International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

UNPACKING THE GENDER DIFFERENCES IN HIGHER EDUCATION STEM BASED ON SPATIAL ABILITY DEVELOPMENT

Parinie Gupta

Amity International School

DOI: 10.46609/IJSSER.2022.v07i08.016 URL: https://doi.org/10.46609/IJSSER.2022.v07i08.016

Received: 23 August 2022 / Accepted: 29 August 2022 / Published: 30 August 2022

ABSTRACT

There is gender disparity present in the STEM (Science, Technology, Engineering, Mathematics) education and workforce which has always been a matter of concern. Previous research study shows that according to the Gender Parity Index (GPI) in India, there is a steep underrepresentation of women in STEM courses of study. The dominant explanation for this trend is found to be the differences in the development of spatial ability in males and females. Many scientists have proved that early gender differences in spatial ability may contribute to the later emergence of gender differences in mathematics and science.

The current study will take into account the status of men and women in STEM education. Then it aims to understand the concept of spatial ability and its various subsets like mental rotation and spatial cognitive processes to understand how it leads to a gender difference in attitude toward mathematics. After that, the paper will briefly explain the social, cultural, traditional, psychological, and neurological factors that contribute in the spatial ability gap.

At the end of the paper, the study will provide solutions to how this variance in spatial ability can be reduced since early childhood and different gender-equity plans that can be adopted by appropriate authorities to increase the representation of women in STEM.

Keywords: STEM, gender-disparity, spatial ability, cognitive processes

INTRODUCTION

Females have always been underrepresented compared to males, especially in the fields of STEM (Science, Technology, Engineering, and Mathematics). The current study has found that there is a difference between the number of males and females studying and working in the

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

STEM fields. According to the data released by the UNESCO Institute for Statistics, 2019, women account for a minority of the world's researchers. There has been a decline in the number of females in doctoral programs as well. The world average for the share of female researchers is only 29.3% and the participation of female researchers in India specifically is just 13%. Moreover, the differences in representation are deeper in mathematics-focused subjects like physics and engineering. For instance, as per the NSF data, only 9000 degrees of physics were obtained by women out of 45,000(Amirtham S, N., & Kumar, A., 2021). And sex-differences in the development of spatial ability are one of the major reasons that can justify the above assertion. While there is individual variability within each gender, on average males score higher than females on tests that measure spatial ability. The simplest way to define spatial ability is that it is an ability to perceive and understand spatial relationships, visualize spatial stimuli such as objects, and to manipulate or transform them in some way. Spatial tasks are intended to measure specific cognitive processes in isolation. Spatial ability also has various components to it such as mental rotation, spatial working memory, and spatial cognitive processes. Mental rotation is basically the ability to manipulate 2-D or 3-D figures mentally. There is a male-female difference in mental rotation and spatial working memory capacity is a critical factor in determining it(Kaufman, 2007).

Spatial working memory is the ability to keep the spatial information active in working memory over a short period of time whereas spatial cognitive processes are processes through which people acquire and use knowledge of their environment to perform certain tasks.

Another one is spatial visualization ability which involves more complicated multistep manipulations of spatial information in order to reach a solution. All the subsets show a gender disparity and the paper provides suitable evidence for them. Spatial ability can be affected by many social and psychological factors. For instance, gendered perceptions of academic disciplines are developed in early childhood through socialization and education, which may impact later lifestyle and career choices(Chan, 2022). Adults' expectancies and attributions are the attitudes and behaviors that also contribute to children's development of gender-related math attitudes(Gunderson et al., 2011). Along with that, traditional gender role beliefs moderates the associations of gender with self-efficacy, interest, and aspirations in STEM, in which gender differences in STEM are more apparent among those who strongly endorsed stereotypical views of male and female roles(Chan, 2022). A growing number of educational psychologists have argued that early education of spatial ability is necessary as a matter of equity for all students and that it may offer substantial benefits for the later development of mathematical and scientific skills across all ability levels and hence, the current study also provides a scope to reduce this

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

gender-disparity in spatial ability by following some useful methods that have also been discussed. The purpose of the current paper is to provide evidence about the gender gap in STEM education and fields.

