Liking by doing: An immersive science program changes students' implicit science attitudes

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Abstract

Does an immersive science experience change science attitudes and beliefs? In pilot and confirmatory studies, first-year college students completed measures of implicit and explicit science attitudes, stereotypes and construals (beliefs that science is solitary) at the beginning and end of Citizen Science, an intensive scientific literacy program that introduces students to the scientific method using laboratory-, computing-, and problem-solving based modules. Across both studies, students' implicit (but not explicit) science attitudes became more positive over the course of the program. These data highlight the importance of educational environments for shaping students' attitudes, and suggest that their effects may differ on relatively more and less conscious measures.

Keywords: implicit social cognition, implicit attitudes, science education

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Scientific literacy - the capacity to use scientific evidence and apply it to decisions with ethical, philosophical, and political implications (American Association for the Advancement of Science [AAAS], 2011; Scheufele, 2014) - is essential for informed decision-making about matters such as health, the environment and politics. It accrues societal and individual benefits, as it can create a more effective workforce (AAAS, 2011; Savage, 2014). Approximately 30% of the American science and engineering workforce has limited formal experience or training in scientific inquiry (National Science Foundation, 2015) and numbers of scientifically literate adults remain low (Miller, 2004). Further, the United States' scientific standing is at risk if students from across all backgrounds are not recruited and retained in science successfully (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007). The current research examines how an intensive program to develop scientific literacy among first-year college students shapes students' cognitions about science.

While most evaluations of science, technology, and engineering (STEM) programs use explicit (relatively more controlled) measures (Ornstein, 2006; Parkinson, Force, & Smith, 2003), we examine how an immersive STEM experience change implicit (relatively less controlled) cognitions. Such an approach can add to the growing understanding of the malleability of implicit cognitions (Dasgupta, 2013; Gawronski & Bodenhausen, 2006). Moreover, implicit attitudes and stereotypes play an important role in STEM pursuit and performance. Stronger implicit stereotypes associating science with male predict weaker STEM performance among women at the individual (Lane, Goh, & Driver-Linn, 2012; Nosek, Banaji, & Greenwald, 2002; Nosek & Smyth, 2011) and national (Nosek et al., 2009) levels. Greater implicit and explicit STEM positivity also predicts higher levels of STEM engagement and performance (Nosek et al., 2002). Positive STEM implicit attitudes may mitigate the deleterious effects of implicit stereotypes on women's STEM pursuit (Dasgupta, 2011; Stout, Dasgupta, Hunsinger, & McManus, 2011).

This approach builds on prior findings that academic experiences shape implicit cognitions. Students who completed a seminar in prejudice and conflict (but not a comparison class) had reduced implicit racial bias (Rudman, Ashmore, & Gary, 2001) at the end of the semester, and women (but not men) with a female calculus instructor had less negative implicit mathematics attitudes and stronger implicit identity with math than those with a male instructor (Stout et al., 2011) after the class.. Although women at a coeducational and an all-women's college began university with similar implicit stereotypes of science as male, women at the single-sex school did not hold this bias after a year (Dasgupta & Asgari, 2004).

Malleability of Implicit Cognitions

This work examines how doing science in a sustained, engaging manner during an intensive STEM literacy program ("Citizen Science") affects students' science attitudes and beliefs. While behavior follows from attitudes (Ajzen & Fishbein, 2005) classic social psychological theories also argue for the converse – behavior changes attitudes, such that "when an individual wants to know how he feels, he may look to see how he acts" (Bem, 1972, p. 5). This idea holds true for implicit as well as explicit attitudes. People exhibited lower implicit bias

after being induced to smile at Black faces (Ito, Chiao, Devine, Lorig, & Cacioppo, 2006) and to engage in approach behaviors toward members of a target group (Kawakami, Phillips, Steele, & Dovidio, 2007). Similarly, repeated approach behaviors toward novel faces led to more positive implicit evaluation of those faces (Woud, Becker, & Rinck, 2008). In the academic domain, approach behaviors toward mathematics-related images increased implicit math positivity among women low in math identification (Kawakami, Steele, Cifa, Phillips, & Dovidio, 2008).

Conditioning may elicit such changes as the act of smiling at targets or approaching category members creates or strengthens associations between the target object and positive concepts. Such conditioning is an efficacious way of changing implicit attitudes: A comparison of 17 interventions showed that exposure to counterstereotypical exemplars or attitudinal conditioning were among the best ways to reduce implicit racial bias (Lai et al., 2014). Further, high “involvement (the degree to which an attitude is linked with the self)” was “a common feature among interventions that were successful in reducing implicit prejudice” (2014, p. 1780).

We might think of Citizen Science as an intervention creating positive associations with science in a deeply personally involved way. It emphasized active learning techniques that challenged students to take a hands-on, collaborative approach to problem-solving, mirroring the practice of science. Activities were commonly open-ended, such that faculty did not know the outcome in advance. This inquiry-based approach can improve explicit STEM attitudes (Ornstein, 2006; Parkinson, Force & Smith 2003).

Changes in implicit science attitudes might be independent of students’ conscious evaluation of the program. The Associative-Propositional Evaluation (APE) Model (Gawronski & Bodenhausen, 2006) argues that while learned associations underlie implicit and explicit attitudes, propositional thinking – which involves judgments of consistency of distinct propositions – underlies explicit but not implicit attitudes. That is, “implicit measures can be regarded as a proxy for the activation of associations in memory unqualified by subjective truth or falsity” (Gawronski & Sritharan, 2010, p. 220). Change on implicit and explicit measures might thus be dissociated, with only the former occurring if students’ overall evaluations of the program are neutral or negative, and change on both sets of measures if students’ overall evaluations are positive.

The Current Research

The current work examines change in science cognitions during Citizen Science, a required program for all first-year students at XXXX College. Citizen Science emphasized hands-on engagement with the process of science (Handelsman, Miller, & Pfund, 2007), and a student-centered approach that featured active learning. A “flipped” classroom model allowed students to acquire content outside of class and focus in class on collaborative and active learning activities (AAAS, 2011; Freeman et al., 2014). Learning goals emphasized the ability to locate, identify, and evaluate scientific evidence and to apply that evidence to evaluate claims. The program also aimed to help students be able to articulate strengths and limitations of common scientific approaches, evaluate data and understand its visual representation, and appreciate the intersection of science and day-to-day life. Using historical and current events as starting points, students learned scientists’ methods and practices while grappling with the relationship between science and politics, economics, ethics, and society. They directly engaged

with coding and quantitative reasoning in model building and analysis of their data, experimental design and execution within the microbiology lab and outside of the lab, scientific writing including primary research, science communication, and attended speaker series that illustrated contemporary scientific questions. Civic engagement required students to work in local schools and teach a scientific concept to schoolchildren. Both the speaker series and civic engagement activities challenged students to apply what they had learned in new contexts.

