	0.12	36.35	<.001	0.75
Equal	3.85	1.41				3.95	1.38				0.36	.55	0.07
Self-concept													
Unequal	3.69	1.36	6.72	.01	0.21	4.18	1.31	0.15	.70	0.04	8.82	.003	1.03
Equal	3.84	1.42				4.16	1.36				3.36	.068	0.23
Behavioral choice													
Unequal	31%					39%							
Equal	69%					61%							
Experiment 3													
Gender-interest ster.													
No information	0.85	1.12	0.64	.42	0.05	0.83	1.26	0.00	.97	0.002	0.01	.91	0.01
Countered	0.79	1.09				0.84	1.13				0.19	.67	0.04
Raw ster. about girls													
No information	3.31	1.17	14.93	<.001	0.22	3.34	1.21	0.04	.84	0.002	0.10	.75	0.03
Countered	3.51	1.14				3.35	1.19				2.24	.14	0.14
Raw ster. about boys													
No information	4.14	1.07	10.25	.001	0.21	4.19	1.13	0.00	.98	0.005	0.22	.64	0.02
Countered	4.29	1.01				4.19	1.13				1.27	.26	0.11
Interest													
No information	2.69	1.38	6.43	.01	0.15	3.61	1.50	0.07	.79	0.02	50.90	<.001	0.63
Countered	2.80	1.44				3.60	1.49				38.07	<.001	0.55
Belonging													
No information	2.98	1.26	13.22	<.001	0.24	3.76	1.31	1.62	.20	0.08	45.23	<.001	0.60
Countered	3.14	1.25				3.81	1.37				32.82	<.001	0.51
Self-concept													
No information	3.61	1.37	9.57	.002	0.20	4.17	1.32	0.38	.54	0.04	22.17	<.001	0.42
Countered	3.75	1.35				4.20	1.37				13.59	<.001	0.33
Behavioral choice													
No information	37%					40%							
Countered	63%					60%							

Note. Interest, belonging, self-concepts, and Experiment 3 raw stereotype scores were on a scale from 1–6. Gender stereotypes were on a scale from –5 to 5 representing a difference score between participants' ratings of most boys' interest minus ratings of most girls' interest. Behavioral choice indicates the percent of participants within each gender who chose each class. Ster. = stereotypes. Diff. = difference. Effect size d_z represents simple effects of condition within each gender, and effect size *d* represents simple effects of gender within each condition.

Table 4. Correlations for Experiments 1–3.

	1	2	3	4	5	6
Experiment 1						
Stereotyped class						
1. Interest	–	.57***	.54***			
2. Belonging	.73***	–	.61***			
3. Self-concept	.67***	.68***	–			
Non-stereotyped class						
1. Interest	–	.58***	.60***			
2. Belonging	.66***	–	.67***			
3. Self-concept	.64***	.79***	–			
Experiment 2						
Equal class						
1. Gender stereotypes	–	−0.20*	−0.13	−0.09		
2. Interest	−0.06	–	.39***	.53***		
3. Belonging	.07	.61***	–	.65***		
4. Self-concept	−0.11	.73***	.71***	–		
Unequal class						
1. Gender stereotypes	–	−0.14	−0.06	.05		
2. Interest	.06	–	.44***	.47***		
3. Belonging	.11	.61***	–	.58***		
4. Self-concept	.06	.67***	.62***	–		
Experiment 3						
Countered class						
1. Gender ster. difference score	–	−0.59***	.42***	−0.25***	−0.20**	−0.14*
2. Raw ster. scores about girls	−0.53***	–	.49***	.50***	.34***	.36***
3. Raw ster. scores about boys	.44***	.53***	–	.30***	.16*	.25***
4. Interest	.06	.44***	.53***	–	.63***	.54***
5. Belonging	.02	.43***	.47***	.62***	–	.59***
6. Self-concept	−0.01	.37***	.37***	.59***	.59***	–
No-information class						
1. Gender ster. difference score	–	−0.57***	.43***	−0.18**	−0.18**	−0.13*
2. Raw ster. scores about girls	−0.58***	–	.50***	.48***	.32***	.35***
3. Raw ster. scores about boys	.49***	.43***	–	.33***	.16*	.24***
4. Interest	.04	.45***	.52***	–	.55***	.52***
5. Belonging	.00	.43***	.45***	.62***	–	.60***
6. Self-concept	.06	.33***	.41***	.64***	.58***	–

Note. Girls (Experiment 1: *ns* = 81–83; Experiment 2: *ns* = 123–124; Experiment 3: *ns* = 234–246) are above the diagonals, and boys (Experiment 1: *ns* = 97 – 98; Experiment 2: *ns* = 139–140; Experiment 3: *ns* = 258 – 271) are below the diagonals. Ster. = stereotypes. ***$p < .001$, **$p < .01$, *$p < .05$.

a gender difference for the stereotyped but not nonstereotyped class, the gender difference in sense of belonging was significant for both conditions but smaller for the nonstereotyped class.

Ability self-concepts

As expected, gender-interest stereotypes reduced ability self-concepts for girls, but not for boys. A 2 × 2 (participant gender × stereotype condition) mixed-model ANOVA revealed a significant interaction between gender and stereotype condition on ability self-concepts, $F(1, 178) = 7.48$, $p = .007$, $\eta_p^2 = .04$. As expected, girls reported significantly lower ability self-concepts for the stereotyped class than for the nonstereotyped class, but there was no condition effect for boys. There was a significant gender difference only for the stereotyped class.

Figure 2. Effects of Stereotypes, Underrepresentation, and Messages that Counter Stereotypes on Motivation to Enroll in Computer Science.