Furthermore, the paper will explain how spatial ability is responsible for this gap. Also, the paper deeply analyses the various factors that lead to the difference in spatial abilities in males and females. Finally, the paper provides some solutions to address the problems of differences in spatial ability as well as improving the number of women in STEM.

METHODOLOGY

The current study has described the gender-disparity in STEM and the difference in spatial ability being the reason behind it. To provide an in-depth explanation for all the assertions made, a qualitative analysis has been done. Under that, first of all, abstracts of previous studies have been understood. After that, annotated bibliographies of those papers have been drafted so as to hold a firm grasp on what the earlier researchers have been trying to explain on the current topic. The method of thematic analysis has been adopted. This involved coding all the data before identifying and reviewing five key themes and each theme was examined carefully. All the data provided in the current paper is secondary data that has been already been verified. The paper intended to provide real-world knowledge about the behavior and attitudes of people toward STEM education and state reasons why there is an underrepresentation of women in math-related fields. Lastly, the paper provides qualitative solutions to the problems discussed during the course of the study.

LITERATURE REVIEW

Spatial ability is a trait that is found to be different for every person. Some people can easily visualize and manipulate objects in their minds while others face much more difficult to perceive and understanding spatial stimuli. Moreover, several research studies show that there is a major gap in the spatial abilities between males and females which can be caused by many factors, for instance, according to Jones(2003), evolution can cause gender differences in spatial ability and range size can be the most effective way to compare it. Spatial ability also lays down the foundation for quantitative reasoning, a collective term for mathematical and science skills. It means that developing spatial ability becomes an important task if one wants to work in the STEM fields. And for this very reason of gender disparity in spatial ability, it is found that women are underrepresented in STEM fields. Although there is a difference in spatial abilities, these gaps can be narrowed if appropriate measures are adopted from a younger age.

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

The research was conducted in 2015 to find out the reasons why women are constantly being underrepresented in STEM. It found out how countries' gender-disparity in socio-economic and cultural areas may affect their student's attitudes toward math(Ghasemi & Burley, 2019). In their research, they answered three questions by conducting a survey with the students from fourth to eighth grades: gender difference in students' interest in mathematics, the gender difference in students' mathematics self-confidence, and gender difference in how much students value mathematics (Ghasemi & Burley, 2019).

Another paper from 2022 focuses primarily on a social cognitive perspective to understand how cultural and gender norms play a role in shaping female underrepresentation in STEM, specifically in China(Chan, 2022). Overall, the study adds to growing evidence of gender disparities in self-efficacy, interest, and academic and career aspirations in STEM in China. The results showed that girls were less likely to perceive that they have the capabilities to do well in mathematical, scientific, and technical tasks than boys, which might make girls lose interest in STEM and subsequently lack motivation to pursue STEM as academic and career endeavors (Chan, 2022). And lastly, the gender difference in STEM engagement was even more prominent among students who endorsed higher levels of traditional gender role beliefs(Chan, 2022). The paper adds scope to study in similar fields in other parts of the world and compares the results with those found in China.

A paper published in 2020 provides a proposal to analyze the gender equality gap in STEM as a first step to defining gender equality action plans focused on processes of attraction, access and retention, and guidance in STEM programs(Garcia-Holgado et al., 2020). The main assertion of this paper has been that universities can be a major cause for the gender gap in spatial abilities and also hypothesized that universities can also help to bring equality(Garcia-Holgado et al., 2020).

The paper released in 2007 conducts a study about mental rotation (which is a subset of spatial ability) and accounts for the sex difference in it. It assessed differences between males and females on various tests of spatial working memory and spatial ability in order to determine whether spatial working memory capacity is a critical factor in determining the male-female difference in mental rotation and spatial visualization ability(Kaufman, 2007). It concluded that there was a direct effect of sex on the unique variance in three-dimensional rotation ability(Kaufman, 2007).

