

Analysis of the Impact of Single-Sex Education on Female Mathematics Anxiety

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Abstract: Mathematics anxiety (MA) is the most common phenomenon in students' study lives, and gender differences exist. Studying MA can play a supporting role in mathematics courses, including the difficulty of test questions and course design. The main objective of this paper has attempted to analyze the impact of single-sex education on female Mathematics Anxiety (MA), particularly research on the relationship between gender stereotypes and female MA. The literature reviews focusing on the causes of MA, the mechanism of MA affecting gender differences, MA levels and mathematics education under single-sex education, as well as the relationship between gender stereotypes and MA can show single-sex education plays a positive role in reducing female MA to a certain extent. This research is expected to improve public education and reduce sexism and gender stereotypes based on understanding the beneficial effects of single-sex education on women.

Keywords: mathematics anxiety, single-sex education, gender stereotype

1. Introduction

Mathematics Anxiety (MA) is described as the feeling of tension, helplessness, disorganization, and having more physical responses while dealing with math [1, 2]. It manifests as a fear of learning and using mathematics, which would be experienced in school and everyday life [3]. Previous studies have demonstrated a negative relationship between MA and math performance [4]. The association between MA and performance may form a vicious circle: for some people, low math performance can lead to MA, and MA, in turn, can make their math performance even worse [5]. MA is strongly associated with math performance but cannot be attributed to math problems [6]. Additionally, studies have reported that people with high levels of MA may secrete more cortisol secretion (stress-related behavior) [7]. Still, current research has not been able to prove it is not entirely clear that MA and the cortisol reaction are directly and absolutely related [6].

Numerous studies have shown that females generally have higher MA than males [4, 6], and there are multiple reasons for this result. Most studies suggest that compared to males, females tend to express more anxiety [6,8,9]. Moreover, it is not just mathematics, women also show more anxiety than men in foreign language learning [10]. Overall, women are more susceptible to MA since their higher anxiety levels. Besides, males are more likely to express confidence than females [6]. Another possible explanation is that stereotypes often threaten women in social life and academic ability [11, 12]. Gender stereotypes are generalizations of attributes shared by men and women in society, including a descriptive component (describing how women and men are) and a prescriptive

component (specifying how women and men should or should not be) [13]. Specifically, women were prompted that men were better at math than men in the process of math learning [6].

Single-sex education is the process of teaching in which students of different genders attend separate classrooms. The principle of this education is teaching students fairly and in a targeted way based on the diversity between males and females. The core of this kind of educational model is to break sexism and seek proper. Several studies provide evidence contrary to the prevailing belief that single-sex learning environments are advantageous and crucial for increasing women's participation in science fields at higher levels [14]. Compared with putting women into society, single-sex education can play a certain role in suppressing sex discrimination and stereotype threats, help promote women's self-awareness development, and enhances achievement-oriented behavior. Girls in single-sex schools may be more likely than girls in coeducational schools to think of their math skills as malleable [15]. Studies have shown that single-sex schools typically have girls with higher levels of self-esteem than coeducational schools and may make it easier for women to be motivated to pursue careers in STEM fields [15,16].

Based on the above contents, the reason why women's MA is generally higher than that of men may come from the existence of women's role in specific social conditions. Besides, as social animals, humans often compare themselves with others before making self-assessments to obtain more accurate evaluation results [17]. Under such conditions, human beings will even compare with others unconsciously. Gender comparison between men and women is human beings' most common comparison activity. In order to fit the research theme, under the condition of single-sex education, the process of receiving education between men and women in the same time is isolated, thereby reducing the gender comparison in the learning process. This review aims to investigate the impact of single-sex education on female MA, especially regarding stereotype threat, by discussing the cause of MA and the mechanism of MA affecting different gender and comparing MA levels between women in single-sex education and in public education. Thereby discussing the influence of stereotype threat on women's MA and even on women's personal cognition and role development.

2. Methods

A thorough literature search was carried out utilizing the database Google Scholar. In addition, supplementary sources in Google Scholar were added in order to generate more inclusive, multi-validated literature reviews. The following search terms, and their derivatives were entered: mathematics anxiety, single-sex education, stereotype threat, math performance, women's development, mechanism, gender difference, compare, cause, effect, and relationship. Studies were included if they: (i) have been published after 2000 (as premature research conclusions may not be adapted to the state of the research), (ii) contain a summary of previous research, (iii) multiple parties can verify the conclusion, (iv) contain empirical data (includes case studies, empirical investigations and experimental setups), (v) stereotype threat on women, (vi) contain some kind of analysis relating to MA, single-sex education, and stereotype threat.