In two years, students at XXXX College completed measures of science cognitions at the start and end of Citizen Science. Because implicit STEM attitudes (liking) may be

more flexible than implicit stereotypes (associations between science and male; Dennehy & Dasgupta, 2017; Ramsey, Betz, & Sekaquaptewa, 2013; Stout et al., 2011) and the program was not designed to counter stereotypes, we expected that science attitudes would become more positive but did not necessarily expect to see change in STEM stereotypes. Given recent work showing that the belief that science is solitary can impede STEM engagement (Diekman, Clark, Johnston, Brown, & Steinberg, 2011; Diekman, Steinberg, Brown, Belanger, & Clark, 2017), we also assessed beliefs that science is individualistic. Based on Citizen Science's highly collaborative nature we anticipated that students might come to view science as more collaborative.

Pilot Study

Method

Participants. Sample size for the pilot study was determined by logistical constraints and the desire to minimize disruption to class time while testing the feasibility of conducting this research during Citizen Science. Our final sample of 52 students yielded 30% power to detect a small effect size of $d = .20$ and 95% power to detect a medium effect size of $d = .50$ on main effects of change over time (G*Power 3; Faul, Erdfelder, Lang, & Buchner, 2007).

Students were required to participate but could exclude their data for research purposes. At Time 1, 78 students (38 female, 37 male, two not reported) participated; 52 of these students (26 female, 24 male, two gender not reported) returned for Time 2. Students from five sections (three female, two male instructors) participated.

The Citizen Science Program. Citizen Science ran in January. Students were randomly assigned to course sections, designed to be capped at 21 students, with adjustments to balance science majors and gender composition across sections. There were 12 teaching days comprised of three (computational activities, microbiological experiments, and problem based learning) rotations. Each day students attended class for 4.5 hour and completed approximately 2-3 hours of homework. XXXX College sophomore and juniors served as Teaching Fellows, supported faculty during their laboratory teaching, and assisted students with experiments and analysis.

Materials. Materials for both studies are available at https://osf.io/9xms3/?view_only=ffd629d688bd4ee3b7a58548214b2958.

Implicit measures. Three Implicit Association Tests (IATs) (Greenwald, McGhee, & Schwartz, 1998) measured science stereotypes (associations between *science+male*, compared to *arts+female*), attitudes (associations between *science+good*, compared to *arts+bad*), and construals (associations between *science+alone*, compared to *arts+together*). In the IAT, participants categorize stimuli from four categories with two responses in one block (e.g. in the *science+female* block of the stereotype IAT, *female* and *science* share one response and *male* and *arts* share the other). In a second block – e.g. *science+male* - pairings switch (e.g., *female* and *arts* share one response and *male* and *science* the other). Faster responses in the second block indicate implicit stereotypes associating science with male. In each IAT, participants completed the predicted less compatible pairing (*science+good*, *science+female*, *science+together*) first to provide conservative estimates of IAT effects, although the number of practice trials between blocks should minimize or eliminate order effects (Nosek, Greenwald, & Banaji, 2005). Other design procedures follow those outlined in Lane, Banaji, Nosek, and Greenwald (2007), and full details are in Online Supplement S1. *D* scores were generated using the procedures recommended by Greenwald, Nosek, and Banaji (2003) such that positive scores reflect greater positivity toward science, stereotypes associating male with science, and construals of science as solitary.

Explicit measures. Participants endorsed statements regarding preferences, stereotypes, and construals of science and arts on a 1 (strongly disagree) to 7 (strongly agree) scale. Five items measured explicit preference for science over arts ($\alpha_{\text{Time 1}} = .92$; $\alpha_{\text{Time 2}} = .87$), and seven measured beliefs that science is more solitary than arts (e.g., $\alpha_{\text{Time 1}} = .69$; $\alpha_{\text{Time 2}} = .72$). Eight questions measured gender stereotypes; because the explicit measure comparing the difference between science and arts had poor reliability ($\alpha_{\text{Time 1}} = .29$; $\alpha_{\text{Time 2}} = .38$), we only use the four questions measuring absolute stereotypes of science as male ($\alpha_{\text{Time 1}} = .72$; $\alpha_{\text{Time 2}} = .75$) as our measure of science stereotypes.

Participants reported confidence in their scientific abilities by indicating agreement with 12 items from the confidence subscale of the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976), rated their ability to use science in specific situations on three items, and responded to 12 items assessing the belief that science is important (Confidence $\alpha_{\text{Time 1}} = .95$, $\alpha_{\text{Time 2}} = .94$; Importance $\alpha_{\text{Time 1}} = .92$, $\alpha_{\text{Time 2}} = .91$; Ability to Use Science $\alpha_{\text{Time 1}} = .29$, $\alpha_{\text{Time 2}} = .76$). They also indicated plans to pursue science on two items, $r_{\text{Time 1}} = .20$, $r_{\text{Time 2}} = .44$ and (at Time 2) responded to 24 statements about Citizen Science. All responses were made on the Likert-type scale described above.

Participants provided demographic information and their major, SAT or ACT math, science and reasoning scores, and how many required and non-required science and math courses they took in high school. No other measures were included. Full explicit measures are available in Online Supplement S2.

Procedure. Students visited the Psychology Program on the first two days and the final day of Citizen Science, where they completed the IATs, followed by explicit and demographic measures. Twenty-seven students participated at Time 1 but not Time 2 – these students did not differ from those who returned on implicit or explicit measures of attitudes, stereotypes, or construals, all $ts < 1.01$, $ps > .32$.

Results and Discussion

To test how cognitions changed during Citizen Science we conducted a series of Gender x Time (Start or End) Analyses of Variance (ANOVAs), summarized in Table 1. Main effects of gender on implicit attitudes and stereotypes showed that men had more positive implicit science attitudes, $p = .004$, $d = 0.70$, 95% CI [0.12, 1.25], and weaker implicit stereotypes, $p = .02$, $d = 0.60$, 95% CI [0.02, 1.16], than women. In contrast, men endorsed stereotypes marginally more than women, $p = .07$, $d = 0.42$, 95% CI [-0.11, 1.00].

The crucial tests focus on temporal change, evidenced by main effects of time, and time by gender interactions. The most important result is a marginally significant effect of time on implicit attitudes, revealing that students became more implicitly positive toward science during Citizen Science, $p = .06$, $d = 0.29$, 95% CI [-0.01, 0.45]. This effect was qualified by a marginal time x gender interaction, $p = .09$. Simple effects tests revealed that while men's science attitudes became more positive, $t(24) = 2.15$, $p = .04$, $d = 0.44$, 95% CI = [0.02, 0.84] women's were stable, $t(25) = 0.20$, *ns*, $d = 0.04$, 95% CI = [-0.36, 0.44].

Explicit attitudes, stereotypes, and construals stayed stable, all $ps > .23$, as did implicit stereotypes and construals, $ps > .86$. There were no time by gender interactions on these variables, $ps > .18$.

