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"GENDER DIFFERENCES IN MATHEMATICS EDUCATION"

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Abstract:

Even within the developed countries, where equity in Education was reached an extended time ago, the rates of enrolment of women in mathematics courses are relatively low. The gender problem and arithmetic education have been studied since 1970 and a few factors of that representativeness are identified, especially within the developed countries. But this area of research remains unexplored within the developing countries. In India, specifically, little research has been done so far on Gender and arithmetic education despite the millennium goals recommending equity in education and therefore the encouragement of Indian females to settle on mathematics studies and to embrace scientific and technological careers. Nevertheless, the role of girls within the scientific development of India has been definitively recognized as an important and determining to think about building and reinforcing the continent's scientific and technological capacities, because no country can afford to go away 50 you look after its population, out of its developed process. It is evident that Education generally in India was, and is until now, seriously suffering from poverty, but concerning the education of women, history, religion, and culture were, and that they remain, important influencing factors. These socio-cultural barriers are more pronounced once they come to scientific, technical, and vocational training and, are, unfortunately, tragic once they concern mathematics education.

Introduction:

The traditional gender gap in educational outcomes advantaging boys has been filled up in most industrialized countries and has now reversed in favour of women. Girls tend to try to do better than boys in reading test scores, in grades at college, within the propensity to settle on academic educational programs in upper middle school, in tertiary education attendance, and graduation rates. The massive scale international tests like the Trends in International Mathematics and Science Study (TIMSS 2003, 2007, 2011) and programs of international student assessment (PISA 2003, 2006, 2009, 2012) have inspired studies comparing knowledge over time and across states and countries. This body of labour throws light on arguments over environmental or biological causes of gender differences. In parallel, the statistical technique of meta-analysis has been used (largely within the United States) to tug together the results of similarly-constructed small-scale quantitative research inquiries. These help to determine overall patterns of significance and effect size, so that we will see what differences are stable over different contexts. In England, longitudinal or large-scale data has been wont to track individual pupils' trajectories in mathematics up to A-level, in projects like the DfE-funded Targeted Initiatives in Science and Mathematics Education (TISME) or Nuffield's ongoing project Re-thinking the worth of A level Mathematics Participation (that has not yet reported).

These studies give information about how choices and attitudes change in individuals over time. This review also reports findings from research projects that are one-off or smaller in scale but closely associated with the Indian mathematics education context.

Literature Review:

The presence of a considerable females' disadvantage in math is of particular importance, because it's likely to be an explanation for the critically low share of girls choosing STEM (Science Technology Engineering and Mathematics) disciplines at university, of gender segregation within the labour market, and gender pay gaps (European Commission 2006, 2012, 2015; National Academy of Science, 2007).

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Several explanations are proposed for the existence of the gender gap in mathematics. Some scholars ask about biological factors (Baron-Cohen and Wheelwright 2004, Baron Cohen et al 2001). However, as shown by international assessments (OECD 2015, Mullis et al, 2012) the gender gap in math differs substantially across countries. Hence, "nature" can't be the sole account for the females' disadvantage in math; there must be alternative explanations associated with societal and cultural factors, supporting the existence of "nurture" effects. During this perspective, some scholars (Guiso et al., 2008, De San Roman and De La Rica Goiricelaya, 2012; OECD 2015) provide evidence that the gender gap in math within the PISA survey is negatively associated with country-level indexes of gender equality.

Focusing on micro-level mechanisms, the literature emphasizes the importance of oldsters' and teachers' beliefs about boys' and girls' capacities. Gender-stereotypes in parent's evaluation of youngsters' ability to affect achievements and children's self-perception (amongst others: Jacobs 1991; Jacobs and Bleeker 2004; Jacobs and Eccles 1992; Bhanot and Jovanovic 2009; Twenge and Campbell 2001). Fryer and Levitt (2010) study shows that parental expectations regarding performance in mathematics are lower for women than for boys even after accounting the test scores. However, Cornwell et al (2012) and Robinson et al (2014) find that teachers rated girls' math skills above those of observationally similar boys.

