

Study of Gender Differences in Mathematics

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Abstract: Mathematics is an essential subject at every stage of learning. The importance of mathematics lies in the excellent application and practice of theoretical knowledge, which in turn requires a very high level of logic from students. Statements such as “boys are better at logic and maths” and “girls are better at liberal arts” are frequently discussed in the realm of education, leading to the formation of stereotypes. Research has shown differences in the physiology, mindset, and upbringing of boys and girls, which are the main factors influencing students’ mathematics performance. The differences in the physiology of males and females will be first analyzed, including differences in brain structure and hormone production, which leads to the differences in thinking and emotions between males and females. Secondly, the deeper reasons why male and female students perform differently in mathematics will be explored based on a thorough understanding of the subject’s characteristics, guided by several theories about stereotypes. Finally, the different approaches to learning resulting from the different psychological phenomena between male and female students will also be discussed as an essential factor in the differences between the male and female performance in mathematics.

Keywords: gender, social psychology, mathematics, stereotype

1. Introduction

Mathematics is a universal means for humanity to describe and derive things’ abstract structures and patterns rigorously. In the development of human history and social life, great mathematicians have invented many theories of practical significance, so mathematics can be applied to the real world to solve complex problems. Mathematics plays an irreplaceable role and is an essential tool for studying modern science and technology to help society develop, which is why people need to look at children’s ability to learn mathematics at the educational level [1].

As a result, the factors contributing to mathematical ability’s strengths and weaknesses are also widely discussed in the academic field. Among these discussions, the differences in mathematical performance due to gender differences have stirred up intense sparks. A report from the CST Digital Library shows that, from a national perspective, countries with significant gender differences and where male students are better at mathematics include Tunisia and South Korea. In comparison, countries, where female students are better at mathematics include Jordan and Bahrain. However, the USA, Sweden, and Germany show no gender differences [2].

Some educationalists also argue that some female students excel in mathematics at the junior high school level but often pale compared to their mathematical studies at the senior high school level.

The difference in female students' performance in mathematics at the junior and senior secondary levels includes an inability to adjust to mathematics in senior secondary school. Passive learning leads to low learning efficiency as the knowledge of mathematics becomes very difficult and complex at the high school level [3]. Regarding significant college choices, female students accounted for 57% of 2016 college graduates in the US, but only 43% of math graduates were female; in engineering and computing, they accounted for only 19% and 18% [4].

Meanwhile, a study released by UNESCO shows that the gender difference in mathematics, which was dominant for male students in the lower grades, is gradually disappearing and that the difference in mathematics performance between male and female students no longer exists. However, the UNESCO study concluded that some factors, such as prejudice, still hinder the development of mathematical learning skills [5].

A famous book describing gender differences between males and females, "Men are from Mars; Women are from Venus", reflects the differences between males and females regarding verbal expression, emotions, and behavior. Males are considered to be more comfortable solving problems rationally and alone. At the same time, females are more comfortable expressing their opinions emotionally, and these differences are hugely linked to the different physiology of males and females, which is one of the reasons for the difference in mathematical performance in the exam [6].

In this study, interviews and questionnaires will be used to show the distribution of academic performance of male and female students in mathematics learning, and the related physiological, environmental and psychological factors will be analyzed.

2. Physiological Factors

A survey of the examination performance of students at an international high school in Xuhui District, Shanghai, China, in the academic year 2021 found that the average scores of female students in the four examinations were 84.3, 81.6, 70.3, and 71.3. The average score for male students exceeded that of female students on every test, which were 89.4, 83.5, 74.0, and 78.9. This result may be related to objective and physiological differences between males and females.

2.1. Brain Structure

Firstly, there are differences in the structure of the male and female brains. One of the most striking features is the different activity of the corpus callosum in the brains of females and males. The corpus callosum is located at the base of the longitudinal fissure of the cerebral hemispheres. It is the largest bundle of nerve fibers connecting the left and right cerebral hemispheres. A study by scientists at the University of Pennsylvania concluded that the fiber pathways travel back and forth within the brain hemispheres in males. In contrast, in females, the fibers travel between the left brain. The left brain is responsible for logical thinking, and the right brain which controlled intuition. In other words, males' brains are more connected within each hemisphere, while in females' brains, the connections between the left and right hemispheres are tighter [7].

In males, the nerve fibers are mainly more active in the front and back of the brain. So, on the one hand, males tend to think more independently to solve problems when processing information rather than communicating ideas to others through words or other means. Conversely, females have more active fibers in the left and right brains. This causes females the messages they receive may sometimes exist in the subconscious realm, and the brain does not process them. The messages in the subconscious can influence decision-making; thus, anxiety can occur in the face of ignorance.

