A JOURNEY OF INDIAN WOMEN MATHEMATICIANS

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Abstract

The German Mathematician Carl Friedrich Gauss stated that mathematics is the queen of all sciences. India has made a remarkable contribution to mathematics through scholars such as Aryabhata, Brahmagupta, Bhaskaracharya II, Varahamihira, Madhavacharya to name a few. However, mathematics in India, since ancient times, has been predominantly the domain of men. The first evidence of a woman mathematician in ancient India, was Lilavati, the daughter of Bhaskaracharya II, a noted mathematician of the 12th century. But the scenario changed positively during the last few years despite the opinion of many that girls cannot do mathematics. We have women mathematicians in India with noteworthy achievements. This research article is an attempt to recognize the achievements of these dynamic ladies of mathematics. We first give a brief outline of the genesis of the famous work of Bhaskaracharya II, Lilavati, named after his daughter. We then delve into the lives of contemporary women mathematicians of India and their significant contributions. Their journey of mathematics, along with their challenges and the motivation behind their accolades are also highlighted in this article. They have done wonders outside India as well. The inspiring stories of these women mathematicians will definitely motivate young minds, especially women, to carve a niche for themselves in the field of Mathematics. We will also examine the possible ways in which the percentage of women in mathematics could be enhanced.

Key words: *Mathematics, Bhaskaracharya II, Lilavati, contemporary women mathematicians of India*

INTRODUCTION

"Just as the crest among peacocks and gem among serpents are at the top, similarly mathematics is at the top of all the Vedangas and scriptures." (RVSS)

This is indeed a befitting ode from the Vedas to the "Queen of Science" - Mathematics. Several Indian mathematicians made noteworthy contributions to mathematics in India. It is heartening to see that it is not just the men but even the women who have done remarkable research in mathematics. In this article, we explore the journey of a few women who made an indelible mark in the research in mathematics regardless of all the odds they faced.

Lilavati

Bhāskara II was a mathematician who lived in the12th century. He served as the head of an astronomical observatory at Ujjain which was the prominent mathematical center of ancient India. His famous works include Bijagaṇita, Siddhantasiromaṇi and Lilavati. He was also an eminent astrologer.

Legend has it that while preparing his daughter Lilavati's horoscope, he discovered that she would remain unmarried. This apparently disturbed him and he tried to devise a solution to this problem. He used his prowess as an astrologer and calculated an auspicious day and time. He made a water clock by using a cup with a small hole at the bottom and placed it in a vessel filled with water. His idea was that the cup would sink at the accurate time. He even warned her and asked her to remain away from the vessel. But Lilavati was inquisitive, and tried to peek at the vessel. A pearl from her dress fell into the cup and blocked the hole which prevented the cup from sinking. The auspicious time elapsed proving the accuracy of the astrological prediction. The crestfallen Lilavati lost all her interest in life.

Bhaskaracharya was aware that Lilavati was an intelligent mathematician. He had a brilliant idea. He tried to cheer up his daughter, by posing mathematical problems in a poetic form. She would solve them perfectly. Bhaskara then collected these problems and thus was born his historical mathematics treatise- Lilavati which was aimed at providing consolation to his daughter. This legend from a 16th-century Persian translation is however doubtful but some problems in Lilavati are addressed to women, using phrases such as "beautiful one." (The Editors of Encyclopaedia Britannica).

Bhaskara II was a prolific poet who wrote verses on mathematical puzzles. The following verse, from Lilavati describes a mathematical problem.

"Oh! You, auspicious girl with loving eyes of a young deer, if you have well understood the above methods of multiplication, tell me what is the product of 135 and 12? Also, tell me what number you will obtain when the product is divided by 12." (Patwardhan).

Neena Gupta

Neena Gupta is a professor at the Theoretical Statistics and Mathematics Unit, Indian Statistical Institute, Kolkata. She completed her graduation in Mathematics from Bethune College, Kolkata. She did her post-graduation from the Indian Statistical Institute. When she began her PhD, she explored various areas in Mathematics for specialization and finally after careful deliberation, she decided to specialize in Affine Algebraic Geometry and Commutative Algebra. She earned her Ph.D. degree in Commutative Algebra as her specialization under the guidance of Prof. Amartya Kumar Dutta. She then did her post-doctoral research at TIFR after which she joined ISI. She was also a visiting fellow at the Tata Institute of Fundamental Research (TIFR) for a brief period.

While pursuing her Ph.D., she came across the famous Zariski Cancellation Problem which was posed in 1949 by Oscar Zariski, a Russian-born American mathematician and one of the most influential algebraic geometers of the 20th century. Her mathematical skills helped her to think of possible solutions and she worked on it religiously for a long time. Finally, in 2012 she arrived at a solution and since then there was no looking back. Due to her excellent work, she received the Saraswathi Cowsik Medal in 2013, awarded by the TIFR Alumni Association. She won the Indian National Science Academy's Medal for Young Scientists in 2014 for cracking this problem.