Although the causal direction is difficult to assess, girls display less math self-efficacy (self-confidence in solving math-related problems) and math self-concept (beliefs in their abilities), and more anxiety and stress in doing math-related activities (OECD 2015, Heckman and Kautz 2012, 2014; Lubienski et al 2013, Twenge and Campbell 2001). As demonstrated by the recent work by Heckman and colleagues (e.g. Heckman and Kautz 2012, 2014; Heckman and Mosso, 2014), non-cognitive abilities including motivation and self-esteem are important predictors of success in life and within the labor market. During this perspective, the females' lower self-esteem in math might be responsible for their relatively poorer performance in STEM subjects and future educational choices and occupational outcomes.

Socioeconomic status, parental education, and occupation play a serious role in school achievement, including math performance. Especially, parenting styles and parents' involvement in children's homework are relevant (Bhanot and Jovanovic 2009, Del Boca, et al 2014, Brilli et al. 2016). Home experiences differ in stereotypically gendered ways, and consistent with Lubienski et al. (2013), somewhat unexpectedly, more strongly among children of high socioeconomic status whether these factors also contribute to determining the gender gap in math test scores remains unclear. However, there's empirical evidence that girls with mothers working in math-related occupations lag behind boys the maximum amount as those whose mothers aren't in math-related occupations (Fryer and Levitt, 2010; OECD 2015)

Schools and academic methods and practices also seem to matter. The tutorial literature provides evidence that different approaches to math and physics can decrease gender inequality in achievements. Problem-solving, class-discussions and investigative work, and cognitive activation strategies are found to enhance girls' performances (Boaler 2002; Zohar and Sela 2003; OECD 2015). Additionally, Boaler et al. (2011) and Good, Woodzicka, and Wingfield (2010) analyze other factors affecting lower achievement in math and science associated with gender-stereotypes, like images shown in textbooks, and show that girls' proficiency increases by using counter-stereotypic pictures with female scientists.

From a policy perspective, it's important to explain when the gap first shows up. Does it exist already at the start of primary school? The prevailing evidence is especially supported by the US dataset "Early Childhood Longitudinal Study, Kindergarten Class of 1998– 1999" (ECLS-K) following students from kindergarten through eighth grade. the most finding from these data is that the maths gender gap starts as early as in kindergarten and increases with the age of the kid (Robinson and Lubiensky, 2011; Fryer and Levitt, 2010; Penner and Paret, 2008). Another relevant result's that the maths gender gap is higher for top-performing students. Initially, boys appear to try to do better than girls among good performers and worse at rock bottom of the distribution; by third grade, the gender gap, still larger at the highest, appears throughout the distribution. Moreover, the male advantage among high performers is largest among families with high parental education. Girls appear to lose ground in math over time in every family structure, ethnos, and level of the socio-economic distribution (Fryer and Levitt, 2010). These findings are confirmed by PISA international data, on children aged 15 (OECD, 2015).

Importance of Gender-Based Evaluation:

This is not an issue that will be determined by research evidence, yet almost every research paper addresses it. All the papers reviewed show a priority for social, economic, and institutional injustices that result from women's unequal participation in advanced mathematics. Many papers also argue that their nation's economic advantage relies on increasing the proportion of the population with mathematical skills. From this attitude, girls who don't follow STEM courses are a possible source for recruiting more mathematicians, and hence their participation deserves scrutiny.

Differential take-up in mathematical and scientific careers is widespread, although the time that these differences appear in education varies. By the age of 15, 51 out of 54 countries in PISA 2006 had a statistically significant difference within the proportion of boys and girls planning a career in engineering or computing, all towards boys. the newest school data for England shows that 20.4% of the females within the 2012-13 A-level cohort entered for the mathematics A-level examination, compared to 37.4% of boys, nearly twice as many (although there are more girls within the cohort therefore the ratio within mathematics lesson is closer to 1:1.5). For Further Mathematics, there are nearly 3 times as many boys, with 2.4% of the women entered for A-level, compared to 7.4% of boys (DfE, 2014). In contrast, within us, boys' and girls' participation in optional calculus courses at highschool has been equal for over ten years (College Board, 2013) and nearly 48% of mathematics-major college degrees are awarded to women (Ceci& Williams, 2010b). These equal rates within the US don't (yet) persist into the later study, dropping to 29% of PhDs. However, they provide us a sign that representation at 16-18 has been challenged in cultures that are on the brink of our own. Thus comparative research, social justice, and economic imperatives combine convincingly to suggest those girls' choices about mathematics and science should be a policy focus. there's also a big gender bias – but in favour of women - in participation in subjects like language or careers like medicine, but this is often not seen to possess the limiting implications for boys that biased mathematics participation has for women.

