



Do single-sex schools enhance students' STEM (science, technology, engineering, and mathematics) outcomes?



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ABSTRACT

In many countries, males currently lag behind females in schooling attainment but females are still under-represented in STEM studies. This pattern has raised renewed interest in the potential of single-sex schools for enhancing STEM outcomes. Utilizing the unique setting in Seoul, where assignment to single-sex or coeducational high schools is random, and with multiple years of administrative data from the national college entrance examinations and a longitudinal survey of high school seniors, we assess causal effects of single-sex schools on students' math test scores and choice of the science-math test. We also assess whether single-sex schools affect students' interests and self-efficacy in math and science, and expectations and actual choices of a STEM college major in university. We find significantly positive effects of all-boys schools consistently across different STEM outcomes but not for girls. We address one possible mechanism by conducting mediation analysis with the proportion of same-gender math teachers.

1. Introduction

Cultivating sufficient numbers of graduates in science, technology, engineering, and mathematics (STEM) occupations has become an important policy concern in many developed countries. A recent study predicted the need for 1 million STEM graduates over the next decade to respond to the growing labor market demand for STEM professionals in the United States (President's Council of Advisors on Science and Technology, 2012). However, the supply of U.S. STEM students is projected to be short (Chen, 2013).

In recent decades, worldwide females have significantly improved their schooling attainment and previous gender gaps favoring males have been substantially reduced and in many contexts including most high-income countries reversed to favor females (Buchmann, DiPrete, & McDaniel, 2008; Grant & Behrman, 2010). The significant overall schooling progress of women is, however, accompanied by persistent underrepresentation of women in STEM college majors, particularly in engineering and mathematics (Freeman, 2004; NCES, 2007).

The lower likelihood for women to choose STEM majors in college naturally leads to limited supply of women in STEM occupations (Frehill, 1997; Xie & Shauman, 2003). Given the growing importance of the science and engineering workforce in globalized economies as well as concerns about gender equity, a variety of educational programs and

research activities to attract women to STEM fields have been enacted (NSF, 2006a, b). Given the growing demand for STEM-trained workers, to attract more female college graduates as well as male students to STEM fields efficiently, systematic evidence is required regarding what factors constrain or enhance students' pursuit of STEM majors and entrance later to STEM occupations.

The major purpose of the current study is to assess the impact of one particular institution that can influence students' STEM outcomes – single-sex schools (Mael, 1998; Sax, Shapiro, & Eagan, 2011; Sullivan, 2009; Jackson, 2012; Sohn, 2016). In this study we first examine causal effects of single-sex schools on high school seniors' national college entrance exam scores on math for seven different senior cohorts (2004–2011, except 2007) in South Korea (hereafter, Korea). Our examination across seven different cohorts helps assess how robust are our estimates of the effects of single-sex schools. Secondly, we investigate causal effects of single-sex schools on students' choice of advanced mathematics. There are two types of national college entrance examinations for math in Korea: general-math and science-math tests. The general-math test is taken by students who apply for university admissions as humanities and social science majors, while the more advanced science-math test is required for those who apply for STEM majors. Therefore, students' choice of the science-math test is an important outcome to be examined with respect to STEM careers. Thirdly,

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using different data from a small-scale longitudinal survey of high school seniors, we assess whether single-sex schooling increases students' interests and self-efficacy in math and science subjects and their expectations to major in a STEM area when they enter college. We expect that increased students' STEM interests, self-efficacy, and expectations are related to their enhanced performance in math and ultimately to the probabilities that they will pursue STEM careers. Finally, we investigate whether those who graduated from single-sex high schools are more likely to attend university with STEM college majors within two years after high school than their counterparts who graduated from coeducational schools.

We investigate these questions for Korea because of the random assignment of students into single-sex and coeducational high schools in Seoul (capital of Korea with population of 10 million) that will be described below in more detail. The unique setting of Seoul high schools provides an exceptional opportunity of estimating causal effects of single-sex schools on students' STEM outcomes. Our analyses of math test scores and the choice of the science-math test are based on administrative data that contain information on all high school seniors in Seoul who took the national entrance examinations for the period 2004–2011. In Korea, more than 95% of students in academic high schools take this examination that is given once a year in November.

We, furthermore, attempt to address possible mechanisms through which single-sex schools affect students' math test scores and choices whether to take the science-math test. First, we present single-sex school effects on Korean and English test scores as well as STEM outcomes. Even though this exploration does not directly identify a mechanism for single-sex school effects, the comparison between non-STEM and STEM outcomes can help us to understand to what extent single-sex school effects are specific to STEM outcomes or general across different subjects. In other words, we can address the extent to which separating female and male students is particularly conducive to enhancing STEM outcomes. Second, using the same administrative data of high school seniors in Seoul linked with school-level information on the numbers of female and male math teachers, we investigate how the gender composition of math teachers may account for single-sex school effects on math-related outcomes. In order to assess to what extent the role of the gender composition of teachers in accounting for single-sex school effects is specific to STEM outcomes, we repeat the analysis for Korean and English test scores as well using *subject-specific* numbers of female and male teachers (i.e., the share of male teachers in each subject of Korean and English).