There was also a research study done in 2020 which worked in a similar field with a different perspective. It investigated how the spatial cognitive processes actually work among the students

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

studying STEM education and its importance(Li & Wang, 2020). It found that students who had psychometrically assessed high levels of spatial ability always outperformed in STEM or STEM-branch learning(Li & Wang, 2020).

The papers discussed above provide evidence that there is a gender disparity in STEM fields and a major cause for it is the difference in spatial abilities in males and females. Overall factors for this difference in spatial ability are social, cultural, psychological, biological, and evolutional. The one field that might be lacking or not adequately described was how can this gender-gap be thinned. They don't mention much about the ways in which the spatial ability of women can be improved so as to increase their representation in STEM. This is a particular topic that can be further explored and aware about to everyone.

This research will provide discussions about the methods that can be adopted to improve the spatial ability of females. It will also mention ways to increase the representation of women in STEM fields.

FINDINGS

The current study has deeply analyzed the gender differences in STEM education based on the development of spatial ability and has concluded with the following results:-

a) Spatial Ability Development Differences in Boys and Girls

While there is individual variability within each gender, on average males score higher than females on tests that measure spatial ability (Reilly et al., 2016). Individual differences in spatial ability measured in adolescence predicted educational and vocational outcomes two decades later, even after controlling for pre-existing mathematical and verbal abilities.

According to the study conducted by Casey (1995), the relationship between spatial ability and mathematics achievement was stronger for females suggesting that girls may be particularly disadvantaged by deficits in spatial reasoning (Reilly et al., 2016). Higher spatial ability was associated with greater self-efficacy beliefs about learning mathematics. Attitudes may exert a powerful influence on whether students decide to undertake further classes of STEM suggesting that there may be motivational effects as well as cognitive effects when spatial competencies are improved. Besides these psychological factors, a neurological reason is that male brains are structured to facilitate connectivity between perception and coordinated action, whereas female brains are designed to facilitate communication (Ingalhalikar et al., 2013).

Mental rotation shows the largest gender differences whereas spatial visualization ability shows

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

the minimum. The meta-analytic review conducted by Voyer and Bryden (1995) represented the most comprehensive meta-analysis of the research on gender differences in spatial ability published at that time. The review categorized tasks by age, comparing children (under 13 years), adolescents (13-18 years), and adults (over 18 years). In the review, mental rotation tasks showed the largest gender differences (d = .33 for children, d =.45 for adolescents and d = .66 in adults) (Reilly et al., 2016).

b) Spatial Ability Affecting STEM Performance and Attitudes

Spatial ability is one of the most important necessities for STEM education and fields. Early gender differences in spatial ability may contribute to the later emergence of gender differences in mathematics and science (Reilly et al., 2016). Reilly, Neumann, & Andrews (2015) observed small but stable mean gender differences in mathematics and science achievement. At the higher levels of achievement, boys outnumber girls by a ratio of 2:1 (Reilly et al., 2016). It has been a trend observed that girls showcase lesser interests in math and technical fields.

Among the eighth graders of the United States, 11% of students do not value mathematics, 38% do not like learning mathematics and almost 44% do not feel confident in mathematics, and out of these most of the students are girls (Ghasemi & Burley, 2019).

One of the major findings of the current study is that the spatial cognitive process of cue integration that was hidden within spatial ability offered strong support for accomplishing complex spatial tasks in the context of STEM education. Students with high levels of cue integration not only had a high commitment to seek the relationships and interactions between new and existing concepts and propositions but would also synthesize more effective ways of thinking from among the existing possibilities, which resulted in meaningful learning, and in turn, led to increased academic performance in STEM and increased motivation to learn STEM(Li & Wang, 2020). Even a mild increase in spatial ability might have ‘‘multiplier effects on girls’ mathematical and science performance(Li & Wang, 2020).

c) Socio-Cultural Factors that Affect Attitude Towards STEM

Gendered perceptions of academic disciplines are developed in early childhood through socialization and education, which may impact later lifestyle and career choices(Chan, 2022). According to the social cognitive career theory (Lent et al., 1994), the results showed that self-efficacy in STEM was positively associated with interest in STEM, which, in turn, was related to higher levels of academic and career aspirations in STEM (Chan, 2022).