3. Review and Analysis

3.1. Causes of MA

Although the causes of the emergence of MA are unclear, latent causal factor variables can still be roughly divided into nature (e.g., brain development, intellectual factors) and nurture (environmental and social factors) [4]. Studies have shown that MA is unlikely to have a unique genetic component. By contrast, general anxiety-related predisposing genetic risk factors influence MA [6]. In other words, in the presence of math-anxious parents, children are likely to have MA too. Nonetheless, this genetic source of anxiety is not directly caused by MA, but by other general factors related to anxiety.

For example, parents with MA may have a psychological condition that is more likely to perceive anxiety, and this perception skill is likely to be passed on to offspring. Besides, personality variables (e.g., personal cognition, self-esteem and confidence, personality traits) are also important variables affecting MA [18]. Students who lack self-confidence are also prone to MA. However, there is still uncertainty. Whether the personality factors are more influenced by nature or nurture. From the perspective of external factors, related studies report that teacher anxiety, teacher adversarial behavior, teacher inexperience, peer pressure, content difficulty, and school as well as the surrounding environment, can all contribute to students' MA [19]. In addition, MA is also often accompanied by test anxiety [4,6,19].

3.2. Gender Differences of MA's Mechanism

According to research, males and females have different sources of MA. Male MA stems from consistently poor math grades [20], while females have more complicating factors. Furthermore, once it manifests, women's MA tends to continue steadily throughout time [20]. Previous studies showed that external or situational factors strongly influenced women's math performance, with stereotype threat being the most prominent [21,22]. The level of woman's recognition that is threatened by stereotypes plays a crucial role, long-term experience with mathematical stereotypes in society and schools may lead girls to accept and endure them eventually, and this would have an adverse effect on their MA, as well as their arithmetic ability [12]. Still, there were no gender differences in the conditions where the stereotype was not presented or where they were informed of the hazard of stereotypes [23]. However, some studies suggested that perhaps MA itself is more affected by self-perceptions of MA than gender stereotypes [6]. Other research also found that female teachers' MA can impact girls' MA, performance, and amount of math learning, but boys were unaffected [24].

In addition, most studies indicated that such gender variations in MA only appear in adolescence and do not occur in primary school students [6,25,26]. Regarding the stability of MA, women are more stable than men. The specific performance showed that low early math performance in men might lead to high MA throughout the math learning cycle, but the condition seems to produce high MA only at crucial transition points for women [20]. Depending on whether one is analyzing the cognitive or affective component of MA and what areas of mathematics are involved, gender impacts on the relationship between MA and performance may also be a factor [6].

3.3. MA and Mathematics Education Under Single-Sex Education

Although there are too few studies on MA in single-sex education, there is still evidence that female students in single-sex education have less MA than co-educational students in general [27]. The reason for less MA in single-sex education needs to be clarified. Changes in teaching patterns, narrowing of the field of competition, less exposure to stereotypes, and less anxiety other than MA are all possible scenarios. It can be proved that single-sex education has a certain influence on female students' attitudes toward mathematics learning. According to related research reports, the attitudes of boys and girls taught in single-sex schools toward math are similar, despite the fact that boys are generally more inclined to think favorably of math than girls [28]. The difference between single-sex education and co-educational education can be roughly divided into gender identity and the learning atmosphere.

From the perspective of gender identity, women in single-sex education have a higher sense of self-identity. Since gender is more prominent in a co-educational environment, masculinity and femininity accepted in social environments significantly impact students' self-identity [29]. In this pattern, educational options could become increasingly gender-stereotypical in a co-educational system [30]. On the contrary, the gender concept is not so important in the single-sex education

environment, which provides more freedom for female students to explore their interests and talents, and forming a self-concept is less influenced by gender-related knowledge and attitudes [29]. Under such circumstances, women's self-concepts are formed more from themselves and other aspects that have nothing to do with gender, thereby increasing their sense of self-identity, including self-affirmation in the process of learning mathematics.

On the other hand, single-sex education provides students with a relatively looser and more targeted learning environment. The looser learning atmosphere means that the single-sex education environment will weaken the gender influence of social conditions and provide female students with a broader perspective of personal development. Additionally, studies have demonstrated that teachers' interactions with males and females in co-educational groups are different [31]. In math classrooms, teacher-student interactions are mostly evenly distributed, but the remaining minority of interactions are directed at male students [31,32]. In co-educational mathematics groups, teachers have been seen to compliment and encourage male students more frequently than female students [32]. Furthermore, the competitive atmosphere of co-educational schools makes men show higher self-identity and be more positive about their mathematics ability to maintain the concept of gender [32]. These survey facts highlight the benefits of single-sex education for women in the learning environment.