Note. Effects of condition on students' motivation (with girls' motivation in solid green lines and boys' motivation in dotted orange lines) to enroll in CS in Experiment 1 (**A**), comparing a class with gender stereotypes to a class without gender stereotypes; Experiment 2 (**B**), comparing a class with unequal gender representation to a class with equal representation; and Experiment 3 (**C**), comparing two classes with unequal representation, one with no information about stereotypes and one where stereotypes were countered. In all studies, girls' motivation to take a CS class was increased by the experimental manipulation. Error bars are ± S.E. *** $p < .001$, ** $p = .01$.

Behavioral choice

As predicted, girls were significantly more likely to choose the nonstereotyped class (79%) than boys were (49%), $\chi^2(2, N = 183) = 16.46$, $p < .001$. Girls were significantly above chance in choosing the nonstereotyped class, binomial proportion test, $p < .001$, but boys did not differ from chance, $p = .92$.

Mediation analyses

Table 5 presents the detailed results of the mediation analyses. We started by examining the effects of condition for girls using the MEMORE macro in SPSS, and then examined mediators of gender differences in enrollment interest for the stereotyped class using the PROCESS macro in SPSS (Montoya & Hayes, 2017). First, for girls, the relation between stereotype condition and enrollment interest in CS was partially mediated by a lower ability self-concept in computer science (as predicted), conditional indirect effect = −0.08, 95% CI [−0.21, −0.005], but not by sense of belonging (in contrast to our prediction), conditional indirect effect = −0.01, 95% CI [−0.08, 0.06]. Second, as predicted, the gender difference in enrollment interest in the stereotyped class was partially mediated by both sense of belonging, conditional indirect effect = −0.72, 95% CI [−1.03, −0.42], and self-concept, conditional indirect effect = −0.40, 95% CI [−0.67, −0.15].

Discussion

When adolescent girls learned about a CS class in which girls were less interested than boys were, they reported feeling less motivated to enroll, less like they would belong, and less likely to succeed in that course compared to a nonstereotyped course in which girls and boys were equally interested. Boys, however, were unaffected by the gender-interest stereotype. Findings largely supported our preregistered predictions that gender stereotypes are harmful for girls' motivation to take CS classes. Girls were also significantly more likely to choose to take the nonstereotyped class over the stereotyped class. Both sense of belonging and ability self-concepts mediated gender differences in enrollment interest in the stereotyped course: The more that girls expected to feel a lower sense of belonging or lower ability in that course compared to boys, the less interested they were in enrolling in it. Ability self-concepts also helped explain why girls were less interested in the stereotyped course: The less well they expected to do in the stereotyped course, the less interested they were in that course compared to the nonstereotyped course. This was evident even though they did not perceive the stereotyped course as objectively more difficult (see Supplementary Material Sections 1.4 and 2 for more details).

These findings replicate and extend previous findings that gender-interest stereotypes reduced elementary-school girls' interest in CS activities (Master et al., 2021a). The current findings provide evidence of the importance of gender-interest stereotypes for adolescent girls' motivation to enroll in CS classes. The stereotype that girls are less interested than boys are in CS can create self-fulfilling prophecies that perpetuate this pattern by causing girls to expect that they will not belong or succeed in this class, which hinders the development of their interest. They may then sign up for other elective courses that do not have this stereotypical barrier. Mediation analyses suggested that ability self-concepts were particularly important in this process for middle-school girls, which may also reflect a developmental difference compared to elementary-school girls.

Experiment 2: Underrepresentation as a cue to gender-interest stereotypes

Experiment 1 showed that girls' stereotypes that boys are more interested in CS can deter them from choosing to enroll in CS classes. To effectively counteract these stereotypes, educators need a better understanding of the sources of such stereotypes. The goal of Experiment 2 was to learn more about the *cues that communicate* to girls that their gender group is less interested than boys are in CS. Given previous work that linked representation to young

Table 5. Mediation Analyses for Experiments 1–3.