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

Traditional gender role beliefs moderated the associations of gender with self-efficacy, interest, and aspirations in STEM, in which gender differences in STEM were more apparent among those who strongly endorsed stereotypical views of male and female roles(Chan, 2022). Along with this, the traditional gender-role beliefs also account for hindering girls from pursuing careers in STEM. Girls who had higher levels of traditional gender role beliefs were likely to doubt their STEM abilities and have a lower self-efficacy in STEM. Girls who lose confidence in their abilities to solve STEM problems and perform STEM tasks might then show lower interest in STEM and be less motivated to consider and pursue

STEM-related careers than boys(Chan, 2022). On the other hand, boys who endorsed higher levels of traditional gender role beliefs were more inclined to believe that they perform well in STEM, which, in turn, boosts their determination in STEM-related careers(Chan, 2022). The viewpoint of parents and teachers is also one of the most important causes of creating sex-differences in spatial ability. A study of 3rd and 4th grade students in Germany found that parents of boys believed that their children were more competent in math than parents of girls; this effect was strongest among parents who endorsed math-gender stereotypes in general(Gunderson et al., 2011). Moreover, these parental perceptions appear to have an impact on children's achievement expectations.

d) Solutions and Suggestions to Reduce Disparity

The current study provides solutions for two different areas which can help reduce the overall disparity discussed above. The first solution is for STEM which is framing gender equality action plans that can be adopted to improve women's representation in STEM. The universities and institutions are the leading promoters of action plans to reduce this gender gap in STEM. New positions, modified policies, and improved practices and resources can be vital for better gender equity outcomes. Following are some graphical representations to provide a clearer understanding of this solution: Figure 1 shows several methods that can be adopted to build institutional transformations. It tells about the internal and external factors and gender equity outcomes as well. Figure 2 shows the gender-equity practices at the individual level, school level, and university level(Alam A., 2021).

The other solution is to improve spatial ability which is educating students from a younger age with respect to improving their spatial ability skills through different sorts of activities. Rich multimedia can present complex scientific concepts visually, and many electronic textbooks offer data visualizations that are interactive rather than static displays (Reilly et al., 2016). There is evidence that playing sports may help to develop spatial ability. When children who play regular sports were compared to similarly aged matches who did not, those who played sports performed better on tests of spatial performance, with similar findings in young adults (Reilly et al., 2016). Another promising enrichment activity that aids in practicing spatial skills may be video games, action-based games, and maze/puzzle genres.

They provide repeated practice in spatial perception, mental rotation, and navigation tasks. Parents and caregivers might also gently encourage spatial learning outside of school by providing children with play and leisure activities that encourage spatial development through attention to spatial relationships (Reilly et al., 2016).

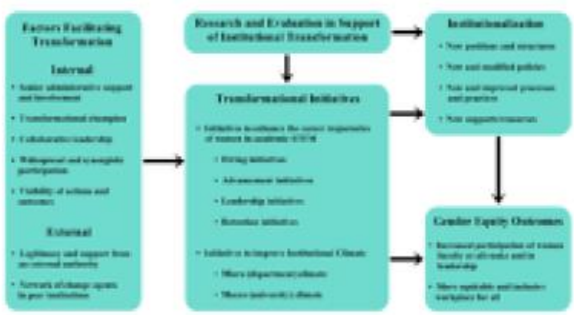

Figure 1: Institution's transformational framework to improve gendered justice in academical STEM