3.4. The Relationship Between Gender Stereotypes and MA

Before demonstrating the impact of gender stereotypes on MA, introduce a concept that is related to both of them—mathematical performance first. A related study has shown that both MA and stereotype threat have a similar mechanism to make the disruption of mathematical performance occur [33]. MA can take up working memory resources, causing a decrease in memory capacity, which can lead to poor performance [33]. Similarly, the stereotype threat literature's study also contends that when threatened, people ruminate and have negative thoughts, temporarily reducing working memory capacity and impairing performance [34]. Additionally, as mentioned above, female students show worse math performance in the premise that mentions gender stereotypes.

In this case, the relationship between gender stereotypes and MA is more varied. Other studies suggest that gender stereotypes can negatively impact women's math performance since they can raise their MA levels, which in turn affects their degree of math self-concept [12]. Although few relevant studies have demonstrated the specific mechanism of gender stereotypes on MA, it can be guessed that the negative thoughts women experience when they are subjected to gender stereotypes include feelings of anxiety. In the face of specific mathematics situations, anxiety may turn into a specific MA. However, the deeper relationship between gender stereotypes and MA still needs further research.

4. Limitations and Suggestions

4.1. Limitations

The major limitations of the present study are the focus on insufficient statistics in single-sex education research and inconsistencies in research findings. In terms of gender stereotypes, this article focuses on demonstrating the role of single-sex education in reducing gender stereotypes, and pieces of literature support this view. Nonetheless, other kinds of literature still put forward the opposite opinion. For example, some previous studies suggest that sex discrimination could lead to more gender stereotypes, which may lead to sexism legalization [35]. The view that Girls at single-sex schools may feel more pressure to conform to gender stereotypes and be more gender-typical is still being discovered by related studies [36]. The reason for too many different opinions may be that there is still a lack of reliable empirical research comparing the effects of single-sex versus co-educational education [37]. From the perspective of MA, most studies focus on bad outcomes rather than the

causes and environments that lead to MA [38,39,40]. In addition, the complex social background is also this study's main force major factor. This paper attempts to prove that gender stereotype threat is the main factor of female MA by analyzing the impact of single-sex education on female students' MA. However, gender stereotyping is a long-standing social fact, and no single environment can eradicate the threat of stereotyping women, including single-sex education.

4.2. Suggestions

The concept of gender equality should be emphasized by schools and relevant education departments, and mathematics classrooms and other classroom development models should be carried out based on blurring gender concepts and reducing gender discrimination. More research should be carried out on the causes and environmental factors leading to MA and the mechanism of gender stereotypes in MA. Although single-sex education provides a new perspective for reducing sex discrimination, stereotype threat, and reducing women's gender pressure, there is still no definite research to prove that single-sex education is better for women's life development than public education. This study is expected to deeply understand the negative impact of the threat of gender stereotypes on women's personal cognition and long-term development, understand why the single-sex education model benefits to women's development, and then improve public education on this basis. Ideally, the threat of sexism and gender stereotypes can be eliminated without gender segregation.

5. Conclusion

This article argues that gender stereotypes play an essential role in women's MA, and even in women's personal cognition and role development by discussing the causes of MA, the mechanism of MA affecting gender differences, MA levels and mathematics education under single-sex education, as well as the relationship between gender stereotypes and MA. The causes of MA can be roughly divided into congenital and acquired factors, innate personality and self-confidence level, as well as the influence of acquired ideas, school environment and teachers are all important factors leading to MA. Gender differences can also show up in MA, and a large number of studies suggest that females generally have higher MA than males. Males and females differ in the source factors and stabilization of MA. In addition, women's attitudes towards mathematics are more likely to be influenced by external or situational factors, especially stereotype threat. In this case, weakening the concept of gender and providing the more consciously free choice of single-sex education to a certain extent positively changed woman's attitudes towards mathematics and other science and engineering subjects. Despite that, there is no evidence that women have higher MA than men solely due to gender stereotypes. Related studies have found that under the single-sex education survey, women's enjoyment is still low. Findings like these could provide a clue to the argument that women are inherently more anxious than men. Regardless, it can be guaranteed that single-sex education under the reduction of gender stereotypes can reduce female MA.

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