QUEST ALLIANCE

Engaging Girls in STEM: Barriers and Enablers in India

Knowledge Partner

TANDEM RESEARCH

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Developed in collaboration with Quest Alliance, IBM STEM for Girls is a digital fluency and life skills curriculum designed to help girls in government secondary schools break gender stereotypes and explore the possibilities of STEM-enabled careers.

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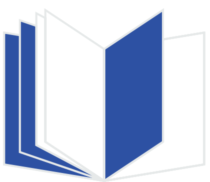
Content List

01 Background



1.1 Introduction

The acronym 'STEM' (Science, Technology, Engineering and Mathematics) originated in the 1990s, but gained popularity after it was used by Rita Colwell at the National Science Foundation in 2001 (Hallinen, 2015). Since then, the term has been used in diverse educational policy contexts, where references to STEM courses, STEM workshops, STEM careers, STEM curriculum and so on have become increasingly regular. More recently, additional components have been added to STEM to include STEAM (adding an A for Arts) and STREAM (adding R for Reading and Writing, besides Arts). For the purpose of this report, we have chosen to work within the framework of STEM, so as to maintain undiluted focus on the participation and representation of girls in courses and occupations related to science, technology, engineering and mathematics, in India.

Three crucial elements make STEM differ from the subjects within its acronym. First, STEM integrates these subjects and allows scope for a holistic understanding. By holistic understanding, we mean adopting a cross-curricular teaching approach that encourages students to learn both inside and outside classrooms. This approach is significant because it not only provides subject knowledge to students but inspires them to become active learners, connecting classroom education to wider community needs and global issues. Second, STEM provides a hands-on approach, focusing on the applicability of learning to ordinary life contexts, rather than being just textbook oriented. And third, STEM allows its composing subjects to be linked to technology, which is indisputably important for preparing students for the future.

The discourse around the Future of Work, which is likely to be led by exponential growth in technology and digitalisation, makes STEM arguably the most relevant and fast-growing concept in the education sector. The National Science Foundation (USA) recently predicted that 80 percent of jobs created in the next decade will require some application of skills in mathematics and science. Hence, the education sector needs to adapt to equip students beyond exam-centric textbook knowledge, in competencies such as critical thinking, problem solving and aptitude towards creativity and innovation.

In addition to becoming crucial for workplaces, exposure to STEM education is also crucial for developing a scientific temperament and methodological thinking. This will have implications for many areas in the personal and political lives of citizens, such as health behaviour, financial decision making, parenting as well as social and political participation. A STEM-literate population will also be able to counter fake news, political propaganda and cultural superstitions, and navigate through the complexities of digital communication of the future.

Meanwhile, the World Economic Forum (2018) states that women are the most underutilised talent in business and growth. With the emergence and popularisation of new technologies in the Fourth Industrial Revolution (4IR), women are more likely to miss the opportunities this technological revolution brings and instead be adversely affected, as they occupy low-mid skill work which is most likely to be replaced through automation. Thus, there is a substantial risk of the 4IR resulting in greater gender inequality unless the associated risks are turned into opportunities.

Amidst this growing need for STEM education, the contemporary Indian scenario presents contradictory trends; on one hand more girls are participating in education, but women's labour participation is declining. Set in the Indian context, this report presents the importance, challenges and enablers of STEM education for girls and provides an array of perspectives which can provide stimulus to both policy and practice.

1.2 Indian Backdrop

The Indian context is marked with two paradoxical scenarios. On the one hand, the country sits on a high demographic dividend, but still faces a shortage of STEM workers which has been predicted to increase. On the other hand, although there has been a steady surge in participation of girls in education, these gains have not transferred to women's participation in the labour force, which has been consistently declining. Both of these scenarios provide the contextual backdrop for the discussion on the relevance of STEM education for Indian girls.