There is a counter-argument or caveat discussed within the more thoughtful papers, which is that the quantity of research attention paid to gender differences far outweighs the importance of the findings. There's a historical legacy of interest in gender. which guarantees an audience. Perhaps more importantly, it's a simple variable for researchers to figure with. Collecting data on gender has no obvious problems of reliability or validity across time or social or national contexts. It not seen as intrusive and yet seems relevant to individuals' performance. For instance, recent scientific research getting to understand participation in mathematics and physics found that some schools were unwilling to ask pupils survey questions that indicated class but had no problems with gender (Mujtaba & Reiss, 2013). Together, the audience interest and simple collection encourage research during which data is routinely analyzed by gender without a clear hypothesis but within the hope of reporting whenever the male and feminine populations are different. This approach keeps attention on gender when there are much larger differences in mathematics performance and trajectories, for instance between students in rich and poor countries (Kane & Mertz, 2012), rural and concrete communities (Wei et al., 2012) and within the INDIA between students of various socioeconomic status. This propensity to seem for the gender angle is worth bearing in mind when interpreting research and should be an unhelpful focus of interventions.

As mathematicians, we all know that statistical significance establishes our confidence in any assertion that male and feminine populations have different means of a given measure. within the discussion below I even have reported quantitative research findings as significant as long as they're reported as statistically significant at a tenth level: there's but a tenth probability that the perceived difference occurred due to the random nature of the sample taken from girls and boys populations with an equivalent mean scores. In research involving thousands of scholars (such as PISA, TIMSS, and UPMAP) even small differences are statistically significant: we will be very confident that there's a really small difference within the averages. Effect size is reported in research so that readers can start to gauge the implications of that difference by comparing it to the variability within the info then to other findings. the foremost common measure, Cohen's d, uses the difference of means divided by a typical deviation to supply a standardized difference. Effect sizes of 0.2 are considered small: present but hardly visible, like the typical height difference between 15-and 16- year old girls. Effect sizes of 0.5 are considered medium, like the peak difference between 14-and 16-year old girls, or one grade at GCSE; and effect sizes of 0.8 are considered large (Coe, 2002).

There are still arguments about implications. Some researchers argue that small effect size can nonetheless make a difference to several people counting on context. for instance, raising US girls' scores on college entrance mathematics examinations to the boys' mean score could end in thousands of more girls qualifying for a STEM subject (Ceci& Williams, 2010b). Post-structural research argues that even finding no difference in male and feminine performance doesn't mean that mathematics isn't gendered. They point to the various ways during which mathematics is connected through language and structures to ideas that are themselves aligned with masculinity (Mendick, 2006) and to the salience of gender in young adults' deciding. this suggests that the boys and girls doing mathematics and further mathematics A-levels have alternative ways of creating a sense of that 'same' experience to themselves and about people (Smith, 2010).

Wiliam (2010) reminds us to gauge good research by the validity of what's being examined and by the researchers' attention to competing explanations of equivalent results. during a recent study, Alcock et al. (2014) have illustrated this approach. They considered whether the gender of 89 undergraduate mathematics students was associated with their grades and self-reported learning approaches, and within the same survey, they assessed for 'personality factors' employing a psychological model that scores people on conscientiousness, extroversion, agreeableness, neuroticism, and openness to experience. Needless to say from previous research, these personality factors showed an association with the students' gender, with women scoring slightly higher on Agreeableness, Conscientiousness, and Neuroticism (with effect sizes of $d = 0.694$, 0.551, and 0.570). The techniques of multilevel modelling allowed the authors to assess the contribution of gender after controlling for the effect of personality factors and, conversely, for every personality factor after controlling for the effect of gender. They found that personality type accounted for significantly more variance in undergraduates' achievement and behaviours than did gender. Especially achievement was correlated in both males and females with conscientiousness, which measures the tendency to point out self-discipline and regulate impulsive behaviours. It certainly is sensible that self-disciplined undergraduates achieve highly. The authors' wider contribution has been for instance that gender can seem a legitimate explanatory factor when it's a proxy for other related factors like personality which are easier (though not easy) to vary. Although a proxy is superficially useful, it obscures the variability within gender groups, for instance ignoring patterns in how disagreeable girls or conscientious boys do mathematics.