Unstoppable was the word for Prof. Neena Gupta. At a young age of 35, she won the Shanti Swarup Bhatnagar Prize for Science and Technology (2019) in the category of mathematical sciences, the highest honor in India in the field of science and technology. She won the prestigious Ramanujan Prize for Young Mathematicians in 2021 for her eminent work in affine algebraic geometry and commutative algebra(Nair;Pandey). The prize is awarded annually to a researcher from a developing country funded by the Department of Science and Technology (DST) of the Government of India in association with ICTP (International Centre for Theoretical Physics) and the International Mathematical Union (IMU)("Prof. Neena"). Prof. Neena stated that it was a big recognition from outside India and added that to receive it at an early age was no big feat. She is the second woman from India who got this award (Shubhangi).

Raman Parimala

This famous mathematician came from a family of non-mathematicians. She was encouraged by her father to continue with higher studies after her graduation. Her interest led her to a post graduate degree in Mathematics. She wanted to work as a lecturer in Stella Maris College, Chennai, her alma mater, but one of her teachers identified the spark of research in her and dissuaded the management from employing her. Prof. Parimala started her journey of mathematical research at the Ramanujan Institute, University of Madras but after a year started working under the guidance of Prof. Sridharan. She earned her Ph.D. degree and her specialization was in Algebra. She was enamored of the research culture at TIFR and decided to continue with research in mathematics(Godbole and Ramaswamy 227-229).

Prof. Parimala worked at TIFR, Mumbai for many years. Currently this 76-year-old mathematician is the Arts & Sciences Distinguished Professor of Mathematics at Emory University. She was conferred an Honorary doctorate from the University of Lausanne in 1999 She has been on the Mathematical Sciences jury for the Infosys Prize from 2019("Prof. Raman Parimala"). Besides this, she is a fellow of the Indian Academy of Sciences, a fellow of Indian National Science Academy. She won the Shanti Swarup Bhatnagar Award in 1987 and the Srinivasa Ramanujan Birth Centenary Award in 2003. She also received the Srinivasa Ramanujan Medal of INSA and the("Prof. Parimala Raman"). She was an integral part of Jawaharlal Nehru Birth Centenary Lecture (2004). She won the Srinivasa Ramanujan Medal of INSA (2006) and the TWAS prize for Mathematical Sciences (2006). She is a Fellow, Indian Academy of Sciences, Bangalore and the National Academy of Sciences (India), Allahabad("Indian Fellow").

Sujatha Ramdorai

Prof. Sujatha was born in a family of non-academicians at Bangalore. Her grandmother was influential in instilling her interest in academics. However, she was perplexed about pursuing engineering or pure sciences. But her dexterity in abstract thinking pushed her towards mathematics. Although she got married before her graduation, she completed her B.Sc. and did her M.Sc. by correspondence. Her destiny brought her to Mumbai where she did her Ph.D. under the supervision of Prof. Parimala. Her specialization was in Algebra but she also got interested in Number Theory. She worked as a professor at Tata Institute of Fundamental Research, Mumbai for a few years. At present she is a professor of mathematics and Canada Research Chair at University of British Columbia, Canada(Godbole and Ramaswamy 248-251). Prof. Sujatha Ramdorai was the first Indian to

win the prestigious ICTP Ramanujan Prize in 2006. She also won the Shanti Swarup Bhatnagar Award in 2004. Recently, in 2023 she received the Padma Shri award from the Government of India, in the field of science and engineering(Amrita).

Rajinder Jeet Hans-Gill

Prof. Hans-Gill was born in Ludhiana in Punjab. Her father, a doctor, was posted in rural areas in Ludhiana district. Education was indeed a challenging task for her as in the 1940's, there were no schools for girls in those villages. Besides this, girls were prevented from attending the schools for boys. Nevertheless, with the constant encouragement from her parents, Prof Hans-Gill studied at home initially. She did get a chance to attend a girl's school in one of the villages but soon after her father's posting elsewhere had to discontinue her schooling. Despite the fact that her uncle disapproved of girls' education, she attended the boy's school in the village, where her father was posted, posing as a boy.

Since science and mathematics were not taught at the girl's schools where she studied, she could not appear for the university examination in science and consequently had to give up the idea of becoming a doctor. She chose to become a mathematician. With the undying support of her parents, she completed her graduation in mathematics from the Government College for Women, Ludhiana and stood first in the Punjab University. She completed her post-graduation from the Government College for Men, Ludhiana. She displayed her academic mettle by doing well in her post-graduation as well, regardless of the opinion of some male teachers regarding women not being capable of doing math. However, there were few teachers who encouraged her to continue her studies and even guided her to do research. She joined the Department of Mathematics in 1962 as a research fellow and after intense hard work, she was able to obtain results by the end of 1963. This became her Ph.D. thesis. She completed her Ph.D. under the guidance of Prof. R.P. Bambah from the Ohio State University, Columbus. Later she received the NaraSinga Rao Gold Medal for Women by the Indian Mathematical Society for the two papers published from her thesis in the Journal of Indian Mathematical Society(Godbole and Ramaswamy 124-127).