Mediation pathway	Type	Effect	SE	t	p	95% CI Lower	95% CI Upper
Experiment 1							
Girls only, belonging as mediator:							
Ster. cond. → bel. (X → M)	Direct (a)	−0.52	.09	−5.84	<.001	−0.70	−0.34
Bel. → int. (M → Y)	Direct (b)	0.01	.09	0.16	.87	−0.16	0.19
Ster. cond. → bel. → int. (X →M → Y)	Indirect (ab)	−0.01	.04			−0.08	0.06
Ster. cond. → int. (X → Y)	Direct (c′)	−0.28	.08	−3.33	.001	−0.45	−0.11
Ster. cond. → int. (X → Y)	Total (c)	−0.29	.07	−4.09	<.001	−0.43	−0.15
Girls only, self-concept as mediator:							
Ster. cond. → self-con. (X → M)	Direct (a)	−0.37	.09	−4.01	<.001	−0.56	−0.19
Self-con. → int. (M → Y)	Direct (b)	0.22	.08	2.75	.007	0.06	0.37
Ster. cond. → self-con. → int. (X →M → Y)	Indirect (ab)	−0.08	.05			−0.21	−0.005
Ster. cond. → int. (X → Y)	Direct (c′)	−0.20	.07	−2.81	.006	−0.35	−0.06
Ster. cond. → int. (X → Y)	Total (c)	−0.29	.07	−4.09	<.001	−0.43	−0.15
Ster. class only, bel. as mediator							
Gender → bel. (X → M)	Direct (a)	−1.11	.22	−5.14	<.001	−1.54	−0.69
Bel. → int. (M → Y)	Direct (b)	0.65	.06	11.48	<.001	0.54	0.76
Gender → bel. → int. (X →M → Y)	Indirect (ab)	−0.72	.15			−1.03	−0.42
Gender → int. (X → Y)	Direct (c′)	−0.51	.17	−2.92	.004	−0.85	−0.16
Gender → int. (X → Y)	Total (c)	−1.23	.21	−5.73	<.001	−1.65	−0.81
Ster. class only, self-con. as mediator							
Gender → self-con. (X → M)	Direct (a)	−0.65	.21	−3.07	.003	−1.07	−0.23
Self-con. → int. (M → Y)	Direct (b)	0.61	.06	10.03	<.001	−1.18	−0.48
Gender → self-con. → int. (X →M → Y)	Indirect (ab)	−0.40	.13			−0.67	−0.15
Gender → int. (X → Y)	Direct (c′)	−0.83	.18	−4.72	<.001	−1.18	−0.48
Gender → int. (X → Y)	Total (c)	−1.23	.21	−5.73	<.001	−1.65	−0.81
Experiment 2							
Girls only, ster. as mediator:							
Ster. cond. → ster. (X → M)	Direct (a)	−0.45	.09	−5.20	<.001	−0.62	−0.28
Ster. → int. (M → Y)	Direct (b)	−0.15	.06	−2.46	.015	−0.27	−0.03
Ster. cond. → ster. → int. (X →M → Y)	Indirect (ab)	0.07	.03			0.01	0.14
Ster. cond. → int. (X → Y)	Direct (c′)	0.16	.06	2.56	.012	0.04	0.29
Ster. cond. → int. (X → Y)	Total (c)	0.23	.06	3.95	<.001	0.11	0.35
Girls only, belonging as mediator:							
Ster. cond. → bel. (X → M)	Direct (a)	0.82	.09	8.75	<.001	0.64	1.01
Bel. → int. (M → Y)	Direct (b)	0.16	.06	2.85	.005	0.05	0.27
Ster. cond. → bel. → int. (X →M → Y)	Indirect (ab)	0.13	.05			0.04	0.24
Ster. cond. → int. (X → Y)	Direct (c′)	0.10	.07	1.39	.17	−0.04	0.25
Ster. cond. → int. (X → Y)	Total (c)	0.23	.06	3.95	<.001	0.11	0.35
Girls only, self-concept as mediator:							
Ster. cond. → self-con. (X → M)	Direct (a)	0.15	.07	2.35	.02	0.02	0.28
Self-con. → int. (M → Y)	Direct (b)	0.29	.08	3.81	<.001	0.14	0.44
Ster. cond. → self-con. → int. (X →M → Y)	Indirect (ab)	0.04	.03			0.005	0.11
Ster. cond. → int. (X → Y)	Direct (c′)	0.19	.06	3.33	.001	0.08	0.30
Ster. cond. → int. (X → Y)	Total (c)	0.23	.06	3.95	<.001	0.11	0.35
Unequal class only, ster. as mediator							
Gender → ster. (X → M)	Direct (a)	−0.30	.16	−1.92	.06	−0.61	0.01
Ster. → int. (M → Y)	Direct (b)	−0.02	.07	−0.23	.82	−0.16	0.13
Gender → ster. → int. (X →M → Y)	Indirect (ab)	0.01	.03			−0.04	0.06

(*Continued*)

Table 5. Continued.

Mediation pathway	Type	Effect	*SE*	*t*	*p*	95% CI Lower	95% CI Upper
Gender → int. (X → Y)	Direct (c′)	−0.88	.19	−4.71	<.001	−1.24	−0.51
Gender → int. (X → Y)	Total (c)	−0.87	.18	−4.73	<.001	−1.23	−0.51
Unequal class only, bel. as mediator							
Gender → bel. (X → M)	Direct (a)	−0.99	.17	−5.93	<.001	−1.32	−0.66
Bel. → int. (M → Y)	Direct (b)	0.59	.06	10.26	<.001	0.48	0.71
Gender → bel. → int. (X →M → Y)	Indirect (ab)	−0.59	.11			−0.82	−0.38
Gender → int. (X → Y)	Direct (c′)	−0.30	.17	−1.82	.07	−0.63	0.02
Gender → int. (X → Y)	Total (c)	−0.89	.18	−4.83	<.001	−1.25	−0.53
Unequal class only, self-con. as mediator							
Gender → self-con. (X → M)	Direct (a)	−0.47	.16	−2.85	.005	−0.79	−0.14
Self-con. → int. (M → Y)	Direct (b)	0.65	.06	11.39	<.001	0.54	0.76
Gender → self-con. → int. (X →M → Y)	Indirect (ab)	−0.30	.10			−0.51	−0.10
Gender → int. (X → Y)	Direct (c′)	−0.59	.15	−3.83	<.001	−0.89	−0.28
Gender → int. (X → Y)	Total (c)	−0.89	.18	−4.83	<.001	−1.25	−0.53
Experiment 3							
Girls only, belonging as mediator:							
Info. cond. → bel. (X → M)	Direct (a)	0.16	.04	3.72	<.001	0.07	0.24
Bel. → int. (M → Y)	Direct (b)	0.46	.06	7.32	<.001	0.33	0.58
Info. cond. → bel. → int. (X →M → Y)	Indirect (ab)	0.07	.03			0.03	0.13
Info. cond. → int. (X → Y)	Direct (c′)	0.03	.04	0.77	.44	−0.05	0.11
Info. cond. → int. (X → Y)	Total (c)	0.10	.04	2.30	.02	0.01	0.19
Girls only, self-concept as mediator:							
Info. cond. → self-con. (X → M)	Direct (a)	0.15	.05	3.02	.003	0.05	0.24
Self-con. → int. (M → Y)	Direct (b)	0.30	.06	5.27	<.001	0.19	0.41
Info. cond. → self-con. → int. (X →M → Y)	Indirect (ab)	0.04	.02			0.01	0.09
Info. cond. → int. (X → Y)	Direct (c′)	0.06	.04	1.30	.19	−0.03	0.14
Info. cond. → int. (X → Y)	Total (c)	0.10	.04	2.24	.03	0.01	0.19
No info. class only, bel. as mediator							
Gender → bel. (X → M)	Direct (a)	−0.79	.11	−6.92	<.001	−1.02	−0.57
Bel. → int. (M → Y)	Direct (b)	0.66	.04	16.22	<.001	0.58	0.74
Gender → bel. → int. (X →M → Y)	Indirect (ab)	−0.53	.08			−0.70	−0.36
Gender → int. (X → Y)	Direct (c′)	−0.43	.11	−3.91	<.001	−0.64	−0.21
Gender → int. (X → Y)	Total (c)	−0.95	.13	−7.39	<.001	−1.21	−0.70
No info. class only, self-con. as mediator							
Gender → self-con. (X → M)	Direct (a)	−0.58	.12	−4.87	<.001	−0.82	−0.35
Self-con. → int. (M → Y)	Direct (b)	0.63	.04	15.97	<.001	0.55	0.71
Gender → self-con. → int. (X →M → Y)	Indirect (ab)	−0.37	.07			−0.52	−0.22
Gender → int. (X → Y)	Direct (c′)	−0.57	.11	−5.28	<.001	−0.78	−0.36
Gender → int. (X → Y)	Total (c)	−0.94	.13	−7.23	<.001	−1.19	−0.68