Gender Differences in Mathematics Performance:

Gender performance in mathematics has been investigated on an outsized scale in two ways. The primary is thru mathematics assessments sat by thousands of scholars. PISA and TIMSS, national grade-by-grade tests and college entrance tests within the US, and public examinations within the INDIA are samples of these. The second is by meta-analyses compiling the info of smaller research studies in individual laboratories and schools. In both cases, the size of the research is merely valuable if we agree that the tests and studies are measuring essentially an equivalent construct over all the sites and test occasions. Although they're hospitable critique, the massive repeated international and national assessments provide evidence that researchers have wont to test and refine hypotheses over time.

If there's a construct like overall mathematics performance being measured by these studies, then it's an equivalent for women and boys. Data has been analyzed from TIMSS or PISA 2003 (Else-Quest, Hyde, & Linn, 2010), TIMSS 2007 and PISA 2009 (Kane & Mertz, 2012), and PISA 2012 (OECD, 2014). there's considerable variation between countries, with more countries whose boys do slightly better than girls in mathematics instead of the other way around. No statistically significant gender gap existed overall within the mean of many fourth and eighth-graders on the 2003 and 2007 TIMSS (Kane & Mertz, 2012). Where statistically significant differences are found, they need very small effect sizes. PISA uses four content subscales (change and relationships, space and shape, quantity and uncertainty and data) and three process subscales (formulating situations mathematically process; employing mathematical concepts, facts, procedures, and reasoning process; interpreting, applying, and evaluating mathematical outcomes). The pattern is analogous for all of those subscales: gender differences aren't significant for Northern Ireland, and therefore the effect sizes are but 0.2 for England Wales.

In the US, Hyde et al. (2008) analyzed the varsity assessments from 7 million students in 10 states in 10 grades between ages 7 and 17 and located trivial gender differences in mathematics performance (effect sizes < 0.06). This confirmed their earlier results from a 1990 statistical meta-analysis, combining the results of 100 trials involving 3 million individuals from the US, Canada, and Australia that found only a small effect size in favor of higher female performance (d=-0.05). The image of small differences is that the same for both GCSE and A-level mathematics in England and Wales, although this is often reported as girls having higher pass rates (Department for Education, 2011). In 2012 and 2013, the odds of boys and girls getting each GCSE grade A* to E differed by but 1%. Differences within the percentages of boys and girls who took A-level are slightly bigger, with 3- 4% more boys getting an A* but 2-3% more girls getting an A, 2% more girls getting a B, and other differences but 1%. Although DfE data don't show effect sizes, these overall differences are small and support the research findings that on average girls and boys achieve equally well in mathematics.

There are two aspects of mathematics performance that have remained of interest. One was a finding from a 1990 meta-analysis that boys performed better than girls on questions involving complex problem-solving. Interpretation of this result was difficult at the time as US girls took fewer advanced mathematics courses aged 16-18. equivalent researchers returned to the present result after US participation rates in advanced mathematics courses became equal, and located that US national test data of 17-year-olds showed no significant differences in tests that include complex problems (Hyde & Mertz, 2009) suggesting that the first difference was a result of differences inexperience. PISA 2012 has focussed on problem-solving in 15-year olds (although not complex problem-solving in Hyde's terms) and shows INDIA girls and boys performing equally well, both above the OECD average. This illustrates the contribution that research can make to refining and testing hypotheses about gender differences, and it does not seem likely that this difference exists.