Riddhi Shah

Riddhi Shah hails from Gujarat. Her mother motivated her to do a Ph.D. in mathematics which did not make sense to her as a child. As a young girl she loved to play with numbers. She would use a simple rule for ordering fractions which she discovered on her own. The Vice Chancellor of Gujarat University, to whom she was sent by her school principal, taught her how to prove the rule. That was enough to arouse her interest for higher studies in mathematics. She completed her graduation from St. Xavier's college, Ahmedabad and won a gold medal. She was encouraged by her teachers to continue her master's degree from IIT, Mumbai. After her post-graduation, she did her Ph.D. from TIFR, Mumbai in 1991. She worked with Prof. M.S.Raghunathan and Prof. S.G.Dani at TIFR. She works in lie groups and probabilities, ergodic theory and dynamical systems(Godbole and Ramaswamy 276-279). She was a faculty member at TIFR, Mumbai from 1990 until 2007 and currently she is working as a Professor of Mathematics at the School of Physical Sciences (SPS), Jawaharlal Nehru University (JNU), New Delhi("Riddhi Shah").

She won the Indian National Science Academy's medal for young scientists in 1995, the Alexander von Humboldt Fellowship in 1997. She was awarded the CNRS fellowship in 2003 and an Invitation Fellowship in 2004 from the Japan Society for Promotion of Science (JSPS)("Speakers At IWM Workshop").

Mangala Narlikar

Prof. Mangala was a bright student as a young girl and was immensely interested in mathematics. She did her M.A. in mathematics as she was advised to do so, which could give her time for pursuing other hobbies such as reading and painting. But soon she realized that though she thoroughly enjoyed pure math, she found the applications of math were an unknown territory for her. She joined TIFR for her research which left after becoming a research associate, to get married. She considered marriage as her first priority, following her parents. She and her husband returned to India from Cambridge where she enjoyed being a housewife. Her husband became a professor at TIFR. She got an excellent opportunity to restart her research and started attending lecture courses. She worked in Prof. Ramchandra's group on Analytic Number Theory. She managed to complete her Ph.D. in 1982, simultaneously managing her aging parents-in-laws and small daughters. She worked briefly as a pool officer at TIFR. She was a guest lecturer at the University of Mumbai and a part time teacher in the department of mathematics, Pune. Her mission was to make mathematics interesting and enjoyable to school kids so that they could get rid of their fear of mathematics and even wrote a book to this effect.(Godbole and Ramaswamy 213-215).

Sadly, we lost her recently, on 17th of July, 2023 to cancer(Nair). Her story is an inspiration to many. In the book (Lilavati's Daughters-The Women Scientists of India) she concluded her autobiographical essay by the statement:

"*My story is perhaps a representation of the lives of many women of my generation who are well educated but always put household responsibilities before their personal careers*"(Godbole and Ramaswamy 215).

The Mathematical Legacy Continues?

A few observations were made after reading the inspiring stories of these women.

● **Keen interest in Mathematics:**

The women above had a passion for the subject. The mathematical problems challenged them but these women carried on their quest for research and eventually came up with a solution. The joy of cracking a problem was precious to them.

● **Motivation of parents and siblings:**

These women had constant encouragement from their parents regarding further studies. In fact, many of them have quoted in their interviews that their parents and in some cases, the grandparents were instrumental in shaping up their career in research. The dissuasion of other people with the notion that 'girls should not do sciences or mathematics', left these women undeterred only because of the backing of their parents.

● **Support of husband and inlaws:**

A common and an essential factor which contributed to the success of these women was steadfast support from their spouses. Even the parents-in-law were quite supportive and had no objection to their daughter in laws' working in mathematical research after marriage. Both sets of parents were a blessing as they gladly took care of the children when their illustrious mothers were pursuing their doctorate or post-doctoral research. The husbands had to move to different cities at times, though temporarily, but they never forced the wives to accompany them. This helped these mathematicians to carry on with their research smoothly.

Encouragement from teachers and colleagues:

These women were blessed with wonderful teachers who identified the research spark in them and guided them towards research. Even the colleagues at work motivated them to move ahead. There was a conducive work culture and research culture which propelled these women towards success.

Motivation by the Government and other organizations:

The government of India is also making sure that more Indian women enter STEM and is providing facilities for the same. Schools for girls are no longer a dream. Scholarships are also provided to girl students which makes education in prestigious institutes easy. Another initiative for promoting research in mathematics among young girls is The Indian Women and Mathematics (IWM) which is a collective of mathematicians established for this purpose. It began as a project supported by the National Board of Higher Mathematics (NBHM), Department of Atomic Energy (DAE), Government of India and continues to be sponsored by NBHM. Their main aim is to encourage more women to pursue higher education and careers in mathematics. They organize regular academic events and networking opportunities in all parts of India, and collaborate with renowned organizations and people across the world("About Us"). This kind of exposure to the budding women mathematicians will definitely provide them opportunities for research.

Life is not all that tough now for Indian women with regards to education. If a woman decides to achieve something, inspite of all odds, she can definitely succeed. It is not an easy task for an Indian woman to balance work, research and the home, nevertheless with strong determination. However, the first step, which is the toughest at times, has to be taken by the woman.

The famous quote of our Father of the Nation, says it all, "*If one takes care of the means, the end will take care of itself.*"(Gandhi)

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