Comparable ANOVAs were conducted on measures of scientific confidence, self-reported ability to use science, and belief that science is important. The only notable result was a marginally significant interaction between gender and time on scientific confidence, $p = .06$, such that women's confidence increased, $t(25) = 1.97$, $p = .06$, $d = 0.37$, whereas men's confidence did not change, $t(24) = -0.73$, $p = .47$, $d = -0.15$.

We had expected based on prior research (Stout et al., 2011) that direct, hands-on engagement with science would change implicit science attitudes but not stereotypes. The pilot data suggested exactly this pattern. The program did not change implicit construals about science, or explicit attitudes, stereotypes, or construals. These initial data are promising about the potential for a program like Citizen Science to change implicit science attitudes. However, the study was limited by a small sample size and high attrition. In the subsequent year we sought to replicate this result with a more robust sample.

Table 1. Pilot Study: Test- Retest Correlations, Descriptive Statistics by Time and Gender, and Summary ANOVA Statistics.

	Test-Rest Reliability	<u>Women</u>				<u>Men</u>				<u>Time* Gender ANOVA Analysis of Variance – F-values</u>			
		<u>Time 1</u>		<u>Time 2</u>		<u>Time 1</u>		<u>Time 2</u>		Main Effect: Gender	Main Effect: Time	Time x Gender Interaction	ANOVA Denominator Degrees of Freedom
		<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>				
<u>Implicit Measures</u>													
Attitude	.46****	-0.50	0.34	-0.49	0.40	-0.30	0.47	-0.03	0.64	8.94**	3.71+	2.91+	49
Stereotype	.58****	0.50	0.29	0.48	0.33	0.27	0.43	0.28	0.40	5.84*	0.01	0.07	48
Construal	.18	-0.08	0.25	-0.13	0.37	-0.10	0.35	-0.03	0.38	0.21	0.03	1.01	47
<u>Explicit Measures</u>													
Attitude	.78****	3.11	1.19	3.22	1.16	3.33	1.41	3.42	1.35	0.40	0.57	0.01	50
Stereotype	.56****	2.61	1.09	2.54	1.09	2.95	.90	3.11	.95	3.36+	0.11	0.73	49
Construal	.58****	3.38	0.65	3.50	0.77	3.43	1.01	3.57	1.01	0.07	1.42	0.01	49
<u>Science Confidence, Ability to Use Science, and Belief in the Importance of Science</u>													
Confidence	.70****	4.44	1.26	4.84	1.22	4.74	1.41	4.60	1.42	0.01	0.88	3.73+	49
Ability	.21	4.85	0.81	5.06	1.43	5.29	0.98	4.91	1.31	0.32	0.20	2.23	50
Importance	.36**	5.87	0.91	5.48	1.54	5.29	1.51	5.12	1.08	2.68	1.83	0.28	50

Note. Positive scores reflect stronger plans to pursue science, positive attitudes, stronger stereotypes associating science with male, stronger science construals of science as solitary, and greater scientific confidence, belief in the ability to use science, and belief that science is important. + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Main Study

Method

Participants. We used G*Power 3.1 (Faul et al., 2007) to estimate the minimum sample required to yield 80% power to detect the effect size ($d = 0.29$) associated with the pilot study's primary finding of change on implicit science attitudes, yielding a target sample size of 98 or greater, and scheduled the required number of sections accordingly. Students again were required to participate but could exclude their data for research. One hundred and seventeen students over the age of 18 opted to include their data at Time 1; the 101 students who returned at Time 2 (60 female, 39 male, 2 not reported) constitute our final sample. Students were drawn from nine sections (six female instructors, three male instructors).

Measures. We measured the following constructs in a manner similar to the pilot study (see Online Supplement S3 for details): Implicit attitudes, stereotypes, and construals; explicit attitudes ($\alpha_{\text{Time 1}} = .91$, $\alpha_{\text{Time 2}} = .93$), stereotypes ($\alpha_{\text{Time 1}} = .59$, $\alpha_{\text{Time 2}} = .64$), and construals ($\alpha_{\text{Time 1}} = .60$; $\alpha_{\text{Time 2}} = .65$); scientific confidence ($\alpha_{\text{Time 1}} = .89$, $\alpha_{\text{Time 2}} = .86$), beliefs about the importance of science ($\alpha_{\text{Time 1}} = .89$; $\alpha_{\text{Time 2}} = .92$), students' self-reported ability to use science ($\alpha_{\text{Time 1}} = .59$; $\alpha_{\text{Time 2}} = .56$), and plans to pursue science ($\alpha_{\text{Time 1}} = .76$; $\alpha_{\text{Time 2}} = .79$). For investigations unrelated to the current study, students indicated their beliefs about malleability of science ability (Blackwell et al., 2007), and the extent to which different careers fulfill agentic and communal goals (Diekmann, Brown, Johnston, & Clark, 2010).

Results and Discussion

Our main goal was to replicate the pilot study's finding that implicit science attitudes became more positive over the course of Citizen Science. As in the pilot study and summarized in Table 2, a 2 (Gender) x 2 (Time: Start or End) mixed ANOVA revealed a main effect of gender, such that women implicitly disliked science more than men, $p = 3.58 \times 10^{-6}$, $d = 0.90$, 95% CI [0.48, 0.132]. Crucially, students once again had more positive implicit science attitudes at the end of Citizen Science than at the beginning, $p = .02$, $d = 0.23$, 95% CI [0.01, 0.35]. Unlike the pilot study, the interaction of gender and time was nonsignificant, $p = .36$, suggesting the program's effects were similar for men and women.

As in the pilot study, men had weaker implicit stereotypes than women, $p = .04$, $d = 0.37$, 95% CI [-0.04, 0.77]. Implicit stereotypes were weaker at the end than the start of Citizen Science, $p = .02$, $d = -0.23$, an effect equally large for men and women (gender by time interaction $p = .96$). While this finding suggests that a program like Citizen Science can change implicit stereotypes, the disparity between this finding and that of the pilot study – in which implicit stereotypes were virtually identical at Times 1 and Time 2, $d = 0.01$ – tempers our enthusiasm for this conclusion. Implicit science construals were stable, $p = .85$, $d = 0.02$, although a marginally significant effect of gender suggested that women had stronger *science+alone* associations than men, $p = .06$, $d = 0.19$.

Results on explicit measures were also similar to the pilot study – men endorsed science stereotypes more than women, $p = .052$, $d = 0.41$, 95% CI [0.00, 0.75] and reported greater liking for science than women, $p = .02$, $d = 0.47$, 95% CI [0.08, 1.18]. Students' explicit cognitions did

not change over the course of Citizen Science (ps of all time main effects $> .17$; interactions between time and student gender, all $ps > .50$).

