ADDRESSING THE GENDER GAP IN MATHEMATICS: RESULTS OF AN INTERVENTION OF SINGLE-GENDER MATHEMATICS ACTIVITIES AT AN INDEPENDENT MIDDLE SCHOOL

Susanna Brock
The Berkeley Carroll School
Brooklyn, NY 11217

In the United States and other developed countries, high-ability girls are underperforming in mathematics compared to boys (OECD, 2015). The gender gap in mathematics achievement is evident as early as first grade and persists as women continue to be underrepresented in mathematics-related majors in higher education and mathematics-related professions (Ellison & Swanson, 2010). Girls tend to earn higher mathematics grades than boys in school and average differences on standardized tests tend to be small. However, the gap between boys and girls widens considerably among the highest achieving mathematics students (Wang & Degol, 2016).

Related to this disparity, girls tend to report lower levels of self-efficacy and sense of belonging in mathematics. Mathematics self-efficacy is the belief that one can successfully complete a mathematics problem (Pajares & Miller, 1994) and sense of belonging in mathematics is one's sense of membership and acceptance in the mathematics field (Good, Rattan, & Dweck, 2012). The gap between boys' and girls' self-efficacy in mathematics tends to mirror achievement; the gap becomes more extreme between highly gifted boys and girls (Preckel, Goetz, Pekrun, & Kleine, 2008). Differences in self-efficacy and sense of belonging in mathematics have been correlated with lower mathematics achievement (Dasgupta, 2011; OECD, 2015; Wang & Degol, 2016).

Assessing Student Self-Efficacy and Belonging in Mathematics

The present research study sought to address the gender gap in mathematics achievement at a co-educational independent middle school that has selective admissions and a high-achieving student body. The average student scores in the top 10% of students nationally on standardized mathematics achievement tests. In 2015 middle school boys outperformed girls on standardized achievement tests with a moderate effect size ($t(195) = -3.35$, $p = 0.01$, $d = 0.49$). There was no statistically significant difference in boys' and girls' verbal scores on the same tests.

A survey conducted in the spring of 2015 with middle school students (n=100 girls, 81 boys) documented a statistically significant

difference in the self-efficacy scores for girls (M=2.78, SD=0.63) and boys (M=3.05, SD=0.50; t(178)=-3.23, p=0.001, d=0.48). The difference in girls' (M=3.15, SD=0.60) and boys' (M=3.30, SD=0.58) sense of belonging scores was not significant (t(179) = -1.60, p = 0.111, d=0.25). In addition, the middle school students' mean mathematics self-efficacy and students' sense of belonging scores were significantly correlated with April 2015 mathematics achievement test scores (self-efficacy – $r(179) =0.22$, $p=0.003$; sense of belonging – $r(179) =0.22$, $p=0.003$). These correlations supported the findings from research literature that self-efficacy and sense of belonging are key constructs in understanding the gender gap in mathematics (Else-Quest, Hyde, & Linn, 2010; Good et al., 2012; OECD, 2015).

Literature Review

There is a great deal of research that seeks to determine if there are any biological differences between boys and girls that could mediate mathematics achievement (Geary, Saults, Liu, & Hoard, 2000; Halpern et al., 2007). At this point, biological and neuroscientific research have found little evidence between the brains of girls and boys that would reliably explain differences in learning (Eliot, 2013). More promising is work documenting the powerful influence that sociocultural influences can have on an individual's performance. In particular, research on psychological mechanisms of stereotype threat, the fear of confirming a negative stereotype about one's group, is helpful in making sense of the gender gap in mathematics. A body of research literature indicates that girls who are high achieving in mathematics may underperform in coeducational settings because gender is more salient when negative stereotypes are primed (Inzlicht & Ben-Zeev, 2003; Neuville & Croizet, 2007).

Although research on the potential benefits of single-sex classrooms in general has been equivocal (Pahlke, Hyde, & Allison, 2014), more targeted research on the advantages of all-girls classrooms for male-stereotyped subjects indicate that this approach could be helpful in promoting girls confidence and performance in mathematics by reducing the salience of gender as an identifying variable and lessening the negative effects of stereotype threat (Eisenkopf, Hessami, Fischbacher, & Ursprung, 2014; Kessels & Hannover, 2008; Picho & Stephens, 2012).