Furthermore, the pass way to the parietal lobe is wider in males, and the pass way to the temporal lobe is larger in females; the larger the pass way, the more activity can be facilitated in that part of the brain. The parietal lobe is vital for sensory perception and integration. It is home to the brain's

primary sensory area, a region where the brain interprets input from other areas of the body. Since males have a wider pass way to the parietal lobe, they can process and perceive information faster, which would explain the fact that in such a limited time in a mathematics test, male students may be able to react faster than female students and therefore be able to have a higher level of completion in the mathematics exam.

2.2. Hormone

Besides the differences in the structure of the male and female brains, males and females secrete different amounts of serotonin, so their abilities to deal with emotions are different. Serotonin is a neurotransmitter produced in the body. The nerves use serotonin as a medium to make different brain parts able to cooperate with each other as a channel to transmit information. Serotonin affects people's internal drive while further affecting mood. The internal drive can be understood simply as desire but not as a subject feeling. It acts as a motivator for behavior to drive the organism's activity to meet needs. Studies have shown that men have a higher density of serotonin receptors and produce serotonin faster than women under acute stress in extreme environments. This means that men can calm their emotions more quickly after being affected by external influences. In other words, men's emotions return faster than women's, and women's emotions are less likely to return. Thus, when students encounter an exam, female students' anxiety may already affect them from the moment they learn of the exam, but for male students, it is simply a matter of knowing. In addition, female students are slower to produce serotonin. Thus, these long-term negative emotions can take a very long time to dissipate and calm down, whereas for male students, even if anxiety arises, it can be quickly extinguished in a short time.

3. Stereotypes as Environmental Factors

In order to further investigate other factors that could potentially influence the differences that male and female students show in mathematics, the author conducted in-depth interviews with high school students from a high school in Xuhui District, Shanghai, China. During the interview, this student reflected on a problem with the author. Throughout her academic career, especially as a child, she often heard advice from her parents: "You are a girl; you might not be so good at mathematics, so that you can study arts in the future."

The notions that "female students are not good at math" and "male students are good at math" almost unconsciously permeate people's minds. The Implicit Project at Harvard University released an online Implicit Association Test from May 2000 to July 2008. The results showed that over half a million people worldwide took the test, 70% of the candidates associated science/mathematics with male students, and female students were considered to associate more with the humanities [8].

Female students are often surrounded by comments that "Girls are not good at math", which is a stereotype. A stereotype is a generalized and fixed view of an object people form and appeal to the public. People then assume that the objects should be identical and has a mutual characteristic, ignoring the multifaceted nature of things which is a logical fallacy of generalization. Stereotypes are the product of cognitive, emotional, socially motivated, and cultural processes, alone or in interaction, which can be about other people, things, or even oneself. Stereotypes are so commonplace that there are limitations to the way people subconsciously ignore such thinking. The gender stereotype in mathematics learning is that "Boys do better than girls in mathematics". The author believes this stereotype has benefits and drawbacks for the development of the individual.

3.1. Positive Impact of Stereotypes on Female Students

Stereotypes can contribute positively to the development of the individual. This is because when individuals encounter an unknown area, they can conclude directly according to the established views of the general public without having to explore the information on their own, which simplifies the cognitive process of understanding the general situation of a particular area quickly. This facilitates people to deal with the complex environment around them. For female students, the apparent acceptance early in their academic careers that they may not quickly achieve great success in this area of mathematics is tantamount to having ruled out a possible pathway for their development. Although this reduces the likelihood of female students being well-rounded, by eliminating one option, female students can explore their preferences and focus more efficiently and effectively on the subjects they are better at and thus find their talents and shine in one area.

3.2. Negative Impact of Stereotypes on Female Students

However, the negative impacts of stereotypes on female students largely influence their performance in mathematics. On one hand, the imposition of negative stereotypes from external pressure, including family, school, etc., can be internalized and assimilated through the socialization process; when the stereotype brainwashes individuals, the stereotype becomes an internal pressure on the individual, a threat that can easily lead to negative emotions. This creates a vicious circle: by defaulting the stereotype from the external that Girls are not good at mathematics, female students may suffer from low self-confidence, which drains their motivation to study and discourages them from studying independently to compensate for their deficiencies. This leads to a great deal of stress before the mathematic exam and a tendency to become nervous and anxious during the exam, which results in exam failure and confirms the dominant stereotype. As a result, female students may take for granted the objective fact that they are naturally bad at mathematics; thus, they may feel reluctant to study further after this brainwashing. This negative influence not only results in low grades in examinations or reluctance to learn, but also causes female students to suffer from severe psychological stress and hinders independent learning.

On the other hand, by interviewing another female student from an international school in the Xuhui district, this interviewee is trying to demonstrate those female students can do well in mathematics which shows that not all female students agree that “girls are not good at mathematics” by default. Although this female student does not agree with this stereotype, she feels that she is still unable to perform as well as she should in all her exams.