Note. CI = confidence interval. Ster. cond. = stereotype condition. Ster. class = Stereotyped class. Bel. = belonging. Self-con. = Ability self-concept. Int. = enrollment interest. Info. cond. = information condition. For girls, two-condition within-participant mediations were conducted using the MEMORE macro in SPSS with 5000 bootstrap samples. Effects of condition (X) on the mediators (M) represent M_{diff}, and effects of condition on the outcome (Y) represent Y_{diff}. For the stereotyped/unequal/no information classes, between-subjects mediations were conducted using the PROCESS macro in SPSS. Both MEMORE and PROCESS produce unstandardized regression coefficients.

women's belonging in STEM (Murphy et al., 2007), one cue may be the gender representation within courses. Indeed, when we interviewed middle-school girls and asked whether they thought boys were more interested than girls in computer science, several of them gave us this rationale. For example, one girl in Grade 8 told us, "I think boys are more interested in computer science than girls at my school. Because of the percentage in our computer science class, there are six girls in my computer science class and about 20 to 25 boys." Experiment 2 sought to test for a causal link between gender representation and stereotypes about courses, to help develop future evidence-based interventions that can counteract stereotypes when girls are underrepresented. If girls see that only about 20% of CS students are girls, they may (quite logically) assume that girls are less interested than boys are in CS. By evaluating whether representation influences stereotypes, Experiment 2 laid the groundwork for Experiment 3, which was conducted to gather information about the design of a practical intervention (i.e., the efficacy of procedures to counteract these stereotypes through explicit statements about girls' enjoyment of CS courses).

Methods

In a Qualtrics survey in January 2022, participants rated their motivation in two CS courses that were identical in all respects except for the experimental manipulation—that girls are underrepresented compared to boys ("unequal representation") or that girls and boys are equally represented ("equal representation"). We used an unequal representation with 20% girls and 80% boys to match the representation typically seen in CS courses and college majors (National Science Foundation, 2019; Code.org Advocacy Coalition et al., 2020). The presentation order of the unequal and equal courses was again counterbalanced across participants, as well as the same names of the courses. We measured participants' stereotypes about how much most girls and boys would enjoy each course and their motivation.

Participants

Participants were 287 eighth-grade students (125 girls, 140 boys; M_{age} = 13.51, $SD = 0.51$) in two mostly White, high-socioeconomic-status, suburban schools in the same school district as Experiment 1 selected by the Character Lab Research Network; see Table 1 for more demographic information. In accord with our preregistration, students who did not report their gender as girl or boy were excluded from analyses involving gender.

Measures

Gender-interest stereotypes

Stereotypes about girls' and boys' interest in courses with equal and unequal representation were measured with three items each (e.g,. *How interested in taking this class would most [girls/boys] at your school be?*) on a 1 (*really not*) to 6 (*really*) Likert scale. Reliability was high for ratings of other girls' and boys' interest in the equal and unequal courses (Table 2). As designed in our preregistration, difference scores were created to measure stereotypes for each class by subtracting average ratings of most girls' interest from average ratings of most boys' interest. Positive values for the difference score represent the belief that boys would be more interested in that class than girls would be, while negative values represent the belief that girls would be more interested than boys would be.

Enrollment interest, sense of belonging, and ability self-concept

Enrollment interest, sense of belonging, and ability self-concept in each class were assessed with the same three items as in Experiment 1.

Behavioral choice

Behavioral choice was assessed with the same item as in Experiment 1.

Results

Tables 3 and 4 display the effect sizes and correlations.