The second aspect is understood because of the greater male variability hypothesis. The spread of boys leads to mathematics is bigger than for women, and hence there are more boys than girls within the top and bottom 5% and 1% of any assessment. this is often found within the large international tests and US college entrance tests also as in assessments that identify gifted mathematicians (Halpern et al., 2007: Heilbronner, 2013; OECD, 2014). However, this result's not stable across time, countries, or ethnic groups. In US tests the greater variance of boys compared to women has reduced over time, getting closer to a ratio of 1, but remaining a big difference (J. Hyde & Mertz, 2009). Hence this is often a hypothesis that research remains looking to check, and far of the interest is within the extremes of ability like mathematics olympiad teams and precociously gifted youth. In the INDIA the greater male variability hypothesis is compatible with the slight over[illegible]ion of girls within the middle A-D grades at GCSE (<1% difference per gra[illegible] over representation of boys with an A* grade (7.1% compared to 6.7% in 2013) but it does not rule out other contextual explanations. However, because the variance ratio is on the brink of 1, albeit the hypothesis is found to carry, it seems impossible to account for male over-representation in A-level mathematics and further mathematics. Within the US context, theoretical models have shown that the known effect isn't large enough to account for the particular differences in STEM participation at the school level (Ceci& Williams, 2010a). The message from the research is that there are slightly more boys than girls who perform either all right or very badly in mathematics tests, but we don't know why nor whether this is often a result that will still change.

International test data has offered researchers the chance to check hypotheses that relate gender differences in mathematics to biological factors (that would be constant between countries and over time) or environmental/ cultural factors (that could vary in predictable ways). The between-country variation in gender differences both at the mean and at the extremes of performance throws doubt on purely biological explanations. Work on cultural hypotheses continues. One interesting hypothesis that has since been rejected was the finding that the gender gap in mathematics in PISA 2003 data was significantly related to the GGI index employed by the planet Economic Forum to point country's gender inequality. An initial study found that the more unequal a country's society, the greater the gap in gender performance. However, this gap thanks to the gender inequity hypothesis was rejected when the finding wasn't reproduced within the TIMSS 2003, 2007, or the PISA 2009 tests. Instead, researchers found that both girls and boys were found to perform better in additional gender-equal countries (Kane & Mertz, 2012).

There is one aspect of mathematics where boys are consistently found to excel, which is in tasks involving the interpretation of 2-D drawings of 3-D objects and mental rotation of those images. The biological and psychological evidence for this was extensively reviewed by Halpern et al. to underpin a US report promoting girls' participation in mathematics and science. The clear definition of the task type has helped establish this result as robust, stable over time and countries. There's a similar agreement that girls outperform boys in writing tasks throughout school, an impact that is larger and similarly stable. Girls also are found on average to possess a stronger personal memory than boys: they remember what they experienced. The review finds that each one of three differences are compatible with contemporary neuroscience findings of brain structure and performance, but warns against attributing them solely to either biological or environmental factors (Diane Halpern et al., 2007, p29). One reason for his or her caution is that experiments (with specialists like taxi drivers) show that practice physically changes the brain's structure. Hence modern neuroscience tells us that nature and nurture aren't as distinct as once thought and that we don't yet know enough about how brains change through education and childhood to guide policy (Fine, Jordan- Young, Kaiser, & Rippon, 2013; The Royal Society, 2014).

Mental rotation is a crucial skill for engineering, architecture, geometry, craft, or construction work, and features in cognitive aptitude tests for non-verbal reasoning. Halpern et al. (2007) point to evidence from engineering courses that it's a skill that will be taught when needed which develops through practice, for instance with video games. Research is ongoing to spot other specific aspects of mathematics on which girls and boys will consistently perform differently, but there are none with an equivalent weight of evidence as to mental rotation.

Conclusion and Suggestions:

Despite these initiatives, females' participation, in Science, and Technology, and especially in Mathematics, from primary through tertiary education to the career level remains very low. This might be explained by, among other factors, the persistent socio-cultural barriers, lack of clear policy guidelines for increasing the rates of enrolment of Indian girls in mathematics, lack of assessment and follow from the varied undertaken initiatives, lack of gender analysis expertise than on.

Recent international evidence suggests that on average girls and boys now perform equally well in mathematics. There remains a little different within the spread of girls' and boys' attainment, with more boys at both extremes of performance. This difference has decreased over time, suggesting that it's suffering from cultural factors. There is one particular spatial skill where gender differences have proved stable across different countries and time, and research will probably find others.

A valorised image of women in mathematics education and arithmetic careers should be promoted and gender stereotypes concerning mathematics careers should be countered by parents, teachers, and everyone other actors within the school and societal environments.

Good teachers will already remember various approaches to mathematics and therefore the skills they involve and can address these when needed. Interventions for females should aim to realize equity of outcomes instead of just equal access to educational opportunities in mathematics. So permanent assessment and relevant follow-up are key elements in any undertaken initiative.

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