About 65 per cent of India's working population is less than 35 years of age. According to the India Skills Report, approximately 12 million people are added to the country's workforce every year (Wheebox, 2018). However, to reap this benefit, the workforce needs to be future-ready, equipped with the skill sets required for workspaces which are increasingly technology-concentrated. Data from Indeed, a prominent job portal, revealed that the shortage of STEM workers increased from 6 per cent to 12 per cent between 2014 to 2018. They attributed this gap to a mismatch between college curricula and skills expected by the industry due to which many positions stayed vacant (Economic Times, February 28, 2018). Similarly, another survey revealed that only 46 per cent of student respondents were considered employable (Wheebox, 2018). Although this improved substantially from a low 24 per cent in 2014, quality concerns remain valid (ibid).

Meanwhile, around half of current jobs in India have been predicted to be impacted by automation. However, forecasts also suggest that enough new jobs will be created to offset any net displacement (McKinsey, January 2017 & December 2017). Thus, with a change in business models, production processes, and service delivery mechanisms, many old jobs will cease to exist and modern job categories will be created, requiring new skill sets. Here, women may face specific disadvantages as they are generally occupied in low skill, low paying jobs.[1] Even among those in the organised sector, around 50 per cent of women in India drop out between junior and middle-level positions, compared with the Asian average of 29 per cent (Wheebox, 2018). A high digital gender gap has a further adverse impact on women's education and employment. The Mobile Gender Gap Report, 2019 estimates that women are 28 per cent less likely to own a mobile phone and 56 per cent less likely to use mobile internet. The World Economic Forum (2016) estimates that if this current disparity continues, only one woman will gain a STEM related job for every 20 lost globally.

1. According to the Ministry of Women and Child Development, 95 per cent of employed women work in the unorganised sector (MWCD, 2016). A report by Deloitte (2019) further states that 81.29 per cent of women in the workforce are engaged in agriculture, where 56 per cent of these women are illiterate.

In the case of India, this gap is likely to be wider. However, the digital divide is not simply a matter of unequal access; often, programming devices and software do not take into account the needs and interests of women and girls (Venezky, 2000)

On the other hand, access to education for women has been steadily increasing since the last decade. According to the latest official data, the Gender Parity Index (GPI) in India is in favour of girls at all levels of schooling.[2] However, there is a high drop-out rate for girls, particularly during secondary education, due to socio-cultural factors (MHRD, 2018). This is also the time when students choose subjects for deeper study. Moreover, beyond physical access to education measured through enrolment, data indicates that more boys are enrolled in private schools than girls, indicating greater household financial allocation to the education of boys. Besides, stereotypical perceptions of STEM subjects as 'masculine' result in further underachievement and unequal participation of girls.

Despite gains in education, the female labour force participation rate (FLPR) in India has steadily declined from 38 per cent in 2005 to 26 per cent in 2018, compared to 48.5 per cent globally (ILO, 2018). This amounts to a fall of over 10 percentage points, where three in four women of working age are currently not employed. This is 50 per cent lower than the male LFPR (Economic Survey, 2018). This paradox of falling workforce participation despite rising educational status means that women's representation in STEM may not improve by simply increasing their participation in education, but will require a multifaceted strategy.

Women are also impacted by the effects of intersectionality, where those living in rural areas or belonging to disadvantaged classes or castes may be further marginalised. Many such women may still be lagging from the third IR, with little access to the internet or even basic services like electricity and piped water supply. Taking STEM to young girls from such households will have additional challenges due to confounding factors like lack of access to schools, quality teachers and disadvantaged social background.

2. Gender Parity Index measures the accessibility of education to girls, in relation to boys. Educational statistics released by MHRD in 2018 shows that in the primary and secondary stage of education more girls are enrolled in Indian schools, than boys, thus having a GPI of more than 1. Even in higher education, the latest AISHE notes that GPI has touched a perfect 1, thus indicating an equal enrolment of boys and girls.

1.3 Methodology

This study aims to present a multifaceted picture of STEM education for girls in India, including how the education system can be repurposed, and the need for enhanced policy support - particularly for girls who face multiple disadvantages.