Gender-interest stereotypes

As predicted in the preregistration, unequal representation served as a strong cue to stereotypes. Both girls and boys reported stereotypes that more strongly favored boys for the unequal course compared to the equal course. In accord with the preregistration, a 2 × 2 (participant gender × representation condition [unequal and equal]) mixed-model ANOVA revealed a significant main effect of representation condition, $F(1, 262) = 82.43$, $p < .001$, $\eta_p^2 = .24$. This was qualified by a significant interaction, $F(1, 179) = 5.63$, $p = .018$, $\eta_p^2 = .02$. Both girls and boys reported stronger stereotypes favoring boys for the unequal class compared to the equal class. There was no gender difference in participants' stereotypes about the equal class, but boys' stereotypes about the unequal class were marginally stronger than girls' stereotypes.

Enrollment interest

Unequal representation reduced enrollment interest for girls, but not boys, though the predicted significant interaction was marginally significant; see Figure 2B. A 2 × 2 (participant gender × representation condition) mixed-model ANOVA revealed a marginally significant interaction between gender and representation condition on interest, $F(1, 261) = 3.49$, $p = .063$, $\eta_p^2 = .013$. As predicted, girls were significantly less interested in the unequal class than the equal class, but there was no condition effect for boys. Although we predicted a gender difference for the unequal but not for the equal class, the gender difference in enrollment interest was significant in both conditions but smaller for the equal class.

Sense of belonging

Unequal representation reduced sense of belonging for girls, but not for boys. As predicted, a 2 × 2 (participant gender × representation condition) mixed-model ANOVA revealed a significant interaction between gender and representation condition on belonging, $F(1, 261) = 65.63$, $p < .001$, $\eta_p^2 = .20$. As predicted, girls felt a significantly lower sense of belonging in the unequal class than in the equal class, but there was no condition effect for boys. As predicted, the gender difference in sense of belonging was significant for the unequal class, but not for the equal class.

Ability self-concept

As expected, unequal representation reduced ability self-concepts for girls, but not boys. A 2 × 2 (participant gender × representation condition) mixed-model ANOVA revealed a significant interaction between gender and condition on ability self-concepts, $F(1, 261) = 4.62$, $p = .032$, $\eta_p^2 = .017$. As expected, girls reported significantly lower ability self-concepts in the unequal class than in the equal class, but there was no condition effect for boys. The gender difference in ability self-concepts was significant for the unequal class, and marginally significant for the equal class.

Behavioral choice

Both girls (69%) and boys (61%) were significantly above chance in choosing the equal class—binomial proportion test, girls: $p < .001$, boys: $p = .014$—which supported our preregistered prediction about girls' choice. Girls and boys were equally likely to choose the equal class, $\chi^2(2, N = 264) = 2.15$, $p = .14$.

Mediation analyses

We examined whether stereotypes, sense of belonging, and ability self-concepts mediated girls' lower enrollment interest for the unequal compared to the equal class, and whether gender differences for the unequal class were mediated by belonging and self-concepts; see Table 5. First, as predicted, girls' lower interest in the unequal class compared to the equal class was partially mediated by stronger stereotypes for the unequal class, conditional indirect effect = 0.07, 95% CI [0.01, 0.14]. As predicted, this effect was also fully mediated by their lower sense of belonging for the unequal class, conditional indirect effect = 0.13, 95% CI [0.04, 0.24]. In addition, and as expected, this effect was partially mediated by girls' lower ability self-concept in the unequal class, conditional indirect effect = 0.04, 95% CI [0.005, 0.11].

As predicted, the gender difference in enrollment interest in the unequal class was fully mediated by sense of belonging, conditional indirect effect = −0.59, 95% CI [−0.82, −0.38], and partially mediated by self-concepts, conditional indirect effect = −0.30, 95% CI [−0.51, −0.10]. As expected based on the pattern of findings for stereotypes, the gender difference was not mediated by gender-interest stereotypes, conditional indirect effect = 0.01, 95% CI [−0.04, 0.06].

Discussion

Experiment 2 clearly demonstrated that underrepresentation matters for adolescent girls, as well as why underrepresentation matters. Underrepresentation served as a significant cue to gender stereotypes, sending the message that boys were more interested than girls were in CS classes. Supporting our preregistered predictions, underrepresentation reduced girls' sense of belonging, ability self-concepts, and enrollment interest. The unequal class had the largest impact on girls' sense of belonging compared with the other measures, with the largest effect size (d_z = 0.76) and the strongest influence on enrollment interest in a mediation analysis. This suggests that adolescent girls' sense of belonging in CS courses is highly sensitive to issues of representation. This has direct implications for schools and programs working to improve girls' sense of belonging in CS: When CS courses do have equal representation, it may be very important to emphasize that information for girls. Educational policymakers should consider making STEM courses like foundational CS courses mandatory as a middle-school graduation requirement (Code.org, CSTA, & ECEP Alliance, 2023). This would improve girls' representation in these courses, with potential immediate effects on their sense of belonging. School counselors should also actively encourage girls to take CS classes to improve girls' representation.

Experiment 3: Providing information to counter stereotypes

Experiment 2 demonstrated that underrepresentation reinforces gender-interest stereotypes by undermining girls' sense of belonging and interest in enrolling CS courses. Solutions to recruit more girls into CS courses must do so in the context of the current state of CS education, in which girls are indeed underrepresented in most courses (31% of students in high-school courses; Code.org, CSTA, & ECEP Alliance, 2021). The goal of Experiment 3 was to experimentally test a method of counteracting stereotypes in the context of underrepresentation.

Methods

Participants learned about two CS courses in a within-subjects design with a counterbalanced order through a Qualtrics online survey in March 2022. For both courses, participants learned girls were underrepresented (i.e., students in the class were 5 girls and 20 boys). For the course that countered stereotypes, participants were told that "girls and boys were equally interested at the end of the course." For the other course, there was no information about stereotypes (participants were informed that students were not asked about their interest). The condition was designed to remain ambiguous in this way (with no way of knowing about girls' and boys' interest) so that it might reflect participants' own stereotypes. This design also provides insights into whether explicitly providing information about interest in a CS class can causally impact interest, compared to when students are not provided with this information (as is typical when students enroll in courses). Students rated their stereotypes and motivation about both classes.