Comparable factorial ANOVAs were conducted on measures of scientific confidence, self-reported ability to use science, and belief that science is important. Recall that in the pilot study women's confidence increased, $d = 0.37$, and men's was unchanged, $d = -0.15$. Here, we found a marginally significant main effect of time, $p = .10$. Although this main effect was unqualified by an interaction with time, inspection of the means separately by gender revealed a similar pattern to the pilot study, such that women's confidence increased, $t(59) = 2.67$, $p = .01$, $d = 0.35$ and men's remained stable, $t(38) = 0.16$, $p = .89$, $d = 0.03$. Men reported greater belief than women in their ability to use science, $p = .01$, $d = 0.73$. There were no other main effects or interactions, $ps > .16$.

Mechanisms of attitude change. We explored the features of Citizen Science that predicted change in implicit attitudes by creating composite variables reflecting students' assessment of Citizen Science on several dimensions (liking for the 1. program; 2. instructor; 3. teaching fellows; 4. speakers; and 5. outreach component; as well as the extent to which it 6. challenged them; 7. was collaborative; and 8. increased awareness of ethical issues). Although students were neutral about the program overall, ($M = 4.04$, $SD = 1.25$), $t(113) = 0.33$, $p = .74$, $d = 0.03$, they were positive about specific program aspects: Peer teaching fellows ($M = 5.34$, $SD = 1.33$), $t(113) = 10.72$, $p = 6.37 \times 10^{-19}$, $d = 1.01$, instructors ($M = 5.15$, $SD = 1.23$), $t(113) = 9.98$, $p = 3.36 \times 10^{-17}$, $d = 0.94$, civic engagement, ($M = 4.89$, $SD = 1.52$), $t(113) = 6.24$, $p = 7.84 \times 10^{-9}$, $d = 0.59$, and speakers ($M = 4.29$, $SD = 1.55$), $t(113) = 1.97$, $p = .05$, $d = 0.19$. They reported that the program was collaborative ($M = 4.46$, $SD = 1.28$), $t(113) = 3.84$, $p = .0002$, $d = 0.36$ and raised awareness of ethical issues ($M = 5.24$, $SD = 1.17$), $t(113) = 11.25$, $p = 3.73 \times 10^{-20}$, $d = 1.06$. Difficulty ratings did not differ from the scale midpoint, ($M = 3.84$, $SD = 1.41$), $t(113) = -1.22$, $p = .22$, $d = -0.11$.

In the first step of a hierarchical multiple regression, we regressed Time 1 implicit attitudes onto Time 2 implicit attitudes. Pre-test implicit attitudes were an excellent predictor of post-test attitudes, $\beta = .65$, $p < .0001$, overall model $F(1, 99) = 70.57$, $p < .0001$, $R^2 = .41$. In the second step we added students' evaluations of Citizen Science. Above and beyond initial attitudes, students' assessment predicted post-test implicit attitudes, overall model $F(9, 91) = 10.45$, $p < .0001$, $\Delta R^2 = .09$, $F(8, 91) = 2.13$, $p = .04$. Pre-test attitudes remained a strong predictor of post-test attitudes, $\beta = .59$, $p < .0001$. Ratings of the instructor drove attitudinal change, as they predicted post-test implicit attitudes, $\beta = .26$, $p = .01$. Students were enthusiastic about the program's civic engagement and ethics components; it is surprising, then, that this model showed a trend that the more students liked these aspects, the less positive their attitudes toward science became, *outreach* $\beta = -.18$, $p = .05$; *ethics* $\beta = -.18$, $p = .07$. Notably, students' global assessment of Citizen Science was unrelated to change in implicit attitudes, $\beta = .03$, $p = .80$. No other variables significantly predicted change in implicit attitudes, all $\beta s < .12$, $ps > .20$.

Table 2: Test- Retest Correlations, Descriptive Statistics by Time and Gender, and Summary ANOVA Statistics.

		<u>Women</u>				<u>Men</u>				Time* Gender ANOVA Analysis of <u>Variance – F-values</u>			
		<u>Time 1</u>		<u>Time 2</u>		<u>Time 1</u>		<u>Time 2</u>					
	Test-Rest <u>Reliability</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	Main Effect: <u>Gender</u>	Main Effect: <u>Time</u>	Time x Gender <u>Interaction</u>	ANOVA Denominator Degrees of <u>Freedom</u>
<u>Implicit Measures</u>													
Attitude	.65****	-0.55	0.45	-0.49	0.37	-0.19	0.48	-0.05	0.48	24.18****	5.33*	0.86	97
Stereotype	.42****	0.45	0.27	0.36	0.35	0.33	0.34	0.24	0.39	4.50*	5.49*	0.00	97
Construal	.23*	-0.04	0.30	-0.04	0.33	-0.14	0.34	-0.14	0.41	3.57+	0.04	0.00	97
<u>Explicit Measures</u>													
Attitude	.91****	2.73	1.17	2.83	1.23	3.38	1.46	3.44	1.49	5.76*	1.83	0.08	97
Stereotype	.41****	2.61	0.90	2.72	0.85	2.97	1.06	3.03	1.12	3.89+	0.64	0.05	97
Construal	.57****	3.34	0.75	3.39	0.75	3.33	0.74	3.29	0.83	0.15	0.00	0.46	97
<u>Science Confidence, Ability to Use Science, and Belief in the Importance of Science</u>													
Confidence	.79****	4.37	1.23	4.62	1.22	4.71	1.31	4.73	1.17	0.92	2.82+	1.98	97
Ability	.53****	4.66	1.03	4.83	0.88	5.19	0.98	5.20	0.97	6.80*	0.77	0.63	97
Importance	.70***	5.73	0.83	5.59	0.95	5.74	0.85	5.66	0.84	0.07	2.68	0.15	97

Note. Positive scores reflect stronger plans to pursue science, positive attitudes, stronger stereotypes associating science with male, stronger science construals of science as solitary, and greater scientific confidence, belief in the ability to use science, and belief that science is important. + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Aggregate Analysis

We aggregated the two data sets and repeated the main analyses with study year as an additional between subjects factor (Table 3). With one exception (described below), there were no significant effects of study or interactions among year, gender, or time; consequently these analyses do not report study year. Our primary finding that implicit science attitudes became more positive emerged in the combined data, $p = .003$, $d = 0.23$. This main effect was qualified by a time by gender interaction, $p = .04$, such that men's attitudes changed, $t(63) = 2.90$, $p = .005$, $d = 0.37$, while women's were relatively stable, $t(85) = 1.06$, $p = .29$, $d = 0.11$. Neither implicit stereotypes nor construals changed over the course of Citizen Science. Explicit attitudes, stereotypes, and construals remained stable.

Consistent with the trend in both studies, there was a marginal increase in scientific confidence, $p = .08$ qualified by a time by gender interaction, $p = .01$, such that men's confidence did not change, $t(63) = 0.36$, $p = .72$, $d = -0.05$, and women's increased, $t(85) = 3.31$, $p = .001$, $d = 0.36$. Men reported greater ability to use science than women, $p = 0.05$; this main effect was qualified by a marginal interaction between time and gender, $p = .06$. Women showed a (nonsignificant) increase in self-reported ability to use science $t(86) = 1.42$, $p = .15$, $d = 0.15$, whereas men showed a (nonsignificant) decrease in self-reported ability to use science, $t(63) = -1.06$, $p = .29$, $d = -0.13$.