Given the descriptive nature of the inquiry, we employed qualitative methods which included a three-step process:

Desk Review:

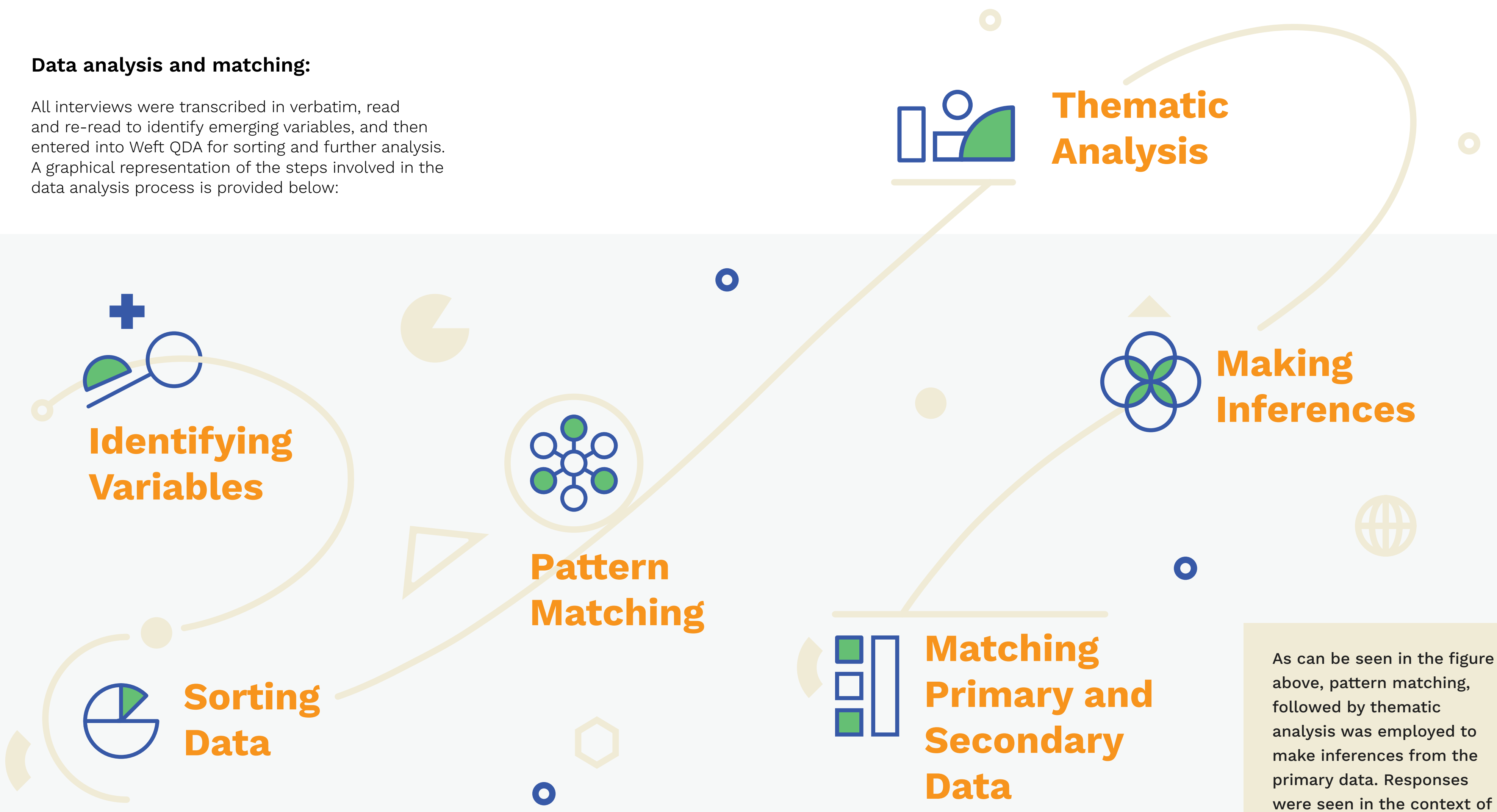
First, we conducted a comprehensive desk review on the status of STEM/ science and mathematics education in India, with special reference to the participation and achievement of girls. The desk review also examined the influencing factors in STEM education of girls at various levels of learning, including individual, socio-cultural as well as the impact of market perceptions. It further explored the possible impact of the 4IR and the policy context. An effort was made to present an internationally comparative picture, where possible. Besides understanding the issue more holistically, findings of the desk review also helped identify the experts/stakeholders for primary data collection and areas of inquiry which needed to be examined.

