Complicated Gender Gaps in Mathematics Achievement: Elevated Stakes during Performance as

One Explanation

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Lay Abstract

Gender differences in mathematics achievement appear by fifth grade and widen, but the size and direction of those gaps varies. We explore whether these differences might be in part explained by the stakes of the performance context. Girls learned more than boys from a mathematics lesson when the stakes were low. When we raised the stakes by promising a reward for high performance, boys and girls showed equal learning, and boys enjoyed the lesson more.

Abstract

Gender gaps in mathematics achievement persist in many contexts and when visible, these gaps are paradoxical. Low-stakes measures of mathematics achievement such as grades and study behaviors favor girls, while gaps tend to reverse on assessments/ competitions. We explore whether different impacts of raising performance stakes could be one explanation.

Study 1 experimentally manipulated the stakes by imposing a performance-contingent, social-evaluative pressure either: before instruction *(n=66)*, before testing (*n=61*), or none (*n =54*). Pressure, particularly when experienced during instruction, reduced learning among girls. In contrast, boys trended towards enhanced learning under pressure. In the absence of pressure, girls exhibited strikingly larger gains in learning.

Study 2 drew from a larger dataset (*n* = 386) to interrogate whether girls' superior learning in the no-pressure context might simply be an artifact of differences in prior knowledge, cognitive resources, or demographic variables, but the effect replicated and was not explained by these factors.

Keywords. Mathematics, gender gaps, learning contexts, performance pressure

Main Text

Men and women do not differ meaningfully in mathematics aptitude (see Spelke, 2005). Yet, mathematics achievement trajectories continue to be patterned by gender in complex and seemingly paradoxical ways that ultimately result in mathematics-intensive fields remaining heavily dominated by men (World Economic Forum, 2017). At the same time, gender differences in mathematics are not unidirectional achievement gaps. In elementary and middle school, girls tend to outperform boys on some measures of mathematics achievement, often those reflecting everyday mathematical knowledge and practices (e.g., grades, study behaviors; Cimpian et al., 2016). The gender gap reverses on high-stakes mathematics assessments and individual and team-based competitions, such that when gaps are apparent, they favor boys (Ceci & Williams, 2010; Ellison & Swanson, 2018; OECD, 2013; though see Reardon et al., 2019). Gender gaps are especially pronounced at high levels of achievement (Ellison & Swanson, 2018). Strikingly, between 2008 and 2017 the female composition of the International Mathematics Olympiad teams ranged from 0% to a high of 14% (Steegh et al., 2019).

Here we explore the hypothesis that gender gaps may be shaped less by differences in mathematics ability, and more by contextual factors (also see Hyde & Metz, 2009). Specifically, across two studies with fifth and sixth grade students (10-12-year-olds), we examine how one contextual factor, the stakes of the learning and performance context, may contribute to disparate gender gaps in mathematics achievement. We focus in particular on the role of *social-evaluative pressure* (see Beilock et al., 2004) in shaping mathematics performance through introducing a situation in which a full class reward is contingent on individual students' performance.

On the one hand, making a desired reward contingent on performance could improve learning by motivating students to put forth increased effort (e.g. Bettinger, 2012). On the other hand, it could harm learning if anxious ideation and intrusive thoughts interfere with students' ability to concentrate on the lesson (e.g. Beilock, 2008; Schmader et al., 2008).

Gender and Mathematics Achievement Patterns

Most meta-analyses assessing mathematics gender gaps report negligible differences between boys' and girls' achievement in elementary and middle school (Halpern, 1986; Hyde et al., 1990; 2008; Lindberg et al., 2011). At the same time, more recent work finds that, among high achievers, gender gaps in standardized mathematics test performance favoring boys start as early as Kindergarten and these gaps widen and spread throughout the achievement distribution as children advance through elementary school (Cimpian et al., 2016; Robinson & Lubienski, 2011): a gap equivalent to girls falling 2.5 months behind boys by fifth grade (Fryer & Levitt, 2011). Gender gaps favoring boys also arise in standardized national and international assessments of higher-level mathematics skill (College Board, 2015; Guiso et al., 2008; Lubienski et al., 2013) and mathematics competitions (Ellison & Swanson, 2018).

Though gender gaps in test performance often favor boys, measures of mathematics achievement requiring sustained effort in low-stakes, everyday settings tend to favor girls. On average, middle and high school girls in the U.S. earn higher grades in mathematics classes (Duckworth & Seligman, 2006; Easton et al., 2017; Kenney-Benson et al., 2006), invest more time towards mathematics homework (Gershenson & Holt, 2015; Guiso et al., 2008), and enroll in advanced mathematics courses at similar rates (Goldin et al., 2006; NSF, 2008c) compared to boys. Grades and homework evaluate additional factors beyond assessments, including students' ability to self-regulate and their teachers' subjective evaluations, which often favor girls (Guez et

al., 2020). Compared to standardized assessments, grades are better predictors of success in upper-level and post-secondary courses, including mathematics (Allensworth & Clark, 2020; Maruyama, 2012). Additionally, girls' higher grades are unlikely due to teachers' bias in evaluation: In fact, holding achievement constant, teachers consistently rate girls' mathematics proficiency lower than that of boys (Cimpian et al., 2016).