In this case, the prejudices others hold about female students’ ability to learn mathematics remain an external pressure and a threat. Although these female students do not share these prejudices, they are still surrounded by these stereotypes. These female students fear that a single mistake they make in mathematics exams will prove that girls cannot do mathematics, resulting in anxiety, nervousness, stress, and over-cautiousness during study and tests, which affects their performance. If not addressed, negative emotions can accumulate over time and lead to female students attributing their failures to their natural abilities, thus losing interest, motivation, and perseverance in learning mathematics. The fear of stereotypes causes female students to lose motivation when it comes to mathematic, develop a lack of confidence and remain bound by this stereotype. Therefore, other negative emotions such as aversion may occur when having to take a mathematics test which will further affect female students' subsequent learning outcomes and choice of profession [8].

3.3. Impact of Stereotypes on Male Students

While this stereotype can affect female students’ performance in math exams, it is a stimulant for male students to promote their math learning. This positive motivation allows boys to be more

confident and thus perform better as a demonstration of the audience effect. For example, when a teacher enters the classroom during a self-study session, students will be more effective in their studies and less distracted by the teacher's presence. In this case, the audience motivates students to study, which is the social facilitation factor. Social facilitation theory was developed by Floyd Henry Allport, an American psychologist who was one of the founders of experimental social psychology. Social facilitation theory states that an individual's behavior becomes more efficient due to the presence of or with others when completing an activity. The stereotype of "Boys being good at math" acts as the "audience" for male students as they complete their tasks. The presence of an "audience" in a familiar task does not disturb the students but gives them a sense of internal motivation to behave, compete, and be evaluated. When male students' awareness of being evaluated is stimulated, it directly increases their level of self-observation, self-evaluation, and self-adjustment, making the behavioral process essentially one of self-expression governed by a high degree of self-awareness, that is, the ability to perform at the level expected at the time of the examination and to put their best foot forward [9].

4. Psychological Factors

The author further asked the interviewees a question in the interview: What method do you use to learn mathematics? Most female students answered: "I make a collection of mistakes and review them repeatedly, and I memorize the theoretical knowledge in my notebook, including the formulae that may be used in the questions." However, the male students had a very different answer: "I always brush up on my knowledge, and when I encounter a topic I do not understand, I go straight from the root of the topic and then to the answer step by step. I never force myself to remember definitions or content by reciting the alphabet. Instead of that, I try to figure out the derivation process of the formula and knowledge."

From the responses of female and male students, it would be found that they have entirely different approaches to learning. The female students studied mathematics more like the method used to study the subjects of liberal arts, which relies on memorization to build up knowledge and interpretation of the concept.

Therefore, here concludes another possible reason for the difference in performance between male and female students. The psychological phenomenon "illusion of knowledge" resulting from the learning method leads to an incomplete understanding of the knowledge, only to formal memorization that does not allow for a logical connection between the knowledge in the exam for female students. This "illusion of knowledge" means that people are "familiar with knowledge" but do not necessarily "master" it. As if "knowing" does not mean "understanding". For example, gel pens are used frequently in examinations, and people should be familiar with this object. However, only a tiny percentage of people could describe the parts of a gel pen and how it works to produce ink to write.

People often think, based on their world of experience, that they have a deep knowledge of the objects that they use frequently and are already familiar with. The illusion of knowledge can mislead female students into confusing the subtle distinction between "knowledge familiarity" and "knowledge mastery". It is as if many female students repeatedly review theoretical knowledge and mistakes they have made to consolidate their knowledge before exams. This process does internalize some of the knowledge. However, by reviewing over and over again, a great deal of time is spent on increasing familiarity with this knowledge, instead allowing the female student to fixate on the part of the knowledge that they have made mistakes on while not promoting understanding but simply memorizing how to do the questions mechanically. These bits and pieces of knowledge are spread particularly thinly, resulting in some knowledge that needs further review, not being thoroughly understood, and often forgotten in exams.

Different from many female students, the way many male students understand knowledge is mostly not by memorization. However, by solving problems or reasoning to understand the essence of theoretical knowledge so that they can fundamentally understand and mobilize the logic between the various knowledge in the examinations, thus male students can think clearly to complete the questions in the examinations [10]. In other words, male students are less impacted by the “illusion of knowledge”.

5. Conclusions

By concluding results of some medical research as well as the interviews and questionnaires, the author explores how differences between the biological structure such as brain structure and hormone level, environmental factors such as upbringing, and psychological phenomena of “illusion of knowledge” of males and female students that may contribute to differences in the performance of mathematics.

Physiological factors influencing male and female students' performance include differences in brain structure and serotonin. Female students are more emotional and more prone to anxiety, while male students are relatively more able to deal with emotions. Environmental factors include the positive impact of stereotypes on male students, which is the social facilitation effect. The stereotype harms female students, which can spill over to the fundamental level. Psychological factors include the illusion of knowledge, which means that female students study mathematics based on memorization while boys prefer to solve problems through logic.

It should be noted that groups cannot represent individuals, nor can individuals represent groups. In addition to gender differences, personal differences between people are also crucial in students, resulting in different mathematics performances. Only some of the differences in performance in mathematics that may be due to gender differences are discussed in the exploration based on the study's findings.

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