Participants

Participants were 558 eighth-grade students (249 girls, 281 boys; M_{age} = 13.63, $SD = 0.53$) in four schools within two school districts selected by the Character Lab Research Network; see Table 1 for more demographic information. In accord with our preregistration, students who did not report their gender as girl or boy were excluded from analyses involving gender. In line with our preregistered exclusion criteria of excluding duplicates, an additional 258 students were excluded for participating in Experiment 1 or 2.

Measures

Gender-interest stereotypes

Stereotypes about girls' and boys' interest in the countered and no-information courses were measured with same three-item scales as Experiment 2. Reliability was high for ratings of girls' and boys' interest in both courses; see Table 2. As in Experiment 2 and in accord with our preregistration, difference scores were created to measure gender-interest stereotypes for each class by subtracting average ratings of most girls' interest from most boys' interest.

Enrollment interest, sense of belonging, and ability self-concept

Enrollment interest, sense of belonging, and ability self-concept in each class were assessed with the same three item scales as in Experiments 1 and 2.

Behavioral choice

Choice was assessed with the same item as in Experiments 1 and 2.

Results

Tables 3 and 4 provide the effect sizes and correlations separated by participant gender and information condition.

Gender-interest stereotypes

In contrast to our prediction that there would be a main effect of condition, a 2×2 (participant gender $\times$ information condition [stereotypes countered or no information]) mixed-model ANOVA revealed no significant main effects or interactions on gender stereotypes as measured by the difference score, which was our primary preregistered analysis plan.

However, exploratory follow-up analyses examining the raw stereotype ratings about "most girls" and "most boys" showed a significant interaction between gender and information condition on stereotypes about most girls' interest, $F(1, 507) = 2.52$, $p = .008$, $\eta_p^2 = .014$. In line with our preregistered prediction, girl participants expected other girls to have more interest in the countered class than in the no-information class, although boy participants did not. The interaction between gender and condition on stereotypes about most boys' interest was also significant, $F(1, 511) = 5.31$, $p = .022$, $\eta_p^2 = .01$. Girl participants also expected boys to have more interest in the countered class than in the no-information class, although boy participants did not. Thus, our condition manipulation was effective in increasing girls' beliefs that other girls would be more interested in the class where stereotypes were countered than in the no-information class.

Enrollment interest

The counter-stereotypical information increased enrollment interest for girls, but not for boys; see Figure 2C. As predicted, a 2 × 2 (participant gender × information condition) mixed-model ANOVA revealed a significant interaction between gender and information condition on interest, $F(1, 507) = 4.09$, $p = .044$, $\eta_p^2 = .008$. As predicted, girls were significantly more interested in the class when stereotypes were countered than in the class with no information, but there was no condition effect for boys. As predicted, the gender difference in enrollment interest was significant in both conditions but smaller in the countered class.

Sense of belonging

Counter-stereotypical information increased belonging for girls, but not for boys, though the predicted significant interaction was marginally significant. A 2 × 2 (participant gender × information condition) mixed-model ANOVA revealed a marginally significant interaction between gender and information condition on belonging, $F(1, 501) = 3.11$, $p = .078$, $\eta_p^2 = .006$. As predicted, girls felt a significantly greater sense of belonging in the class when stereotypes were countered than in the no-information class, but there was no condition effect for boys. As predicted, the gender difference in sense of belonging was significant in both conditions but smaller in the countered class.

Ability self-concept

Counter-stereotypical information increased ability self-concepts for girls, but not for boys, though the predicted significant interaction was marginally significant. A 2 × 2 (participant gender × information condition) mixed-model ANOVA revealed a marginally significant interaction between gender and information condition on ability self-concepts, $F(1, 498) = 3.30$, $p = .07$, $\eta_p^2 = .007$. As predicted, girls reported significantly higher self-concepts for the countered class than for the no-information class, but there was no condition effect for boys. As predicted, the gender difference in ability self-concepts was significant in both conditions but smaller in the countered class.

Behavioral choice

Supporting our preregistered prediction for girls, both girls and boys were significantly above chance in choosing the countered class: binomial proportion test, girls, $p < .001$, boys, $p = .002$. Both girls (63%) and boys (60%) were equally likely to choose the class with stereotypes countered, $\chi^2(1, N = 510) = 0.52$, $p = .47$.

Mediation analyses

As predicted, girls' greater interest in the countered class compared to the no-information class was fully mediated by their greater sense of belonging in the countered class, conditional indirect effect = 0.07, 95% CI [0.03, 0.13]. See Table 5. Similarly, and as predicted, girls' greater interest in the countered class compared to the no-information class was also fully mediated by their stronger ability self-concepts for the countered class, conditional indirect effect = 0.04, 95% CI [0.01, 0.09].

As predicted, the gender difference in enrollment interest in the no-information class was partially mediated by sense of belonging, conditional indirect effect = −0.53, 95% CI [−0.70, −0.36], and partially mediated by ability self-concepts, conditional indirect effect = −0.37, 95% CI [−0.52, −0.22].

Discussion

Experiment 3 presented adolescent students with counter-stereotypical information about a CS class in which girls were underrepresented. In the counter-stereotypical condition, participants were told that boys and girls were equally interested in the course. This was contrasted with a class with no information, in which participants were told that students in the class were not asked about their interest. Providing the counter-stereotypic information boosted girls' enrollment interest, sense of belonging, and ability self-concept for that course, but had no effects for boys.