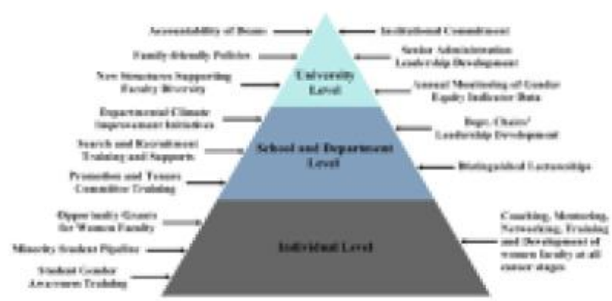

Figure 2: Effective practices for gender equity transformation

DISCUSSION

The findings of the current study indicate that there is a disparity in the number of men and women present in STEM education and the workforce. It means that there is a vast gender disparity in overall disciplines at the under-graduation, post-graduation, and M. Phil levels. Another major finding of the paper is that the reason behind this gender disparity in STEM is the differences in spatial ability development among males and females. While individuals may differ, on average males score higher in tests of visual-spatial ability (Reilly et al., 2016). Gender differences in spatial ability emerge from an early age. While clearly observable in children, the gender gap widens in adolescence and continues to grow into adulthood where it is quite large(Reilly et al., 2016). It is also found that spatial ability has various subsets to it and the highest sex-difference observed is mental rotation, which is determined by the spatial working memory capacity(Reilly et al., 2016). The paper also discusses that these spatial ability differences emerged due to various factors. For instance, socio-cultural beliefs and social norms affect the perception of STEM since early childhood and later on also shape the academic and career decisions of students(Chan, 2022). The findings show that stronger self-efficacy beliefs

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

may foster greater interest in STEM pursuits and predict educational and occupation choice goals in STEM-related fields. Most importantly, girls were less likely to form an enduring interest in STEM than boys, as girls view themselves as less competent in performing well in mathematical, scientific, and technical tasks(Chan, 2022). Lastly, the most optimistic finding of the current study is that the differences in spatial ability can be reduced through various methods like providing early education, encouraging girls to play sports and video games, and instilling the importance of spatial relationships among children(Reilly et al., 2016). Also, one of the most effective methods to improve the representation of women in STEM is to reframe gender-equality action plans, especially in schools and universities.

Our study has been consistent with the previous research which also suggests that there is an underrepresentation of women in STEM. It is also in alliance with the earlier studies that there is a difference in spatial ability between males and females and that it is caused due to various social and psychological factors. This study, however, adds to the current field that spatial ability differences can be reduced by adopting the appropriate methods listed above.

The hypothesis of the study was to prove that there is a gender-disparity in STEM, to find out whether spatial ability has been a reason to cause the underrepresentation of women in STEM, and what the factors based on which there are sex-differences in spatial ability. The results are completely in accordance with the hypothesis. It provides evidence that globally, there is a gender disparity in STEM fields and that women themselves have a lesser inclination towards mathematical and technical fields. One of the major aims of the paper was to provide solutions to reduce spatial ability differences and improve the current conditions to the women's participation in STEM education. This is where the potential future research lies. There is a critical need for more solutions that can be amended so as to solve the problems discussed throughout the paper. It will help in diverse manners; first of all the STEM industry will have a more decentralized distribution of views and contributions from both genders which will overall aid to improve future technologies. Secondly, it will help create gender-equality and help women to become more independent and adaptable in the present world. Hopefully, future generations will be able to overcome this gender-disparity and have significant improvements in spatial ability. Gender parity in STEM education could help reduce the skills gap in spatial ability, increase the employment and productivity of women and reduce occupational segregation. This will also diversify the various fields in STEM. Ultimately this would foster economic growth via both higher productivity and increased labor market activity.