In low-stakes mathematics contexts, girls typically outperform boys, but in high-stakes assessments of mathematical achievement, boys typically outperform girls, suggesting the context in which learning occurs and is evaluated may be an important factor shaping mathematics gender gaps. Below, we review literature that has manipulated the stakes of learning and performance contexts, revealing both positive and negative effects of high-stakes assessments for student outcomes. Critically, the direction of said effects depend on student gender.

Raising the Stakes Can Incentivize Performance. Research, predominantly in the field of behavioral economics, has shown the incentivizing potential of raising the stakes with performance-contingent rewards. Field experiments reveal that rewarding elementary students with money or prizes for correct responses on standardized exams boosts their performance (e.g., Bettinger, 2012), with larger effects for boys (Levitt et al., 2016). Studies have also suggested that men prefer and, when given the option, chose higher-stakes performance contexts (particularly on tasks deemed male-typical, e.g., math; Niederle & Versterlund, 2007; 2011).

Raising the Stakes Can Threaten Performance. While the possibility of being rewarded (or sanctioned) for performance can be incentivizing, it can also be distracting. Raising the stakes can in some cases harm performance by generating intrusive thoughts and worries that consume limited cognitive resources that are necessary for math engagement and performance

(Beilock, 2008; Schmader et al., 2008). In everyday mathematics learning and performance contexts, the stakes may already be heightened for girls, as they contend with negative stereotypes about women and math (Ambady et al., 2001; Galdi et al., 2014) and experience higher math anxiety (Devine et al., 2012; Hill et al., 2016) and lower confidence (Goetz et al., 2013) than boys, despite equivalent ability. If girls are already concerned about their performance, potentially experiencing the everyday mathematics classroom as high-stakes, then raising the stakes further may be experienced as threatening. This could harm girls' learning and performance by depleting cognitive resources necessary to succeed.

Impacts of Raising the Stakes: Gender Matters. Critically, research in other male-typical fields (here, science) that has experimentally heightened the stakes while learning reveal differential effects by gender. For example, Souchal and colleagues (2014) found that girls saw larger learning gains from a science lesson than boys when they were told they would not be evaluated on their performance (low-stakes). The gender gap reversed when students were informed that their performance would be graded (high-stakes). Cotner and Ballen (2017) similarly found that undergraduate women underperformed relative to men on biology exams, but not on other, lower-stakes graded activities (see also Ballen et al., 2017; Guez et al., 2020).

Present studies

The gendered patterns described above suggest that the stakes of the classroom learning and performance context should be more meaningfully considered when analyzing gender gaps in mathematics. Most of the studies to date examine impacts of pressure experienced solely while testing–yet relatively less is known about effects of pressure when experienced during *learning*–particularly mathematics learning. Impacts of raising the stakes prior to learning could compound over time and contribute to subsequent patterns of student engagement and retention.

We report on findings from two studies examining fifth and sixth grade students' mathematics achievement across high and low-stakes learning and performance contexts, where the instruction itself is held constant through video-based delivery. With this design, we can examine gender gaps in learning itself, versus solely final performance measures, allowing us to examine how any observed gaps may have unfolded.

Students in these studies were drawn from twenty-one different private, charter, and traditional public schools in the greater Chicago area. As is increasingly reflective of the nation's student body, the majority of students who participated in these studies were non-white. Although much prior research on gender gaps in mathematics has focused on majority white populations (for discussion, see Leyva, 2017), understanding the role of gender in shaping mathematics trajectories among diverse populations is of critical importance given issues of intersectionality (see Velez & Spencer, 2018) and the potential for gender and race in particular to intersect in complex ways to shape children's mathematics learning experiences (e.g., Brown & Leaper, 2010; McGee & Bentley, 2017; Young et al., 2017).

In the present studies, we assess students' learning from one single high-quality lesson on ratio. In Study 1, we test how raising the stakes with pressure influences boys' and girls' learning from the video lesson, showing gender gaps in mathematics learning favoring girls only in the low stakes, unpressured learning context. We extend this finding in Study 2, where we pooled data from seven prior studies in which our research team has used this same ratio video lesson. We meta-analyzed the data from all students who were assigned to a low-stakes, non-experimental condition. We again found a gender gap favoring girls' learning from the same lesson, replicating our findings from the No Pressure condition in Study 1.

Study 1

In Study 1, we experimentally manipulated whether students' learning and performance contexts were high versus low-stakes by imposing a performance-contingent, social-evaluative pressure (Beilock et al., 2004) prior to or immediately following students viewing the lesson.