Counter to predictions, there was no difference in participants' gender-interest stereotypes about the two classes as measured by whether they expected boys to be more interested than girls are. At first, this may appear to be a failed manipulation check: The counter-stereotypical information did not change participants' perceptions of gender differences in interest in the class. Another potential explanation could be that participants were thinking about students' initial interest in the class, rather than their final interest. However, exploratory analyses showed that girl participants were sensitive to this information, but it increased their beliefs that everyone (both girls and boys) would be more interested in that class. Thus, girls thought the counter-stereotypical class would be more broadly appealing. As in Experiment 2, both girls and boys reported a similar choice of class, with both preferring to take the class with counter-stereotypical information compared to the class with no information. Both girls and boys may have reasoned that the counter-stereotypical class involved course content that was broadly appealing and likely to appeal to them as well.

Although the counter-stereotypical information boosted girls' interest, sense of belonging, and self-concepts, effect sizes were small. More work is needed to find ways to provide information about classes that can meaningfully change stereotypical perceptions and reduce gender gaps in enrollment interest, especially in the face of real-world underrepresentation. However, the current study provides support that countering gender stereotypes is a promising approach to improving equity in CS enrollment.

General discussion

These three preregistered experimental studies add to the body of literature examining the effects of gender-interest stereotypes in STEM. These studies demonstrate a new mechanism for understanding consequences of girls' underrepresentation in CS classes, with potential new targets for interventions. Across Experiments 2 and 3, students reported strong stereotypes that boys would be more interested than girls would be in CS classes, replicating previous findings that middle-school students hold these beliefs (Master et al., 2021a). Experiment 1 went beyond this previous work and additionally showed that these gender-interest stereotypes about CS classes can have causal effects. Adolescent girls were less motivated to enroll in CS classes when reminded of the stereotype that boys are more interested than girls are in CS. Experiment 2 made a further advance and demonstrated that numeric underrepresentation serves as a cue for interest stereotypes. This provides a generalizable experimental paradigm that can be used in future research to test different messages and interventions (such as that used in Experiment 3) to counter stereotypes and encourage girls to enroll in foundational CS classes. As such CS classes are offered by more K–12 schools (Code.org, CSTA, & ECEP Alliance, 2023), this type of research has important applications for educators working to increase girls' representation in STEM classes. While it is still important to counteract stereotypes about girls' *ability* in CS, it may be just as important (or more so) to counteract *interest* stereotypes.

These preregistered studies also helped illuminate the mechanisms by which interest stereotypes can reduce girls' motivation to enroll in CS. Across all three studies, girls were less motivated to enroll in CS classes when they were less confident in their ability to succeed in that class. They were also less motivated to enroll when they felt a lower sense of belonging, which in turn was particularly sensitive to their level of underrepresentation in the course. In comparing girls and boys, girls' lower sense of belonging and ability self-concepts contributed to their lower motivation to enroll in CS classes.

The present findings also revealed consistent patterns across studies in terms of gender differences. Boys largely reported greater interest, belonging, and higher ability self-concepts for CS courses compared to girls across studies and conditions. Although our experimental conditions were generally able to reduce the size of the gender gap, we were unsuccessful in completely eliminating the gender gap in interest. This contrasts with previous studies with younger elementary-school students, in which gender gaps disappeared (Master et al., 2021a). By middle school, there may be other important sources of gender differences in interest other than gender stereotypes (including gendered differences in experiences with computing that students have already encountered), and/or gender stereotypes may be so entrenched that they are difficult to effectively counter (Tang et al., 2024).

Implications for educational theory and practice

Teachers know that they face barriers in motivating students into CS classes. The Computer Science Teachers Association (2015) surveyed 1,354 high-school CS teachers and found that "lack of student interest/enrollment" was perceived to be a "great" or "moderate challenge" by 89%. When asked why students did not take their course, 89% said that "CS is perceived as male-dominated" was a "very" or "somewhat common" reason. These gender stereotypes can come from many sources and are often difficult to eradicate. Stereotypes can come from (a) media sources such as television and movies in which most computer scientists are men, (b) implicit and explicit messages favoring boys from parents and teachers, and (c) the gender disparities they see in informal learning environments like afterschool programs or their cultural environment (Cvencek et al., 2024; for a review, see Tang et al., 2024). What can educators and administrators do in the face of these common beliefs? We suggest three key recommendations.

First, teachers who are aware of the effects of these stereotypes can work to counter them by promoting the idea that girls enjoy computer science. They can share examples and stories about diverse girls and women with a passion for computing (Moya et al., 2023). They can also enlist girls who are already involved with CS as role models and ambassadors to share their enthusiasm for CS (Chen et al., 2023; Dasgupta & Stout, 2014). Although many researchers have argued for the importance of role models for promoting girls' interest in computing (Boston & Cimpian, 2018; Cheryan et al., 2015; Happe et al., 2021), the current work suggests that the specific messages that role models send may be critically important. Role models who communicate about their ability and success in computer science may be less effective than role models who communicate about their passion and enjoyment of computing. These findings also provide new insights into how stereotypes affect motivation within a situated expectancy-value theory framework, by indicating that different types of stereotypes may differentially affect self-schemata.

Second, school districts can create policies to eliminate girls' underrepresentation in these courses. For example, policies that make CS courses mandatory for all students lead to more equal representation (Code.org, CSTA, & ECEP Alliance, 2023). Teachers can also encourage girls to sign up for CS classes with friends or ask guidance counselors to steer girls into CS classes (Mak & Torrejon Capurro, 2024). The current findings also suggest that such policies to increase girls' representation will not be harmful for boys' motivation, because boys also preferred CS classes with equal representation.