Expert Interviews:

To further understand and delve into nuances of the trends captured during the desk review, a total of 23 experts/stakeholders were interviewed through a semi-structured, qualitative questionnaire. These experts were selected through purposive sampling, where their experience, as well as availability were the main criteria. These included academics of repute, members of civil society organisations, school representatives (Principals/Atal Tinkering Lab (ATL) coordinators/Niti Aayog mentor for change) and private sector actors providing STEM education products and/or services (see annexure 1 for a full list of participants). The questionnaire included 11 common questions and two specific questions (from a pool of eight questions), depending on the respondent profile and previous responses (see annexure 2).

Data analysis and matching:

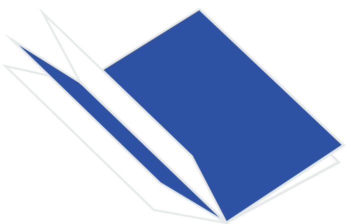
All interviews were transcribed in verbatim, read and re-read to identify emerging variables, and then entered into Weft QDA for sorting and further analysis. A graphical representation of the steps involved in the data analysis process is provided below:



As can be seen in the figure above, pattern matching, followed by thematic analysis was employed to make inferences from the primary data. Responses were seen in the context of the respondent profile and triangulated with findings of the desk review to arrive at final conclusions.

02

STEM education for girls in India



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2.1 Perspectives on the relevance of STEM

Broadly, three significant perspectives on the relevance of STEM can be outlined. First, STEM is an integrated educational response to the future of work and life preparedness, promoting the development of critically important skills needed in the 21st century. The second approach reconceptualises STEM education with a focus on transformative learning, hence placing the pedagogic processes at the centre stage while embedding it in the local cultural contexts. It thus becomes the tool to promote inclusion by developing agency through experiential education. In the third perspective, STEM education is situated firmly within the agenda to achieve sustainable development by motivating future generations to think, ideate and invent green solutions to global problems.

To emphasize the significance of STEM for future work and life preparedness, the concept of 6C's of the 21st century, popularised by Michael Fullan, was actively cited by the educators in the sample. These include Creativity, Collaboration, Communication, Critical thinking, Character building and Citizenship. As students pursue STEM, they not only develop a scientific grounding but also develop the above-mentioned 6C's. When students are in younger grades, such as 4th standard, they are driven by curiosity which sparks creativity. At that stage, as part of STEM projects, they may make a paper flower and fit a small LED light in the centre to transform it into a glowing flower.

Or they may make a paper frog and add a sound device so that it becomes a croaking frog. In the process, they learn creativity. As they grow up, they focus on things in the immediate environment which builds their character.

To prove their contention, educators listed a few innovations like an electronic class-pass to maintain a record of who leaves a class, and for what duration, or an IR sensor voice command for checking students who drop out of the straight line. This way they enhance their collaboration and communication and also strive to maintain self-discipline. In the third stage, they are driven by critical thinking and citizenship where they are able to think about problems that have broader relevance. Thus, they self-select a team, come up with ideas, and work to create useful innovative solutions. Examples include an automatic opening umbrella which can be fixed to a bicycle, a clothesline with wet sensor to pull in clothes when it rains, a GPS enabled cane with voice command for visually challenged, or an e-cane for farmers, fitted with reptile sensors. This way, STEM progresses from a holistic approach to subjects, to thinking about social problems, to collaborating and developing utility items by students and, in the process, also helping them to evolve into considerate citizens. Thus, STEM is not about experimentation and innovation alone, but about the inevitability of a technology-driven future where the ability to use and apply basic concepts of science, mathematics and engineering has an important role in everyday accomplishment.