How does raising the stakes impact boys' and girls' learning? On the one hand, we predicted that introducing a performance-contingent, social-evaluative pressure could boost motivation and effort, resulting in improved learning and performance. On the other hand, raising the stakes could also result in anxious ideation and intrusive thoughts that interfere with learning and performance. We tested whether average impacts of the pressure manipulation on learning and performance differed between boys and girls. As prior research suggests a larger performance boost in response to incentives (Levitt et al., 2016) and high-stakes testing contexts (Schlosser et al., 2019) among boys and men, we believed manipulating the stakes with pressure could partially explain gender gaps in mathematics achievement. Moreover, we further consider how raising the stakes shapes boys' and girls' mathematics engagement and learning, as opposed to just performance.

Method

Participants

205 fifth grade students from five schools around Chicago participated. 27 students who were absent on one or more study days were excluded due to missing data, leaving 178 students. Demographic information is provided in Table 1.

Procedure

Procedures were group administered during three visits to each classroom over a two-week period, as outlined in Figure 1. At session 1, students completed a pretest assessing their initial understanding of ratio. Two to three days later, at session 2, students viewed a previously

recorded, conceptually challenging mathematics lesson on individual laptops, immediately followed by a posttest. A week later, at session 3, students completed a final posttest and a demographics questionnaire. Students completed all tasks alongside their peers in their everyday mathematics classes.

Pressure Manipulation

Prior to session 2, students were randomly assigned within each classroom to receive a performance-contingent, social-evaluative pressure manipulation prior to learning (LP condition), prior to testing (TP condition), or not at all (NP condition). To enable within-classroom condition assignment, the social-evaluative pressure manipulation was delivered via laptop, either at the start (LP) or end (TP) of the lesson.

We modeled our pressure manipulation after Beilock and colleagues (2004), who effectively induced feelings of pressure and social-evaluative threat by informing participants that their performance would determine not only whether or not they would receive a reward, but also whether or not a partner would. In our study, students in the high-stakes, pressured conditions (LP or TP) were told that they would be taking a test, and if they scored at least 80%, their class would be given a pizza party, but if they failed to earn 80% or higher, their class would lose the pizza party. Conversely, students in the low-stakes, no added pressure (NP) condition were told the aim of the study was to better understand how students learn mathematics and that they would be asked to solve some problems after the lesson. All prompts were made visible and narrated on the laptop. See Supplemental Materials for full condition manipulations.

Mathematics Lesson

Students watched a thirty-minute recording of classroom instruction during which a teacher introduces ratio to a class of fifth grade students. The teacher compares a correct strategy (least common multiple) and an incorrect strategy (subtraction, a common misconception) to solve ratio problems, both generated first and described by students in the videotaped classroom. This is a recommended teaching strategy (Common Core State Standards Initiative, 2010), but requires considerable higher-order thinking on the part of the learners (Author et al., 2016), making this lesson a challenging learning opportunity. The video lesson was segmented with interactive questions for participants to complete during learning. All students received the same instruction while remaining seated in their typical mathematics classrooms, affording much experimental control.

Assessment

The same assessment was administered at pretest and both posttests with counterbalanced item orders. The assessment was designed to assess students' conceptual understanding of ratio in addition to their procedural knowledge and included a mix of open-ended response items and multiple-choice questions (– & Author, 2016; see Supplemental Materials for sample items). Importantly, the assessments included items that not only measured students' ability to solve problem types introduced during the video instruction, but also their ability to transfer their understanding of ratio to untaught problem types and contexts. We obtained two scores for each test: accuracy, which was the proportion of problems answered correctly or solved using a valid strategy (out of 15), and misconception use, which was the proportion of problems students attempted to solve using subtraction (out of 5). Our four outcomes of interest were immediate and sustained gains in accuracy and misconception use, which were calculated by subtracting the pretest score from each posttest score.

Measures

Student Cognitive Resources

Student cognitive resources were assessed using the d2 Test of Attention, a measure of sustained and selective attention and inhibitory control (Brickenkamp & Zillmer, 1998). The task requires participants to search for target characters ("d"s with two dashes surrounding it) from among perceptually similar distractors (e.g., "d"s with one dash, "p"s with two dashes) under a time pressure and was group administered to each class. The focal outcome score analyzed in this study was the total number of items processed minus errors (TN-E), which yielded a range of 133 to 539.

Student Engagement

We assessed student mathematics motivation and engagement using both a behavioral (optional math puzzles) and self-report measure (situational interest and exploration intention).

Optional Math Activity. After completing the immediate posttest, students were given the option to engage with four math puzzles. The math puzzles were selected because they were designed to be fun and engaging: They involved detecting patterns and completing sequences. Students were informed they could choose whether or not to complete the puzzles. The students' other option was to independently read quietly. An example puzzle is provided in the Supplemental Materials.

Math Enjoyment and Exploration. Using a 5-point Likert scale, students rated the extent to which they found the lesson enjoyable (2 items) and the extent to which they were motivated to learn more (2 items) (Chen et al., 2001).