Third, teachers can work to support girls' sense of belonging and ability self-concepts in CS. Affinity groups like Black Girls Code and Girls Who Code may help create supportive communities and mentorship for girls, while culturally responsive teaching practices can also support girls of color (Lunn et al., 2021). Opportunities to use CS in altruistic ways to support social justice can also promote girls' belonging (Lewis et al., 2019; Vakil, 2018). Supporting students' growth mindset practices may help support the development of positive ability self-concepts through mistakes and failures (Morales-Navarro et al., 2021).

Limitations and future directions

One limitation of these studies was the lack of diversity in the sample, who were predominantly White students from middle or upper socioeconomic status backgrounds. Although our aim was to recruit students from a diverse school district, our research partners had difficulty recruiting diverse samples. Initial research suggests high similarity between Black, Latina, Asian, and White girls in their belief in gender-interest stereotypes about CS and in links between stereotypes and motivation to pursue CS (Master et al., 2021a). However, future studies should recruit more diverse samples and examine intersectional effects for Black and Latina girls. For example, Black girls comprise only 2% of AP CS exam takers, and Latina girls comprise only 5% (Code.org, CSTA, & ECEP Alliance, 2021). Black and Latina girls are also less likely than White girls to intend to major in CS and engineering (Riegle-Crumb & Morton, 2017). Understanding how minoritized girls are influenced by stereotypes about both gender and race/ethnicity is important for developing more effective approaches to engaging them in CS. For example, organizations like Black Girls Code use culturally responsive learning environments to support the values of girls of color in a context where marginalization is less likely (Latanision, 2023). Efforts to help Black and Latina girls feel a greater sense of belonging in CS should pay careful attention to racial adversities experienced by these students, as well as work to change the broader culture of CS education to be more inclusive (Matthews et al., 2024).

Another limitation is the issue of real-world validity. This is a common issue in experimental research studies, in which researchers seek to isolate and examine how specific, controlled changes might affect students' responses, with random assignment to conditions. Although students may sometimes be choosing between CS courses, it is more common for students to be choosing between CS courses and other elective options. Future research should examine how counter-stereotypical information might affect CS enrollment interest in comparison to other elective course options to provide greater insights into how to promote girls' actual selection of CS courses. Such research should also examine the durability of such interventions. A recent systematic review of interventions in computing education found that the most successful interventions took place at the college level, rather than in secondary education, and involved long-term changes to courses or extracurricular programs (Perez-Felkner et al., 2024).

It is also important to be cautious in interpreting the results for at least two reasons. First, some interactions between gender and condition were only marginally significant, suggesting that girls and boys often show similar responses overall to cues of representation and information countering stereotypes. Across studies, girls consistently reported significantly greater motivation for courses with equal representation and no stereotypes, but boys also showed some similar preferences, especially in terms of course choice. Although speculative, this immediately raises an empirical question: Why might boys prefer to take courses with equal representation or equal interest across gender? Some previous studies suggest that boys may feel greater social belonging in coed rather than non-coed educational settings (Belfi et al., 2012; Lirgg, 1994). Also, there may be meaningful individual differences among boys, with some boys more confident they would be interested in CS when the course was designed to be broadly appealing across genders (Master et al., 2016). Second, we acknowledge that the effect sizes in Experiment 3 were small to medium. This suggests that simply providing information that counters stereotypes may not be enough to drive meaningful changes in girls' motivation in CS. This is especially true for future interventions that aim to change real-world outcomes like girls' actual enrollment in CS courses. Future studies should examine ways to increase the impact of messages that counter stereotypes, such as providing real-world role models who offer testimonials about their own interest in CS, and test long-term effects of such interventions.

Another promising direction for future research is to examine how factors such as gender-interest stereotypes and sense of belonging can be integrated into other existing theoretical frameworks that are useful for studying CS motivation. For example, social cognitive career theory (SCCT) has been used to examine the development of interest in computing pathways and careers. According to this framework, students begin with certain personal characteristics such as gender. Those characteristics and background contextual affordances (including gender stereotypes) influence students' learning experiences (Lent et al., 1994). Based on those learning experiences, students have both self-efficacy expectations (*can I do this?*) and outcome expectations (*if I do this, what will happen?*). Those in turn influence interests, which influence choice goals and actions, leading to performance and attainments. Links between interests, goals, and behavior can be moderated by contextual influences proximal to choices, which include supports and barriers such as family supports and role models/ mentors (Lent & Brown, 2019). An interesting topic for future research might be to examine whether a "sense of belonging" could fit into the SCCT framework as a proximal contextual influence for adolescents, with high belonging supporting the development of computing interest and low belonging serving as a barrier (George et al., 2022). As another example, disciplinary identity theory has argued that identity development in a domain such as computing is influenced by three subcomponents of identity: interest, recognition, and competence/ performance (Mahadeo et al., 2020). Some researchers have also argued that belonging should be considered a fourth subcomponent of identity, but empirical findings have been mixed (Lunn et al., 2021; Taheri et al., 2019; Verdín, 2021). Findings from the current studies support belonging as an important mechanism supporting the development of girls' interest in enrolling in CS classes, but more work needs to be done to examine how it may concurrently predict interest and identity development along with students' competence beliefs (Master & Meltzoff, 2020).

Conclusions

The stereotype that CS is for boys can reinforce girls' sense that they do not belong and will not enjoy CS classes. Educators and parents can help counter this stereotype for girls to show them more equal representation in who enjoys CS and encourage them to give CS a chance.

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