Intervention Design

The present research study investigated differences in middle school girls' self-efficacy, sense of belonging, and mathematics achievement following an all-girls mathematics class experience (Eisenkopf et al., 2014; Kessels & Hannover, 2006). The school piloted a single-gender mathematics course called "math workshop" once during each eight-day cycle of classes in 2015-2016 with students in fifth (n=53) and seventh (n=70) grades, for a total of twenty 50-minute sessions between September and June. This program was an additional mixed-ability mathematics class that was added to the students' schedules. Both boys and girls participated in the mathematics workshop program. Regular mathematics courses continued to meet daily in co-educational sections, grouped by ability into "on-level" and "advanced" tracks. During the pilot year of the mathematics workshop, students in the mathematics workshop participated in activities that were similar both in content and delivery to their regular mathematics classes. Students worked independently or in pairs on skills that were tested on the annual standardized mathematics achievement tests.

Pilot Year Results

The response to the pilot year was unexpected. Students in fifth grade seemed largely indifferent to the separation by gender, but students in seventh grade expressed a high degree of outrage about the change. The first two mathematics workshop classes of the year were devoted to explaining the theory of stereotype threat and sharing the results of the student survey, on which girls reported feeling less comfortable and confident in mathematics than boys. Several girls wrote angry comments on their papers expressing their frustration, including comments like "I am not stupid" and "I am not in the majority." These sentiments were recurring themes with the seventh-grade girls. Interestingly, girls with the highest mathematics achievement scores were the most upset.

To further express their discontent, the seventh grade students wrote a lengthy signed petition to the faculty that was signed by both boys and girls. Two points made in the petition were especially noteworthy. First, despite a detailed explanation for why the program was implemented, the seventh grade students felt the program implied girls were not as capable as boys in mathematics,

confirming instead of denying the stereotype. The petition read, "This class makes girls and boys alike feel as though you believe girls are not as good at mathematics as boys." Teachers made repeated efforts to dissuade students of this notion, but students remained unconvinced. Second, the students denied experiencing the negative effects of stereotype threat and claimed they were unaware of their gender in mathematics class. In the words of the petition, "When we are in a classroom situation that is co-ed, we don't spend time pondering our gender. In fact, we don't think about our gender at all." This quotation revealed a fundamental confusion about stereotype threat. The students had trouble understanding that stereotype threat refers to subconscious and implicit beliefs and not to a student's conscious awareness of identity threats.

In April 2016, middle school students took the standardized mathematics test. Changes in fifth-grade standardized mathematics test scores were not statistically different by gender (boys: M = 22.30, SD = 16.96; girls: M = 20.75 SD = 13.92). The results in seventh grade were also not statistically significant (boys: M = 2.31, SD = 12.25; girls: M = 5.00, SD = 12.13). However, in seventh grade the gender gap did reduce by approximately 6 percentile points compared to April 2015. In order to further investigate the potential of this type of intervention, the school administration decided to renew the program for a second year with some adjustments.

Year Two Study

A number of changes were made to the intervention for the second year. First, the curriculum and pedagogy of the mathematics workshop program was revised to emphasize open-ended problems that students would complete collaboratively. The middle school mathematics teachers identified topics in the curriculum that seemed to be relative weaknesses for students based on standardized mathematics assessments. The first 16 mathematics workshop sessions, conducted before the annual standardized testing period in April, aimed to address these specific content areas. The final four classes in each grade were devoted to an end-of year project. To ensure that the two mathematics workshop instructors were teaching with a similar pedagogical approach, both

were observed several times by trained observers using a Reformed Teaching Observation Protocol (RTOP) (Sawada et al., 2002).

A second important change was a new focus on communicating about the reasoning and research behind the program with parents and faculty, instead of students directly. In 2016-2017, fifth- and seventh-grade students participating in the mathematics workshop were introduced to the course with a brief one-sentence explanation: "Sometimes doing mathematics in a single-gender group helps girls feel more confident and have more fun doing mathematics." Following this introduction, students were immediately engaged in a problem-solving task. The negative student response during the pilot year suggests that excessive discussion about stereotype threat may have heightened gender awareness instead of lessening it as intended. Although prior research by Johns, Schmader, and Martens (2005) with undergraduates suggested that educating girls about stereotype threat could reduce its negative impact, this may not hold true for younger students. Finally, students in the second year were asked to self-identify their gender identity at the beginning of the year. If their gender identity did not match their assigned sex at birth they were asked which class they felt most comfortable attending. Students who identified their gender as non-binary were permitted to work separately or join either group.