Students reported that science was less important at the end than at the start of Citizen Science, $p = .03$. This variable was the sole case where a difference emerged across studies, such that there was a marginal interaction between gender and study, $F(1, 147) = 2.81$, $p = .096$. There were no interactions between time, gender, study, or their interaction, suggesting that while men in the pilot study placed relatively low importance on science, men's and women's trajectory of change was similar across both studies.

Instructor gender was excluded from prior analyses because of the small samples in the four possible student/ instructor gender pairings; even aggregating across studies, cell N s were small (ranging from 22 male students/ male instructors to 56 female students/ female instructors). In an exploratory sense we conducted a series of 2 (student gender) $\times$ 2 (instructor gender) $\times$ 2 (time) ANOVAs, with the first two factors between and the last within to examine how change varied by student and instructor gender. Across the outcome variables, there were no two-way interactions between instructor and student gender or instructor gender and time, and no three-way interaction between time, student gender, and instructor gender, suggesting that change over time did not differ as a function of instructor gender or its interaction with student gender.

As described in more detail in Online Supplement 4, aggregate analyses revealed that when variables were considered in isolation, students with more positive implicit and explicit attitudes and stronger associations between science and their own gender on the IAT tended to report greater plans to pursue science. When all explicit and implicit variables were considered simultaneously, explicit attitudes were consistently and robustly associated with plans to pursue science.

Discussion

In two studies, students completed measures of implicit and explicit science social cognitions before and after XXX College's Citizen Science program. The central finding is that students' implicit attitudes toward science became more positive over the course of Citizen Science. While implicit *science+male* stereotypes decreased in the main study, the absence of such an effect in the pilot or aggregate data make the conclusion that the program changed implicit stereotypes tentative. Implicit and explicit construals, as well as explicit attitudes and stereotypes did not change during Citizen Science.

The pilot and aggregate analyses suggest that men's attitudes changed more than women's; however, the confirmatory study, with its larger sample and lower rate of attrition than the pilot study, did not show the key time by gender interaction that would suggest differential change for men and women. Due to this inconsistency, we conclude that the data suggest, but do not provide strong evidence for, the possibility that Citizen Science was more effective in changing men's than women's attitudes. Notably, even if women did not become more implicitly positive toward science, they became more confident about science and showed greater gains in their self-reported ability to use science than men.

Table 3. Aggregate Analysis: Test- Retest Correlations, Descriptive Statistics by Time and Gender, and Summary ANOVA Statistics.

	Test-Rest Reliability	<u>Women</u>				<u>Men</u>				Time* Gender ANOVA Analysis of <u>Variance – F-values</u>				ANOVA Denominator Degrees of Freedom
		<u>Time 1</u>		<u>Time 2</u>		<u>Time 1</u>		<u>Time 2</u>		Main Effect: Gender	Main Effect: Time	Time x Gender Interaction		
		<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>					
<u>Implicit Measures</u>														
Attitude	.56****	-0.53	0.41	-0.49	0.37	-0.23	0.48	-0.05	0.54	28.26****	9.37**	4.49*	146	
Stereotype	.48****	0.47	0.28	.40	0.35	0.31	0.37	0.25	0.39	10.99***	2.17	.87	145	
Construal	.23**	-0.05	0.29	-0.06	0.34	-0.13	0.34	-0.10	0.40	0.52	0.06	0.69	144	
<u>Explicit Measures</u>														
Attitude	.86****	2.85	1.18	2.95	1.21	3.36	1.43	3.43	1.42	3.78+	2.06	0.05	147	
Stereotype	.46****	2.61	0.95	2.67	0.92	2.97	0.99	3.06	1.05	7.26**	0.54	0.28	146	
Construal	.58****	3.35	0.72	3.42	0.75	3.37	0.84	3.40	0.91	0.00	1.16	0.08	146	
<u>Science Confidence, Ability to Use Science, and Belief in the Importance of Science</u>														
Confidence	.76****	4.39	1.24	4.68	1.21	4.72	1.34	4.68	1.26	0.40	3.16+	6.49*	146	
Ability	.40****	4.72	0.97	4.90	1.08	5.23	0.97	5.08	1.12	3.94*	0.00	3.60+	147	
Importance	.51****	5.73	0.83	5.61	0.90	5.60	1.26	5.31	1.34	1.94	4.91*	0.58	147	

Note. Positive scores reflect stronger plans to pursue science, positive attitudes, stronger stereotypes associating science with male, stronger science construals of science as solitary, and greater scientific confidence, belief in the ability to use science, and belief that science is important. + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

These data contribute to understanding implicit cognitions' malleability. Just as work on attitudes shows that "liking is for doing" and attitudes shape behavior (Ajzen & Fishbein, 2005), the converse also holds: Doing is for liking, and engaging in a behavior can change attitudes. Immersing oneself in science, and practicing it in a deeply engaged, personal way for three weeks, elicited more positive attitudes about science. Student's overall neutrality about Citizen Science, which sat side-by-side with strong positivity about the program's individual components, is striking. On a day-to-day basis, students enjoyed the specific, focused activities they were completing. Attitude change as a result of the cumulative effects of engaging in such positively-regarded activities is consistent with conditioning models of implicit attitude change, which suggest that building new associations drives implicit attitude change, and is a particularly effective way at doing so (Lai et al., 2014). The APE model (Gawronski & Bodenhausen, 2006) predicts exactly the pattern of data we observed - new associations were built and repeatedly activated ("I like working on antibiotic sensitivity assays"), but contradicted by a conscious propositional thought ("Citizen Science was fine, but not great"), resulting in change on implicit but not explicit measures.

Our findings also bring insight to the evaluation of teaching and learning. Traditional (self-report) student evaluations have been criticized on a number of grounds, including their focus on student liking rather than learning (Carrell & West, 2010). Their reliance on self-report measures may miss an important component of attitudinal change that happens at a level of which students are unaware. Students may not realize the true influence of their classroom experience. They also highlight the importance of faculty in shaping students' disciplinary attitudes.

Because every student at XXXX College is required to complete Citizen Science, we could not include a control group of students who did not complete the program. It is possible, then, that attitude change occurred naturalistically. Given work showing that students' implicit STEM attitudes are stable over the course of a semester (Lane & Driver-Linn, 2008), there is little reason to think that in two consecutive years implicit science attitudes would spontaneously change over a three-week period in January. A further limitation of the work is its focus on short-term change; given questions about the long-term effects of interventions to change implicit cognitions (Lai et al., 2016), future work in this vein ought to explore the downstream consequences of educational experiences.

We began this work by considering the importance of scientifically literate workforce. The teaching of science – and its focus on rote memorization rather than process and discovery – has rightfully been criticized (Waldrop, 2015). The current work demonstrates that students who engage with science in a way that encourages inquiry and active learning may find themselves more positive about the discipline.