Results

Analytical Plan

We first describe pretest performance between the three conditions and confirm successful random assignment.

In our focal analyses, we first examine **predictors of student learning in the high (TP and LP) versus low-stakes (NP) experimental conditions** using a series of regression analyses. In the analyses, pretest performance and students' school were entered first as control variables (Step 1). Next, student gender, race and ethnicity (largest group, African American, as reference), and cognitive resources (range: 132 to 444) were added to the model (Step 2). Mirroring broad-scale patterns of achievement, we found that girls had larger learning gains in the low-stakes leaning context, while the gender gap disappeared, and showed possible trends towards reversing, in the high-stakes conditions.

To examine this effect of gender and learning context more precisely, we next tested **interactions between gender and each of the high-stakes social-evaluative pressure manipulations (LP and TP)**. Analyses revealed a significant interaction between gender and pressure condition, thus we subsequently examined impacts of pressure separately for boys and girls.

Finally, we describe **gender differences in student engagement in the high-stakes (LP and TP) versus low-stakes (NP) experimental conditions.**

We use regression analyses to test all focal analyses and report standardized beta coefficients and standard errors. Descriptive statistics for all study measures are provided in Table 2.

Pretest Performance

Pretest performance did not differ between the three conditions nor between boys and girls (all ps >.24). Pretest performance was not predicted by student cognitive resources or race and ethnicity, but did differ between schools. An indicator variable for school (largest school, School 4, as reference category), along with pretest performance were included as controls in all analyses of learning.

Predictors of Student Learning in the High versus Low-Stakes Conditions

Low-Stakes Condition

Among the 54 students (28 Girls) in the No Pressure (NP condition), girls exhibited significantly larger immediate mathematics gains ($\beta = 0.29$, $p = .03$) and trended towards greater sustained gains ($\beta = 0.21$, $p = .09$). Gender was the only student characteristic that predicted either immediate or sustained mathematics gains among NP students. Neither student cognitive resources nor race and ethnicity predicted gains following the lesson, although it is possible the model may have been underpowered to detect these relations. Results of the full regression analysis are shown in Table 3.

High-Stakes Conditions

All gender gaps in performance disappeared in the high-stakes learning contexts. Gender did not predict learning gains among students in either LP or TP (all ps > .45)

Gender Differences in Impacts of Pressure Manipulations

Pressure before Learning (LP)

We next examine the relation of student gender and the high-stakes LP and TP manipulations separately, this time testing the interaction between gender and condition. Gender marginally interacted with LP to predict sustained learning gains ($\beta = -0.32$, $p = .05$) and to a lesser extent, immediate learning gains ($\beta = -0.27$, $p = .07$). See Table 4 for full regression

analysis results. To understand these possible interactions, we separately examined the main effect of LP among boys and girls. For girls, LP predicted smaller immediate (β = -0.26, p = .04) and sustained (β = -0.29, p =.03) learning gains (Table 5, Figure 2), suggesting that pressure before instruction served more as a distracting threat than as a motivating incentive. Conversely, LP did not harm boys' learning. Instead, LP boys had numerically larger learning gains as compared to NP boys, although these differences were not statistically significant (Table 5, Figure 2).

Pressure before Testing (TP)

We next examined main effects and interactions of TP and gender. In contrast to the LP findings, the analysis indicated no main effect of TP or interactions with gender (Table 4). Notably, however, TP girls had numerically smaller learning gains than did NP girls, while among boys the reverse pattern was observed (Figure 3).

Gender Gaps in Engagement in the High versus Low-Stakes Conditions

Lastly, we examined students' mathematics motivation and engagement across the three conditions. Results of the full regression are shown in Table 6. Mirroring findings for learning, in the NP condition, girls exhibited higher engagement as compared to boys. Specifically, NP girls attempted more optional mathematics puzzles (β = 1.63, SE = 0.69, p = .02) and completed a greater number of these puzzles successfully (β = 1.96, SE = 0.61, p = .002). Additionally, NP girls trended towards reporting greater exploration intention and numerically reported greater enjoyment.

Conversely, in the LP and TP conditions, the gender gap in engagement not only disappeared, but in some cases reversed, mirroring findings on learning outcomes. LP boys completed more optional mathematics puzzles successfully (β = -1.11, SE = 0.55, p = .04) and

reported numerically greater enjoyment and exploration intention than LP girls. TP boys reported higher enjoyment than TP girls (β = -0.58, *SE* = 0.27, *p* = .03).

Discussion

Our findings lend evidence to suggest that gender differences in responses to high and low-stakes performance contexts may explain the seemingly paradoxical ways in which mathematics achievement remains patterned by gender. Among students in the low-stakes, no pressure condition, girls not only learned more, but also exhibited higher engagement outcomes. In contrast, gender gaps in learning disappeared in the high-stakes conditions, with boys and girls showing similar learning gains when pressure was imposed either before learning or before testing. With the introduction of pressure, gender gaps in engagement actually reversed, where boys now exhibited higher engagement outcomes.