Method

This study used a mixed-method pretest-posttest treatment-control group approach to evaluate the effects of the intervention during the second year on three dependent variables: students' mathematics achievement scores, students' self-efficacy scores, and students' sense of belonging scores. A pretest-posttest design was used, and students' scores on the three variables were compared before and after the intervention. The change in scores for girls who participated in the intervention were compared with boys who participated in the intervention to determine if this intervention benefitted girls more than boys, thereby helping reduce the gender gap. In addition, a control group, constituting students in sixth and eighth grades, was selected to match the characteristics of the treatment group. The control group students were similar in age, attended the same school, and had a similar distribution of

mathematics achievement test scores. Year-over-year changes in standardized mathematics achievement scores and pre- and post-intervention survey responses regarding mathematics self-efficacy and sense of belonging for students who participated in the intervention (students in fifth and seventh grades) were compared against changes for middle school students who did not receive the intervention (students in sixth and eighth grades). Qualitative data, in the form of interviews conducted with girls who participated in the intervention, were used to help understand the quantitative results and to strengthen reliability and validity through tri-angulation.

Participants

In September 2016, 251 out of a total enrollment of 285 students in the middle school (89% participation rate) completed the mathematics attitude survey regarding self-efficacy and sense of belonging. This group included students in fifth and seventh grades who participated in the math workshop intervention and those in sixth and eighth grades who did not. The results in this research study include only those students (n=203) who gave assent and whose parents provided consent for their participation in the research study. The research sample represents approximately 70% of the student body in the middle school.

Results

Mathematics Achievement

Analyses of the standardized tests results suggested that, during the intervention year, the mathematics workshop program was effective in reducing the gender gap in mathematics test scores for some students. Specifically, the results indicated that the all-girls mathematics workshop intervention helped to close the mathematics gender gap between high-ability boys and girls in the intervention group, with girls in the advanced ability groups in fifth and seventh grades (n=32) gaining more scaled score points on average (M=12.09, SD=9.74) than advanced boys (n=27) (M=5.11, SD=12.99), $t(57)$= - 2.36, p =0.022, d =0.60. The benefits for students in the on-level ability group were more equivocal, and did not reach statistical significance.

Sense of Belonging

Analysis of survey responses indicated that students who participated in the mathematics workshop intervention saw a greater increase in sense of belonging scores compared to students in sixth and eighth grades who did not receive the intervention (t (200) = 2.299, p =0.023). However, this result was not significant by gender. Both boys and girls who received the intervention reported an increased sense of belonging in mathematics.

Self-Efficacy

A 3-way ANOVA for the main effects of gender (boy, girl), ability grouping (on-level, advanced), and intervention (intervention, control) on students' self-efficacy found no statistically significant effects.

Qualitative Data

Interview data were used to help make sense of the quantitative findings. Of 12 girls interviewed, nine of them distinguished the math workshop from their mathematics class as being more "fun," citing the opportunity to work with friends, the all-girls environment, the reduced focus on tests, and more open-ended material. Of these explanations, the most pronounced theme was the importance of friends. Eight of the 12 interviewees mentioned working with peers as helping them feel more confident and comfortable in mathematics. One fifth grade girl said:

> I like how it's only one gender and it's just girls. It makes me feel stronger and sometimes like I can feel if there is...sometimes in my regular mathematics class there can be some boys that always call out the answers and don't like let everyone else just think about it. So it makes me feel better to have a group of girls working together and it makes me feel stronger. And no one calls out most of the time…they all work together and that makes me feel good. (Fifth-grade girl, personal communication, May 9, 2017)

Implications for Research and Practice

The study provides insights into the potential challenges and benefits of implementing a supplementary all-girls mathematics class in a coeducational middle school. There are several main

findings from this study. 1) Supplementary all-girls mathematics classes may be beneficial for certain populations. In particular, this study provides support for the hypothesis that all-girls classes may improve achievement for girls of high-mathematics ability and identity. 2) Mathematics classes or supplemental mathematics activities that are single-sex may increase middle-school students' sense of belonging regardless of gender. 3) Sense of belonging in girls may have been influenced by a "friend effect," or what girls' reported as an increase in confidence and enjoyment when solving mathematics problems with their friends.

Limitations

This research study had several limitations including a small sample size (n=203), and the lack of a randomized control group. The design used a matched control group. All participants in the study attended the same school, whose students are predominantly affluent socioeconomically, majority white, and generally high achieving in both mathematics and verbal domains. It may be difficult to generalize from this sample to other populations. Another limitation common to studies of the relationship between mathematics self-efficacy, sense of belonging, and achievement is the reliance on self-report measures of self-efficacy and sense of belonging. Many young students are not aware of their own feelings about mathematics, and may be unmotivated to complete a survey thoughtfully. Given that stereotype threat functions at a largely implicit level, explicit report measures may fail to capture changes in self-efficacy and sense of belonging accurately. Future studies may consider using an Implicit Attitudes Test (IAT), which aims to assess attitudes that exist below conscious awareness.

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