In the second perspective, STEM brings back notions of 'people's science' and 'street mathematics'. The first implies the application and utility of science in everyday life, and the second focuses on the use of mathematics in routine tasks. This allows all people (including those who are uneducated) to understand and use science and mathematics by drawing learnings from the social and material realities of their local context. In education, it is yet another opportunity to encourage experiential and blended learning in the school ecosystem so that they can work towards individual, social and national advancement.

Respondents argue that when students learn by doing, rather than learning by listening/reading, every activity in daily life gets transformed into a subject. They look at the rain and seek to understand the science behind it. Each one constructs their own knowledge and derives meaning from their experiences, thereby developing agency.

Thus, STEM is inherently a constructivist pedagogy, which when made accessible to children from marginalised backgrounds, provides them with the necessary skills and tools to develop as learners and eventually empower themselves. Taking a cue from this, some of the participants - particularly those belonging to civil society - find the value of STEM in its ability to empower the disadvantaged groups they work with. Opposed to an instructional method of teaching or, as Paulo Freire referred to as the 'banking model of education', Mitchel Resnick contends for an educational philosophy which is based on exploring, knowing and self-learning. According to him, computers must be used less like television and more like finger paint, i.e. for creating and designing rather than passive receiving of messages (Mitchel Resnick, 2002).

When children from marginalised backgrounds participate in STEM, they not only open doors to various occupations, increasing their chances of occupational and income mobility, but also learn to question, experiment and develop agency. This approach talks about making STEM accessible specifically to members of certain social groups, such as girls, by removing barriers and using interventional strategies that promote inclusion to challenge stereotypes and narrow gaps. For them, access to quality STEM education allows for the possibility of achieving social equity, reducing social and household inequality and promoting an inclusive society.

Likewise, the STEM For Girls programme from the Quest Alliance in partnership with IBM uses a blended approach i.e. a mix of both platform based and classroom activities to impart STEM education to girls. Through these sessions, the aim is to cultivate digital fluency, coding skills, life and work preparedness and STEM learning. The focus is to embed a STEM mindset which includes both the subject knowledge as well as building crucial attitudes, values and core skills among the target group. For girls, this includes gender education and building agency to enhance their ability to negotiate gender norms and motivate them to seek more inclusive solutions to problems at hand. The STEM mindset framework from Quest, which is a work in progress, includes the following:

STEM Framework for Quest

Values/Attitudes

- Self-motivated
- Self-learner
- Logical
- Rational
- Scientific temper
- Experimental
- Learning from failures
- Flexibility
- Self-belief
- Creatorship

Skills/Competencies

- Deciphering facts
- Critical thinking
- Analytical thinking
- Researcher
- Technological proficiency
- Construct from abstract to reality(concrete)
- Application of knowledge
- Tinkering

Knowledge

- History of STEM
- Theoretical knowledge
- Current/ Upcoming
- Overall context of society

In the same tangent, UN agencies note the centrality of STEM education for promoting the global sustainability agenda. This perspective contends that STEM envisions a better future for the world, by developing environmentally conscious problem solvers. Some participants of the study believed that when girls do STEM, they focus on green solutions, due to their ingrained qualities like concern for the health and wellbeing of family, community and ecology. Although one respondent felt that this belief attributes quintessentially 'feminine' traits to women, potentially legitimising the already existing biases. According to this perspective, a better understanding of technology should be accompanied by a wider ecological sensitivity so that technological solutions balance economic growth and environmental impacts. Inclusion of girls is of particular importance, both in terms of meeting the Sustainable Development Goals (SDGs) targets around gender equality, as well as the spiral effect it can achieve by augmenting diversity and agency of women in ecological sustainability.

Put together, these three perspectives align STEM to the current and future needs of the world; economically, socially and environmentally. It not only focuses on the preparation of students for a tech-driven competitive global future but supports a range of learning outcomes. It also takes learning beyond classrooms and textbooks, to stimulate creativity and purposeful innovation, alongside building the agency and everyday life problem-solving capacities of students.