The disappearance of gender gaps across the high versus low-stakes contexts raises the question as to whether this was due to pressure facilitating boys' mathematics learning and engagement, or whether it harmed girls'. The clearest answer from this experiment is that raising the stakes with pressure during learning was harmful for girls on average. Compared to girls in the no pressure condition, girls who experienced pressure while learning had significantly smaller learning gains immediately following the lesson and these differences persisted one week later, even after the threat of pressure was removed. Corroborating these learning differences, girls who experienced pressure while testing were less likely to attempt and complete optional mathematics activities than girls in the no pressure condition. However, data patterns suggest that the disappearance or reversal of the gender gap in the high-stakes contexts may also be partially due to pressure boosting boys' learning and engagement outcomes.

For girls, raising the stakes–particularly while learning–predicted lower learning, performance, interest, and motivation. Perhaps girls were already engaging effortfully with the lesson and assessments when the stakes were low. Raising the stakes with pressure may have generated intrusive thoughts and worries that interfered with cognitive engagement (see Beilock, 2008) while having limited incentivizing effects as girls were already engaged. This may have been the case particularly if girls were more math anxious or if an increased emphasis on performance invoked concerns that they would be judged stereotypically (e.g., Duckworth & Seligman, 2006; Ellison & Swanson, 2018). In contrast, raising the stakes appears to have facilitated boys' performance, interest, and motivation up to girls' baseline in the low-stakes context. Raising the stakes may have motivated boys, who otherwise may have been more likely to disengage during low-stakes instruction or testing (e.g., Easton et al., 2017; Gershenson & Holt, 2015), to exert more effort. Future research that probes precisely what aspects of the pressure context interfered with girls' learning and engagement while supporting those of boys could elucidate methods to raise mathematics achievement for all students across high and low-stakes settings.

Study 2

Study 2 aimed to address the relatively low power we held to examine the gender gaps in our data, and to explore whether the girls' higher achievement identified in our studies could be attributed to explanatory variables we were not able to include in our Study 1 analysis. We have taken advantage of the fact that we have tested this lesson in seven additional studies (four of which were previously published: – et al., under review*;* Author et al., 2017; – et al., 2018; Author & Author, 2020) conducted in 16 schools in the Chicago area. Here, we collapsed the data from all students in the control conditions of these studies. Students in these conditions

learned and tested under low-stakes conditions– they were informed that their performance would not be reported to anyone. Students were told to try their best on the lesson and test. These allowed us to test and characterize the presence of gender gap, and include additional tests of potentially explanatory variables to determine whether other affective, cognitive, or motivational factors could explain the identified relative gains by girls.

Method

Participants

Fifth and sixth grade classrooms at 16 private, public, and charter schools around Chicago were invited to participate in the studies analyzed here. Students who were absent on one or more study days were excluded from analyses, yielding 386 participants (52% girls). Where applicable, we used pairwise deletion to handle other sources of missing data (e.g., a tardy student). Students' self-reported race and ethnicity represented the Chicago area (48% Black, 18% Latinx, 21% White, 13% Biracial/Other).

Because each study assessed different affective, cognitive, and motivational elements of mathematics learning, we compiled these measures in a supplemental analysis to test determinants of the gender gap: None of these factors accounted for the gendered learning gap (see Supplemental Materials for analyses and details for each measure).

Design and Procedures

Study procedures were identical to Study 1, with two exceptions. First, pressure was not manipulated. We included only students who were assigned to the non-experimental, control conditions for their respective studies, meaning that all students learned in a context equivalent to the No Pressure (NP) condition of Study 1. Second, students in Study 2 completed additional

measures assessing affective, cognitive, and motivational elements of mathematics learning, which are described more fully in the Supplemental Materials.

Results

See Table 7 for descriptive statistics. We use regression analyses to test gender differences in pretest performance and learning gains. We include school fixed effects (largest school as reference) as schools differed in their pretest performance. Standardized beta coefficients are reported. Boys and girls did not differ in misconception use ($\beta = 0.01$) or accuracy ($\beta = 0.01$) at pretest. However, girls had larger gains in accuracy immediately following the lesson ($\beta = 0.36$), which widened at the final posttest ($\beta = 0.49$). Girls also had greater declines in misconception use at both posttests (Immediate: $\beta = -0.19$; Sustained: $\beta = -0.24$), whereas boys on average increased in their misconception use at both timepoints. Student race and ethnicity did not moderate gender differences in learning, nor did any motivational, affective, or cognitive factors account for the gender gap, though we did find evidence to suggest that boys might have had a less accurate–and often inflated–perception of their performance. See Supplemental Materials for more details.