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Online Supplementary Materials S1: Procedural Details for the Implicit Association Test (Pilot Study and Main Study)

Implicit measures. Participants completed IATs assessing implicit academic stereotypes (*science* = *male*/ *arts* = *female* associations relative to *science* = *female*/ *arts* = *male* associations), implicit science attitudes (*science* = *good*/ *arts* = *bad* relative to *arts* = *good*/ *science* = *bad*, and implicit science construals (*science* = *alone*/ *arts* = *together* relative to *science* = *together*/ *arts* = *alone*).

As described in the main text, when completing the IAT participants categorize stimuli from four categories with two responses in one block (e.g., in the *science*+*female* block of the stereotype IAT, *female* and *science* share one response and *male* and *arts* share the other). In a second block - *science*+*male* in this example - pairings switch (e.g., *female* and *arts* share one response and *male* and *science* the other). Category labels and stimuli are included below in Table S1.

Table S1.
Category Labels and Stimuli for the Implicit Association Test (Both Studies)

Category label	Stimuli
Sciences	Chemistry, Physics, Math, Biology, Engineer, Science
Arts	Music, Theater, Dance, Orchestra, Art, Sculpture
Good	Happy, Wonderful, Fantastic, Pleasant, Excellent
Bad	Terrible, Awful, Horrible, Agony, Evil
Female	Girl, Female, Aunt, Daughter, Women
Male	Boy, Male, Uncle, Son, Men
Alone	Singular, Independent, Alone, Solitary, Solo
Together	Together, Group, Collaborate, Joint, Collective

The first IAT followed the standard seven-block design described by Lane et al. (2007). The three IATs were presented to participants in one of three possible orders. In Block 1 of the first IAT all participants practiced categorizing *sciences* and *arts* stimuli by categorizing 20 items from the *sciences* and *arts* categories by pressing the “e” (left) computer key for *sciences* words and the “i” (right) computer key for *arts* words. In Block 2 they practiced categorizing items in the other two categories of the first IAT (e.g., *female* and *male*). The combined task then began, consisting of 19 practice and 39 critical trials in which participants classified items from all four categories with two responses (e.g., *sciences* + *female*/ *arts* + *male*) in Blocks 3 and 4, respectively. In Block 5, the labels for the *non-sciences*/ *arts* categories switched sides, and participants practiced categorizing items into these two pairs of categories for 40 trials, which has been shown to be sufficient practice to mitigate the effects of order on IAT scores by Nosek et al. (2005). In Blocks 6 and 7 participants repeated the tasks completed in Blocks 3 and 4 with the opposite pairing of categories (e.g., *sciences*+ *male*/ *arts* + *female*). In the two following IATs, participants completed Blocks 2-7 as described above (*sciences*/ *arts* kept their location throughout the study so participants did not repeat that practice categorization). An overview of a potential block order for a single participant who is included in Table S2.

Table S2.

Sample IAT Block Order for a Participant

IAT 1	1	Science/ Arts
	2	Female/ Male
	3	Science + Female/ Arts + Male (practice)
	4	Science + Female/ Arts + Male (critical)
	5	Male/ Female
	6	Science + Male/ Arts + Female (practice)
	7	Science + Male/ Arts + Female (critical)
IAT 2	8	Together/ Alone
	9	Science+Together/ Arts+Alone (practice)
	10	Science+Together/ Arts+Alone (critical)
	11	Alone/ Together
	12	Science+Alone/ Arts+Together (practice)
	13	Science+Alone/ Arts+Together (critical)
IAT 3	14	Good/ Bad
	15	Science+Good/ Arts+Bad (practice)
	10	Science+Good/ Arts+Bad (critical)
	11	Bad/ Good
	12	Science+Bad/ Arts+Good (practice)
	13	Science+Bad/ Arts+Good (critical)

Stimuli appeared serially in the middle of the screen. Participants sorted items into their appropriate categories by pressing the “E” key for stimuli belonging to categories on the left and the “I” key for stimuli belonging to categories on the right. The letter “X” appeared in red following errors and remained on the screen until participants made the correct response.

Online Supplementary Materials S2: Complete Explicit Measures (Pilot Study)

Unless otherwise noted, participants responded the extent to which they agreed with each of the following statements on a scale from 1 – 7 with 1 labeled as “Strongly disagree,” 4 labeled as “Neither agree nor disagree,” and 7 labeled as “Strongly agree.”

Attitudinal Questions

1. I like science.
2. In general, I would rather take a class in the arts than in the science.
3. I like arts.
4. Please rate how warm or cool you feel toward the arts.
(1 – 7 scale, with 1 labeled as “Very cool” and 7 labeled as “Very warm”)
5. Please rate how warm or cool you feel toward the sciences.
(1 – 7 scale, with 1 labeled as “Very cool” and 7 labeled as “Very warm”)
6. Which of the following best describes your preferences?
(1-7 scale, with the following labels: 1: “Strongly prefer arts to sciences”; 2: “Moderately prefer arts to sciences”; 3: “Somewhat prefer arts to sciences”; 4: “Like arts and sciences equally”; 5: “Somewhat prefer sciences to arts”; 6: “Moderately prefer sciences to arts”; 7: Strongly prefer sciences to arts”)

Collaborative Nature of Science and Arts Questions

1. Arts courses let me work together with other students often.
2. When I picture an artist, I see someone working alone.
3. Collaboration is essential in the sciences.
4. Science courses let me work together with other students often.
5. When I picture a scientist, I see someone working alone.
6. Collaboration is essential in the arts.
7. Artists are more collaborative than scientists.

Stereotype Questions

1. Men are better at science than women.
2. I think that women are generally better than men at sciences.
3. Men are better at arts than women.
4. I think that women are generally better than men at arts.
5. Women can achieve as much as men in the sciences.
6. If I were having trouble with a problem in a science class, I would go to a man instead of a woman.
7. Women can achieve as much as men in arts.

8. If I were having trouble with a problem in an art class, I would go to a man instead of a woman for help.

Scientific Confidence (Confidence subscale of Fennema-Sherman [1976] scale)

1. I am sure that I can learn science.
2. I don't think I could do advanced science.
3. Science is hard for me.¹
4. I am sure of myself when I do science.
5. I'm not the type to do well in science.
6. Science has been my worst subject.¹
7. I think I could handle more difficult science.
8. Most subjects I can handle OK, but I just can't do a good job with science.
9. I can get good grades in science.¹
10. I know I can do well in science.¹
11. I am sure I could do advanced work in science.
12. I'm no good in science.

Scientific Importance (Usefulness subscale of Fennema-Sherman [1976] scale)

1. Science is a worthwhile, necessary subject.
2. Taking science is a waste of time.
3. I study science because I know how useful it is.
4. Science will not be important to me in my life's work.
5. I'll need science for my future work.
6. I don't expect to use much science when I get out of school.
7. I will use science in many ways as an adult.
8. I see science as something I won't use very often when I get out of college.
9. I'll need a good understanding of science for my future work.
10. Science is not important for my life.
11. Knowing science will help me earn a living.
12. Doing well in science is not important for my future.