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

CONCLUSION

By analyzing the basic trend of women being underrepresented in STEM education, this study has shown that spatial ability has been a major cause of that which is also affected by several social and psychological factors. It has been found that males perform better than females in spatial ability tests. Another major takeaway of the study was that cue integration which is a rather hidden component of spatial ability has strongly supported the performance of students in STEM. The attitudes, perceptions, and beliefs of students, parents and teachers have been the most influential factor in creating a sex difference in spatial ability. However, not much data was gathered about the neurological factors that cause gaps in spatial ability. Since a qualitative methodology is adopted, the paper has been able to provide more information and evidence from relevant data. To better understand the implications of these results, future studies could address the problem of the underrepresentation of girls and women in STEM and find solutions to how this can be overcome. As mentioned earlier in the literature review section, the paper contributes to the overall area of gender equity, especially in the rigorous academic fields of STEM as well as creates more awareness about the column of spatial abilities among people and how can they be influenced and improved.

REFERENCES

Alam, A. (2021). Psychological, Sociocultural, and Biological Elucidations for Gender Gap in STEM Education: A Call for Translation of Research intoEvidence- Based Interventions. *Atlantis Highlights in Social Sciences, Education and Humanities*

Amirtham S, N., & Kumar, A. (2021). Gender parity in STEM higher education inIndia: a trend analysis. *International Journal of Science Education*, *43*(12), 1950–1964. https://doi.org/10.1080/09500693.2021.1946867

Chan, R. C. H. (2022). A social cognitive perspective on gender disparities in self-efficacy, interest, and aspirations in science, technology, engineering, and mathematics (STEM): the influence of cultural and gender norms. *International Journal of STEM Education*, *9*(1). https://doi.org/10.1186/s40594-022-00352-0

Garcia-Holgado, A., Mena, J., Garcia-Penalvo, F. J., Pascual, J., Heikkinen, M., Harmoinen, S., Garcia-Ramos, L., Penabaena-Niebles, R., & Amores, L. (2020). Gender equality in STEM programs: a proposal to analyse the situation of a university about the gender gap. *2020 IEEE Global Engineering Education Conference (EDUCON)*. https://doi.org/10.1109/educon45650.2020.9125326

ISSN: 2455-8834

Volume:07, Issue:08 "August 2022"

Ghasemi, E., & Burley, H. (2019). Gender, affect, and math: A cross-nationalmeta-analysis of trends in international mathematics and science study 2015 outcomes. *Large-Scale Assessments in Education*, *7*(1). https://doi.org/10.1186/s40536-019-0078-1

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2011). The Role of Parents and Teachers in the Development of Gender-Related Math Attitudes. *Sex Roles*, *66*(3–4), 153–166. https://doi.org/10.1007/s11199-011-9996-2

Ingalhalikar, M., Smith, A., Parker, D., Satterthwaite, T. D., Elliott, M. A., Ruparel, K., Hakonarson, H., Gur, R. E., Gur, R. C., & Verma, R. (2013). Sex differences in the structural connectome of the human brain. *Proceedings ofthe National Academy of Sciences*, *111*(2), 823–828. https://doi.org/10.1073/pnas.1316909110

Jones, C. M., Braithwaite, V. A., & Healy, S. D. (2003). The evolution of sex differences in spatial ability. *Behavioral Neuroscience*, *117*(3), 403–411. https://doi.org/10.1037/0735-7044.117.3.403

Kaufman, S. B. (2007). Sex differences in mental rotation and spatial visualization ability: Can they be accounted for by differences in working memory capacity? *Intelligence*, *35*(3), 211–223. https://doi.org/10.1016/j.intell.2006.07.009

Li, X., & Wang, W. (2020). Exploring Spatial Cognitive Process Among STEM Students and Its Role in STEM Education. *Science & Education*, *30*(1),121–145. https://doi.org/10.1007/s11191-020-00167-x

Reilly, D., Neumann, D. L., & Andrews, G. (2016). Gender Differences in Spatial Ability: Implications for STEM Education and Approaches to Reducing the Gender Gap for Parents and Educators. *Visual-Spatial Ability in STEM Education*, 195–224. https://doi.org/10.1007/978-3-319-44385-0_10