Discussion

In our meta-analysis of our studies assessing students' learning from the same video ratio lesson as described in Study 1, we found a large gender gap favoring girls' learning from a conceptually-rich mathematics lesson on ratio in a low-stakes context. The students included in the meta-analysis were in the non-experimental control conditions, meaning their learning was low-stakes. Notably, this gender gap emerged from data across multiple research studies, schools, and classrooms. Though they had similar pretest performance, girls immediately learned more than boys from the lesson and sustained these gains one week later. Our supplemental

analyses suggest no cognitive, affective, or motivational elements of the learning context could explain the gap in boys' and girls' learning. These data are consistent with a growing body of literature (e.g., Souchal et al., 2014) demonstrating that girls outperform boys in low-stakes performance contexts, and provide new evidence from a learning context.

General Discussion

Across two studies, we explored gender differences in mathematics performance, testing the role of high versus low-stakes performance contexts as one possible explanation for the often-disparate patterns of gender gaps in mathematics achievement. All students watched the same video lesson on ratio and completed the same assessments. In Study 1, we conducted an experiment wherein we manipulated high and low-stakes by imposing a social-evaluative pressure either before the lesson or before the test. We found that when the stakes were raised, boys enjoyed the activity more than girls, and there were no differences in learning between genders. Yet, when learning was low-stakes, girls learned significantly more from and were more engaged during the lesson than boys. We further explored the role of gender in the low-stakes learning context in Study 2: An analysis of the 386 students assigned to the non-experimental control conditions across multiple data collections revealed a large, consistent gender gap favoring girls across a racially representative sample.

Across both studies, and consistent with a growing literature, we found that girls outperformed boys only in the lower-stakes, no pressure contexts. The stakes of the performance context may be an important contributor to gender differences in mathematics performance and feelings of interest and engagement, which contribute to longer-term likelihood of a STEM career. Raising the stakes has the potential to both incentivize and threaten mathematics performance, yet little work has considered this duality on STEM performance (though see

Cotner & Ballen, 2017; Souchal et al., 2014), nor specifically in explaining gender gaps in children's mathematics learning.

We assessed students' mathematics learning across one week and from one brief video lesson. However, given that mathematics concepts build upon themselves, initial gender gaps in learning may compound over time, underscoring the need for intervention. Importantly, this work and broader current achievement data patterns suggest that conducting research to improve classroom teaching in mathematics, while important, may not be the key lever to improving girls' participation in STEM pipelines, since much data suggests they are already learning as much, if not more than, boys in low-stakes contexts. Instead, we suggest that these more malleable contextual factors could be powerful leverage points impacting not only gateway high-stakes performance measures but also engagement and affective relationships to mathematics.

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Table 1

Participant self-reported demographics by school.

	School 1 Traditional Public		School 2 Catholic		School 3 Catholic		School 4 Charter		School 5 Private		Total
	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy	
White	1	0	5	7	0	1	3	2	16	9	44
Black	15	20	0	0	2	6	0	0	5	5	53
Latinx	0	2	0	0	4	1	17	21	0	0	45
Biracial	5	1	0	1	2	2	7	6	8	4	36
Total	21	23	5	8	8	10	27	29	29	18	178

Table 2
Mean pretest performance and learning gains among boys and girls assigned to the No Pressure (NP), Learning Pressure (LP), and Testing Pressure (TP) conditions.

	Pretest Performance (SE)	Immediate Gains (SE)	Sustained Gains (SE)
NP			
Boys (*n*=26)	0.25 (0.06)	0.13 (0.04)	0.12 (0.04)
Girls (*n*=28)	0.24 (0.05)	0.30 (0.07)	0.24 (0.06)
LP			
Boys (*n*=33)	0.21 (0.05)	0.16 (0.04)	0.18 (0.05)
Girls (*n*=30)	0.21 (0.04)	0.22 (0.04)	0.18 (0.04)
TP			
Boys (*n*=30)	0.20 (0.05)	0.23 (0.06)	0.22 (0.06)
Girls (*n*=31)	0.28 (0.05)	0.24 (0.05)	0.20 (0.05)

Table 3

Predictors of student learning in the No Pressure (NP) condition

Predictor	Immediate Gains		Sustained Gains	
	ΔR^2	β	ΔR^2	β
Step 1	0.25*		0.17*	
Pretest		-0.45**		-0.38**
School 1		-0.20		-0.18
School 2		-0.20		-0.20
School 3		-0.25^		-0.11
School 5		0.05		0.04
Step 2	0.16*		0.18*	
Girl		0.29*		0.21^
Cognitive Resources		0.10		0.21
White		0.42		0.41
Latinx		-0.08		0.03
Biracial		-0.06		-0.02
Total R^2	0.41		0.40	

Note. ^p <0.10 * p <0.05. **p <0.01.

Table 4

Regression analysis showing main effects and interactions of the Learning Pressure (LP; top) and Testing Pressure (TP; bottom) manipulations and student gender in predicting immediate and sustained learning gains.