There are many claims that single-sex schools (or classrooms) enhance educational outcomes, particularly in STEM for female students, because of the absence of social interactions with boys that divert attention from academic activities and because of the absence of competition from boys for teachers' attention (Mael, Smith, Alonso, Rogers, & Gibson, 2004; Riordan, 1990). However, some other studies question any benefits of single-sex schools, highlighting the likelihood that better educational outcomes among students in single-sex than their peers in coeducational schools may simply reflect prior differences in ability, motivation and other background factors between students in single-sex and coeducational schools before entering the schools (Jackson, 2012; Lavy & Schlosser, 2011; LePore & Warren, 1997; Marsh, 1989). If students, or their families, choose between single-sex schools and coeducational schools, students attending the two types of schools probably differ in their characteristics, including those difficult to measure such as ability, motivation, effort, and parental involvement in children's education that could potentially affect students' educational outcomes. This self-selection may lead to biased estimates of the single-sex school effects from observational data (Mael, Alonso, Gibson, Rogers, & Smith, 2005; Sax, 2009).

Although there has been an increasing body of studies that attempt to estimate causal effects of single-sex education or effects of gender composition on educational outcomes, the results are quite mixed.

Booth, Cardona-sosa, and Nolen (2013) conduct an experiment in a coeducation university to examine the effect of single-sex classes on performance of college students taking economics courses (also see Booth and Nolen, 2012a, b). They find positive effects of single-sex classes for females and no effects for males, and they suggest that their findings are consistent with a reduction in stereotype threat for females. Investigating the impact of single-sex education on math achievement at the top of the distribution in Ireland, Doris, O'Neill, and Sweetman (2013) find that boys in single-sex schools are more likely to show better performance than their counterparts in coeducational schools with little evidence of a similar effect for girls. Schneeweis and Zweimuller (2012) study the causal impact of the gender composition in coeducational classes on the choice of school type for girls in Austria. They find that if girls were exposed to a higher share of girls in earlier grades, they were more likely to choose a male-dominated school type at the age of 14. In contrast, some recent studies find little evidence for positive effects of single-sex schooling on STEM outcomes (Jackson, 2012; Nagengast, Marsh, & Hau, 2013; Sohn, 2016). In sum, despite recent attempts to identify causal effects of single-sex schooling by addressing selection bias using various methods and research designs, we still need more evidence on relevant outcomes under various contexts to better assess the potential costs and benefits of single-sex schooling.

According to the national policy for high school equalization in Korea, especially Seoul, middle-school graduates, who advance to academic high schools (the major form of high schools in Korea), are randomly assigned into high schools within residential school districts regardless of whether schools are single-sex or coeducational, and also whether schools are private or public. In Seoul for the time period for which we have data, students attending academic high schools could not choose their schools, and academic high schools had to receive students who were assigned by lottery. It is notable that this policy of random assignment has been implemented for a long time, since 1974, and so single-sex schooling due to random assignment is not a novelty but instead a long-established institution. Therefore, a potential bias in estimating the effect of a novel and innovative program, caused by participants' 'novelty-based enthusiasm' or interest in innovation, is not of serious concern for evaluating the impacts of single-sex school effects in Korea (cf. Behrman & King, 2008; Halpern et al., 2011; King & Behrman, 2009). Moreover, the number of students attending single-sex high schools is considerable, suggesting the broad relevance of single-sex schooling.

In an earlier study Park, Behrman, and Choi (2013) used this unique random assignment to assess the effect of single-sex schools in Korea on students' scores on Korean and English subjects for a high school senior cohort without examining any outcomes directly related to STEM. They found that both boys and girls attending single-sex schools showed better performance on Korean and English tests than their counterparts attending coeducational schools. However, it is notable that the effects of single-sex schools were more substantial among boys than girls. Park et al. (2013) also used school-level data on the number of graduates who transitioned to college to investigate the effects of single-sex schools on overall college attendance rates but did not examine students' choices of STEM college majors. Our current study significantly extends the previous study not only by focusing on a set of explicit STEM-related outcomes, but also by assessing the role of gender composition of teachers in accounting for single-sex school effects. By presenting the results for Korean and English test scores as well as STEM outcomes, we address the extent to which single-sex school effects and the roles of gender composition of teachers to explain such single-sex school effects are specific to STEM outcomes. Also, by examining the effects of single-sex schools across seven different cohorts of high school seniors, our estimates of the single-sex school effects should be more robust than those based on only one cohort in Park et al. (2013) study.

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