Ability to Use Science

1. I can make educated decisions using scientific evidence.

¹ Not included in main study.

2. When I read or hear about scientific stories in the media (TV, Internet, etc.), I can usually understand what is being discussed.
3. I am not very strong at interpreting data.

Pursuit of Science (Time 2 Only)

1. I will major in a math or science subject.
2. I will major in a humanities subject.
3. I will major in an arts subject.
4. I doubt I will attend many science lectures outside of those required for my courses.

Questions about Citizen Science (Time 2 Only)

1. I enjoyed the teaching and outreach opportunities presented in Citizen Science.
2. I worked hard at communicating science (i.e., in my class or during Civic Engagement activities).
3. I am more aware of ethical issues regarding science due to Citizen Science.
4. I enjoyed thinking about the ethical implications of science during Citizen Science.
5. There are many open issues in bioethics.
6. After Citizen Science, I better understand the relationship between scientific practice and public policy.
7. I enjoyed the speakers.
8. I liked my Citizen Science professor.
9. The speakers gave me a new perspective on science.
10. My professor was engaging.
11. I liked hearing the Citizen Science faculty talk about their own work.
12. The laboratory Teaching Fellows were knowledgeable.
13. The laboratory Teaching Fellows made me more comfortable with my ability to do the labs.
14. I worked closely with my peers during Citizen Science.
15. Citizen Science was a collaborative experience.
16. I enjoyed Citizen Science.
17. I enjoyed the computer modeling rotation of Citizen Science.
18. I enjoyed the problem-solving rotation of Citizen Science.
19. I enjoyed the laboratory rotation of Citizen Science.
20. I enjoyed the civic engagement component of Citizen Science.
21. Overall, I do not feel that Citizen Science was a good use of my time.
22. Citizen Science was challenging.
23. Citizen Science was too easy.
24. I was enthusiastic about the material we learned during Citizen Science.

25. I think that XXXX should continue Citizen Science.

Demographic and Background Questions

Question

Sex

Age

Race

Ethnicity

Nationality

Mat SAT Score

Math ACT Score

Science Reasoning ACT Score

How many science classes were *required* in your high school?

How many math classes were *required* in your high school?

How many NON-REQUIRED science classes did you complete in high school?

How many NON-REQUIRED math classes did you complete in high school?

How many college-level (including AP and IB) science classes did you complete in high school?

How many college-level (including AP and IB) math classes did you complete in high school?

Response Options

Male, Female

Open-ended

American Indian/
Alaska Native, East
Asian, South Asian,
Native Hawaiian/
Pacific Islander,
Black/ African origin,
White/ European
origin, Other or
Unknown, Prefer Not
to Say

Hispanic or Latino,
Not Hispanic or
Latino, Unknown

American or Other
(open-ended if other)

Open-ended

Open-ended

Open-ended

1, 2, 3, 4, 5 or more

1, 2, 3, 4, 5 or more

0-15

0-15

0-15

0-15

Online Supplementary Materials S3: Complete Explicit Measures (Main Study)

Participants completed all of the explicit, demographic, and background measures as in the pilot study. They also responded to the questions below. As before, unless otherwise noted, participants reported the extent to which they agreed with each of the following statements on a scale from 1 – 7 with 1 labeled as “Strongly disagree,” 4 labeled as “Neither agree nor disagree,” and 7 labeled as “Strongly agree.”

Scientific Pursuit

1. I will major in a math or science-related subject.
2. I will major in a humanities subject.
3. I will major in an arts subject.
4. I doubt I will attend many science lectures outside of those required for my courses.
5. I plan to pursue science at Bard.
6. Please indicate which Division(s) you are likely to major in
Arts, "Language and Literature, Social Studies, Science, Math, and Computing
7. Will you major in a science field?
Yes, No, Not Sure

Additional Questions on Importance of Science (Included for internal assessment)

1. I study science because I know how useful it is.
2. It is important that the average person understand science.
3. Understanding science is an important part of a liberal arts education.
4. I use science in my everyday life.
5. Science has been important to me, even outside of the classroom.

Growth Mindset Questions (Not analyzed for the current research)

1. You have a certain amount of science ability and you really can't do much to change it.
2. You can learn new things, but you can't really change your basic level of scientific talent.
3. You can always greatly change how good you are at science.
4. No matter who you are, you can significantly change your level of scientific talent.

Ability of Careers to Fill Communal and Agentic Goals (Not analyzed for the current research)

1. How likely would a career as a [career title] be to fulfill agentic goals (such as power, achievement, and seeking new experiences or excitement)?

Career title: Mechanical engineer, Computer scientist, environmental scientist, actor or actress, photographer, musician

(1 – 7 scale, with 1 labeled as “Not at all” and 7 labeled as “Extremely”)

2. How likely would a career as a [career title] be to fulfill communal goals (such as intimacy, affiliation, and altruism)?

Career title: Mechanical engineer, Computer scientist, environmental scientist, actor or actress, photographer, musician

(1 – 7 scale, with 1 labeled as “Not at all” and 7 labeled as “Extremely”)

Online Supplementary Materials S4: Additional Aggregated Analyses

This supplement examines the ability of the implicit and explicit measures to predict students' plans to pursue science. Analyses are based on data aggregated across the pilot and main studies in order to achieve more stable estimates of the correlations. We first computed a composite variable of students' plans to pursue science at the start and end of Citizen Science by averaging the relevant items.

Tables S3-S6 show the correlations among plans to pursue science, explicit measures, and implicit measures at each time point for the whole sample (S3, S5) and separately for men and women by time point (S4, S6). Inspection of the zero-order correlations reveals, not surprisingly, that students who reported greater liking for science also reported stronger intentions to pursue science (Time 1 $r = .75$, $p < .0001$; Time 2 $r = .69$, $p < .0001$). Students with more positive implicit science attitudes also reported stronger intentions to pursue science (Time 1 $r = .42$, $p < .0001$; Time 2 $r = .36$, $p < .0001$). The magnitude of the relationship between attitudes and plans to pursue science were similar for men and women.

We examined the relationship between students' stereotypes of sciences as being associated with their own gender and plans to pursue science. Explicit stereotypes were unrelated to plans to pursue science at both time points, across the whole sample ($r_{\text{Time 1}} = -.02$, $r_{\text{Time 2}} = -.11$), as well as in the subsamples of men ($r_{\text{Time 1}} = .05$, $r_{\text{Time 2}} = .07$) and women ($r_{\text{Time 1}} = -.06$, $r_{\text{Time 2}} = .13$). On the other hand, implicit stereotypes predicted plans to pursue science. Across the entire sample, stronger associations between one's own gender and science predicted plans to pursue science at Time 1 ($r = .21$) but not at Time 2 ($r = .08$). Stereotypes were inconsistently associated with men's plans ($r_{\text{Time 1}} = .20$, $r_{\text{Time 2}} = .01$), but were more consistently associated with women's plans ($r_{\text{Time 1}} = .27$, $r_{\text{Time 2}} = .19$). Other than a single negative correlation between explicit construals of science as solitary and plans to pursue science among men at Time 2, science construal was unrelated to plans to pursue science.