Predictor	Immediate Gains		Sustained Gains	
Learning Pressure (LP)	ΔR^2	β	ΔR^2	β
Step 1	0.21***		0.14*	
Pretest		-0.42***		-0.35***
School 1		-0.21*		-0.16
School 2		-0.17^		-0.11
School 3		-0.23*		-0.13
School 5		0.11		0.13
Step 2	0.03		0.01	
Girl		0.16^		0.07
LP		-0.07		-0.03
Step 3	0.02^		0.03*	
LP*Girl		-0.27^		-0.32*
Total R^2	0.27		0.17	
Testing Pressure (TP)	ΔR^2	β	ΔR^2	β
Step 1	0.21***		0.16**	
Pretest		-0.44**		-0.38***
School 1		-0.23*		-0.16
School 2		-0.09		-0.03
School 3		-0.19		-0.15
School 5		0.05		0.10
Step 2	0.03		0.01	
Girl		0.17*		0.22^
TP		0.04		0.16
Step 3	0.12		0.01	
TP*Girl		⁻0.22		-0.20
Total R^2	0.25		0.19	

Note. ^ *p* <0.10 * *p* <0.05. **p* <0.01. ****p* <0.001.

Table 5

Regression analysis showing impacts of Learning Pressure (LP) among girls and boys separately.

	Immediate Gains				Sustained Gains			
	Girls		Boys		Girls		Boys	
Predictor	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	0.28**		0.19*		0.20*		0.15	
Pretest		-0.45**		-0.39		-0.33*		-0.34*
School 1		-0.34*		-0.05		-0.28^		-0.02
School 2		-0.1		-0.15		-0.14		-0.06
School 3		-0.17		-0.28*		0.01		-0.27
School 5		0.05		0.16		0.14		0.1
Step 2	0.06*				0.07*			
LP		-0.26*	0.01	0.07		-0.29*	0.02	0.13
Total R^2	0.34		0.2		0.28		0.17	

Note. ^*p* <0.10 * *p* <0.05. ***p* <0.01.

Table 6

Single regression analysis showing relations between gender and engagement outcomes in the No Pressure (NP; top), Learning Pressure (LP; middle), and Testing Pressure (TP; bottom) conditions.

	Exploration Intention			Enjoyment			Puzzles Attempted			Puzzles correct		
	R^2	β (SE)	t	R^2	β (SE)	t	R^2	β (SE)	t	R^2	β (SE)	t
NP Gender	0.05	0.47^ (0.29)	1.66	0.02	0.30 (0.27)	1.10	0.10	1.63* (0.69)	2.38	0.17	1.96** (0.61)	3.21
LP Gender	0.001	-0.08 (0.28)	-0.27	0.01	-0.27 (0.29)	-0.92	0.04	-1.05 (0.69)	-1.52	0.06	-1.11* (0.55)	-2.03
TP Gender	0.04	-0.46^ (0.28)	-0.21	0.07	-0.58* (0.27)	-2.17	0.007	0.46 (0.73)	0.73	0.07	1.30 (0.61)	2.12

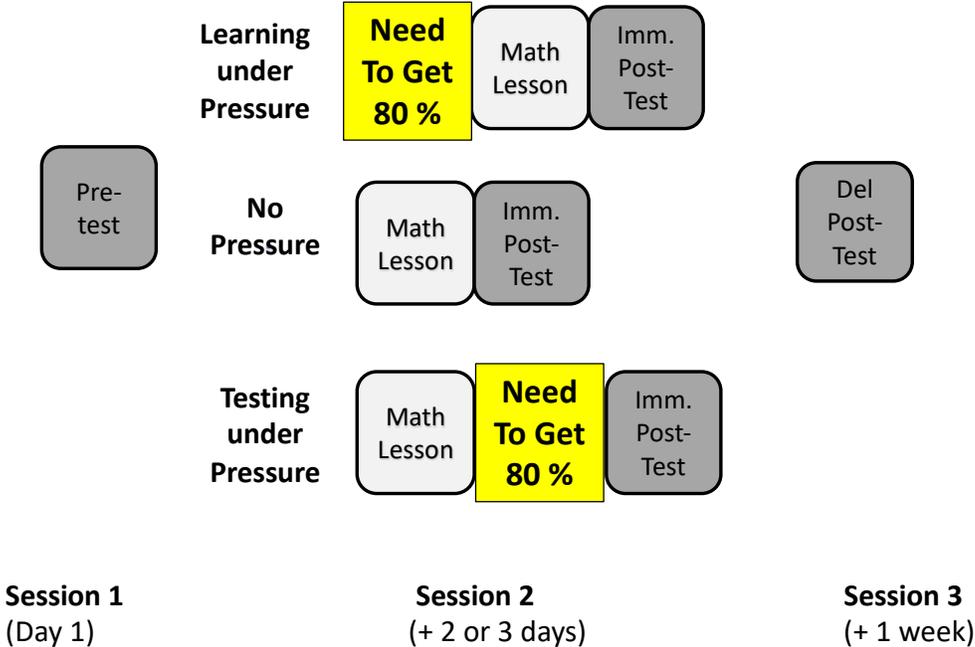*Note.* ^ $p < 0.10$ * $p < 0.05$. ** $p < 0.01$.