We next examined the ability of the implicit and explicit measures to predict plans to pursue science simultaneously by regressing each of the six measures onto plans to pursue science separately by for time (again, in the entire sample, and separately by gender; Table S7). The conclusion is identical across time and sample breakdowns — as a whole, the measures explained a substantial proportion of variance in plans to pursue science (Adjusted R^2 range .37 - .63, all $ps < .0001$), and this predictive power was driven by students' explicit science attitudes (β s range .58 - .79, all $ps < .0001$). This may suggest that the relationship between implicit constructs and behavior is mediated by explicit attitudes (Zitlney Shalom, & Bar-Anon, 2017), and may also reflect the close methodological and conceptual similarity between the attitudinal questions (e.g., "I like science") and behavioral pursuit questions (e.g. "I will major in a math or science subject").

Table S3.

Correlations Among Science Pursuit and Implicit and Explicit Attitude, Stereotypes, and Construals (Time 1; Full Sample)

	Science Pursuit		Explicit Attitude		Explicit Stereotypes		Explicit Construals		Implicit Attitudes		Implicit Stereotypes		Implicit Construals
Science Pursuit	1.00												
Explicit Attitude	.75	****	1.00										
Explicit Stereotypes	-.02		.11		1.00								
Explicit Construals	-.09		-.18	*	.07		1.00						
Implicit Attitudes	.42	****	.56	****	.21	**	.02		1.00				
Implicit Stereotypes	.21	*	.38	****	.17	*	-.05		.42	****	1.00		
Implicit Construals	-.09		-.14	+	-.14		.25	***	-.24	**	-.18	*	1.00

Note. Positive scores reflect stronger plans to pursue science, more positive implicit or explicit science attitudes, stronger implicit or explicit stereotypes associating science with one's own gender, and stronger implicit or explicit science construals of science as solitary + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Table S4.

Correlations Among Science Pursuit and Implicit and Explicit Attitude, Stereotypes, and Construals (Time 1; By Gender)

	Science Pursuit	Explicit Attitude	Explicit Stereotypes	Explicit Construals	Implicit Attitudes	Implicit Stereotypes	Implicit Construals
Science Pursuit	-	.69 ****	.05	-.01	.37 **	.20	-.14
Explicit Attitude	.80 ****	-	.19	-.29 *	.52 ****	.40 ***	-.16
Explicit Stereotypes	-.06	.03	-	-.04	.19	.29 *	-.22 +
Explicit Construals	-.15	-.10	.14	-	-.07	-.24 *	.35 **
Implicit Attitudes	.46 ****	.56 ****	.18 +	.09	-	.26 *	-.28 *
Implicit Stereotypes	.27 *	.34 ***	-.10	-.01	.42 ****	-	-.24 +
Implicit Construals	-.04	-.10	-.05	.16	-.19 +	-.05	-

Note. Correlations for men are presented above the diagonal, and correlations for women are presented below the diagonal. Positive scores reflect stronger plans to pursue science, more positive implicit or explicit science attitudes, stronger implicit or explicit stereotypes associating science with one's own gender, and stronger implicit or explicit science construals of science as solitary + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Table S5.

Correlations Among Science Pursuit and Implicit and Explicit Attitude, Stereotypes, and Construals (Time 2; Full Sample)

	Science Pursuit	Explicit Attitude	Explicit Stereotypes	Explicit Construals	Implicit Attitudes	Implicit Stereotypes	Implicit Construals
Science Pursuit	1.00						
Explicit Attitude	.69 ****	1.00					
Explicit Stereotypes	.11	.18 *	1.00				
Explicit Construals	-.18 *	-.31 ****	.21 **	1.00			
Implicit Attitudes	.36 ****	.49 ****	.17 *	-.15 +	1.00		
Implicit Stereotypes	.08	.31 ***	.06	-.06	.47 ****	1.00	
Implicit Construals	-.11	-.21 **	-.09	.22 **	-.10	-.09	1.00

Note. Positive scores reflect stronger plans to pursue science, more positive implicit or explicit science attitudes, stronger implicit or explicit stereotypes associating science with one's own gender, and stronger implicit or explicit science construals of science as solitary + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Table S6.

Correlations Among Science Pursuit and Implicit and Explicit Attitude, Stereotypes, and Construals (Time 2; By Gender)

	Science Pursuit	Explicit Attitude	Explicit Stereotypes	Explicit Construals	Implicit Attitudes	Implicit Stereotypes	Implicit Construals
Science Pursuit	-	.62 ****	.07	-.34 **	.40 **	.01	.08
Explicit Attitude	.78 ****	-	.08	-.55 ****	.48 ****	.18	-.14
Explicit Stereotypes	.13	.14	-	.20	.14	-.09	.04
Explicit Construals	-.01	-.07	.25 *	-	-.27 *	-.04	.20
Implicit Attitudes	.43 ****	.53 ****	.01	.04	-	.19	-.08
Implicit Stereotypes	.19 +	.32 **	-.09	-.09	.36 ****	-	-.11
Implicit Construals	-.19 +	-.20 +	-.18	.25 *	-.10	-.03	-

Note. Correlations for women are presented above the diagonal, and correlations for men are presented below the diagonal. Positive scores reflect stronger plans to pursue science, more positive implicit or explicit science attitudes, stronger implicit or explicit stereotypes associating science with one's own gender, and stronger implicit or explicit science construals of science as solitary + $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Table S7.

Multiple Regression Predicting Plans to Pursue Science From Implicit and Explicit Attitudes, Stereotypes, and Construals

Variable	Overall		Men		Women	
	<u>Time 1</u>	<u>Time 2</u>	<u>Time 1</u>	<u>Time 2</u>	<u>Time 1</u>	<u>Time 2</u>
	<u>B</u>	<u>β</u>	<u>β</u>	<u>β</u>	<u>β</u>	<u>β</u>
Explicit Attitudes	.77 ****	.72 ****	.79 ****	.58 ****	.76 ****	.78 ****
Explicit Stereotypes	-.02	-.08	-.08	-.02	.08	.06
Explicit Construals	.04	.07	.24 *	-.01	-.07	.06
Implicit Attitudes	.02	.09	-.06	.16	.08	.04
Implicit Stereotypes	-.08	-.12	-.03	-.11	-.01	-.08
Implicit Construals	.01	.03	-.12	.16	.04	-.06
<u>Overall model</u>						
<u>Statistics</u>						
Adjusted R ²	.54	.48	.48	.37	.63	.59
df _{between}	6	6	6	6	6	6
df _{within}	139	142	58	56	74	79
F	29.29 ****	24.08 ****	10.80 ****	7.18 ****	23.67 ****	21.04 ****