Table 7

Descriptive statistics and regression analyses for boys' and girls' learning measures.

M(SD)	Girls (n = 201)	Boys(n = 185)	β (SE)	t	Sig.
Pretest Score					
Accuracy	2.40 (3.12)	2.42 (3.23)	0.01 (0.10)	0.11	.92
Misconception Use	1.40 (1.56)	1.37 (1.54)	0.07 (0.10)	0.73	.47
Immediate Gains					
Accuracy	3.82 (4.36)	2.52 (3.82)	0.36 (0.10)	3.64	<.001
Misconception Use	-0.17 (2.01)	0.15 (1.83)	-0.19 (0.10)	-1.91	.06
Sustained Gains					
Accuracy	3.17 (4.36)	1.51 (3.41)	0.49 (0.10)	4.81	<.001
Misconception Use	-0.18 (1.89)	0.22 (1.72)	-0.24 (0.10)	-2.32	.02

Note. School fixed effects are included in regression analyses.

Figure 1

Overview of Experimental Procedure, Time course and Conditions

Learning under Pressure

Need To Get 80 % | Math Lesson | Imm. Post-Test

Pre-test

No Pressure

Math Lesson | Imm. Post-Test

Del Post-Test

Testing under Pressure

Math Lesson | Need To Get 80 % | Imm. Post-Test

Session 1 (Day 1)

Session 2 (+ 2 or 3 days)

Session 3 (+ 1 week)

Figure 2

*Differences in boys' and girls' learning gains between the No Pressure (NP) and Testing Pressure (TP) conditions. Error batrs are ± 1 standard error. * p <.05*

Learning Gains among boys and Girls in NP vs. LP Conditions
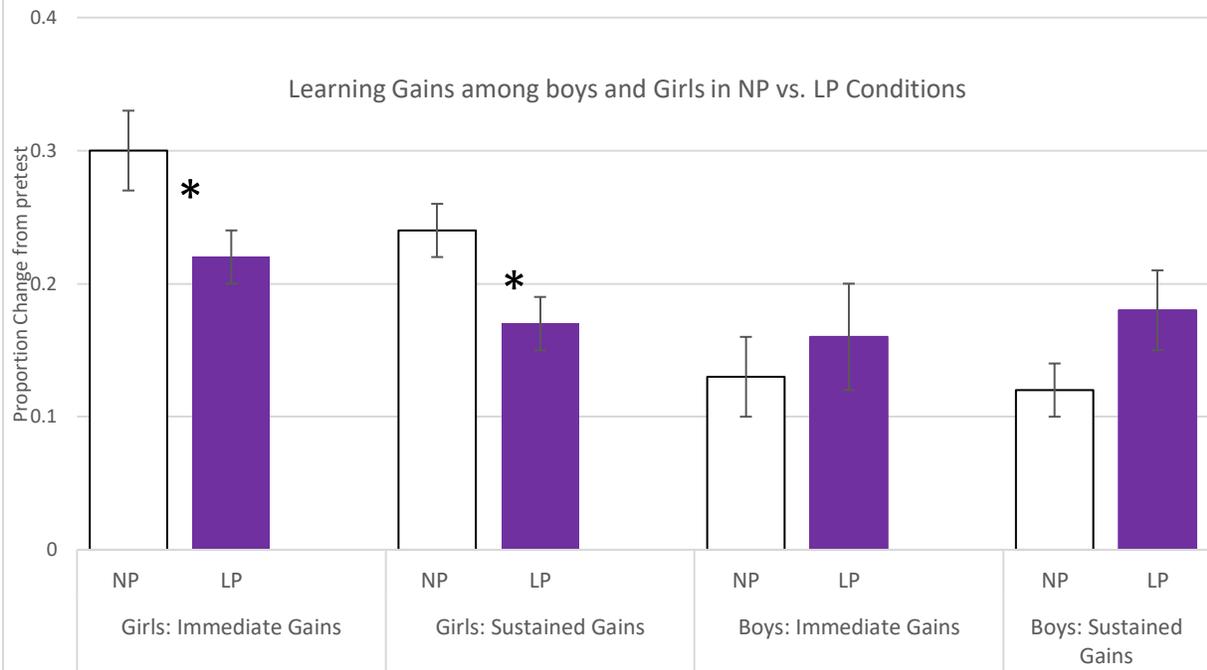
Figure 3

*Differences in boys' and girls' learning gains between the No Pressure (NP) and Testing Pressure (TP) conditions. Error batrs are ± 1 standard error. * p <.05*

Learning Gains among boys and girls in the NP vs. TP conidtions