2.2 The Gender Gap in STEM

In the last two decades, there has been a proliferation of both the supply and demand of education. This has resulted in vastly improved educational access for girls at all levels. Although the net enrolment ratio[3] for girls is a low 51.9 per cent for secondary and 32.7 per cent for senior secondary, the figures are comparable to those of boys (Children in India, MHRD, 2018). Likewise, the drop-out rate among girls at the secondary stage, although high, is not any higher than boys according to the official figures (Educational statistics at a glance, (MHRD, 2018)[4]. Even in higher education, the share of female enrolment has consistently risen and females now constitute 48.6 per cent of the total enrolment (AISHE, 2019).

However, despite these overall figures which give the impression that gender equality has been largely achieved in education, the details can be revealing. For instance, the gross attendance ratio of girls in rural areas is only 58 per cent, indicating that nearly 42 per cent of girls enrolled at this stage do not attend schools regularly (MHRD, 2018). In higher education, girls who pursue science subjects are found to congregate in certain courses which support traditionally female-dominated occupations, like nursing. Percentage of female students enrolled in nursing is at 86 per cent, whereas boys only constitute 14 per cent. The course has nearly 100 per cent female enrolment in states like Himachal Pradesh, Delhi, and Sikkim, followed by 95.4 per cent in Andhra Pradesh. Although for Bachelors of Science (B.Sc.) programmes, there are 106 females per 100 males, their proportion reduces to 40 per 100 males in professional courses like Bachelors of Technology (B.Tech.) and 34 per 100 in Bachelor of Engineering (B.E.). In 2018, women constituted less than 30 per cent of the total applicants for IIT-JEE and only 12 per cent made it among the top 25,000. AISHE 2019 also notes that the share of female students is lowest for Institutes of National Importance and stands at only 23.93 per cent.

Time and again, several studies have also pointed out underachievement and unequal participation of girls, particularly in subjects like science and mathematics. A longitudinal study by Duke University in 2016 documented the presence of "large and meaningful" differences in performances of boys and girls in science and mathematics in its Indian sample. Tracking the performance of over 7,000 gifted students[5] from 2011-15, the study found that only 11 per cent of girls accounted for top-level scores in maths, compared to 89 per cent of boys. In science, only 18 per cent of girls received top scores, compared to 82 per cent of boys (Makel et.al, 2015).

3. Enrolment of children within the official age-group for that stage as a percentage of the population of that age group.
4. Drop-out rates for girls is 16.8, compared to 7.2 among boys at the secondary stage. Comparable figures for the senior secondary stage is not available. Data from, In NIEPA 2014-15, cited in Educational Statistics at a glance, MHRD, 2018.
5. Talent Identification Programme of Duke University adapted a list of characteristics given by VanTassel-Baska, in, Excellence in Educating Gifted and Talented Learners (1998) to identify gifted children.

Similarly, ASER (2019) found that between the ages of 8-10, 36.4 per cent of boys and 35.7 per cent of girls could do basic subtraction. However, this marginal difference grew to 61.1 per cent of boys against 58.4 per cent of girls being able to solve a given arithmetic problem in the 11-13 age category. A further increase of over 5 per cent was found in the age group of 14-16 where 50 per cent of all boys could solve a division correctly, compared to 44 per cent of girls. In the same age group, only 25.5 per cent of girls could calculate the final price of a Rs 300 shirt on a 10 per cent discount, compared to 33.8 per cent of boys.

Thus despite seemingly equal access to education for girls, a gender gap, particularly in courses related to science, mathematics and engineering persists. The gap further widens due to poor school-to-work-transition, where women constitute only 14 per cent of the total STEM workers in India, compared to 28.8 per cent world average. The result is evident of over 500 recipients of the Shanti Swarup Bhatnagar Prize, India's top award for Science and Technology, only 16 have been women.

The school education quality index (SEQI) developed by Niti Aayog shows large regional variation in the quality of education between states. For instance, Jharkhand has the highest shortfall of teachers in the country, with only 3.5 per cent of schools with separate teachers for all five core subjects[6], while Uttar Pradesh has only 3 per cent schools with functioning computers. In 2016-17, only one state, i.e. Gujarat had more than 50.0 per cent of its schools with CAL (computer-assisted learning) in its elementary school. Comparatively, states like Bihar, Tripura, Jharkhand, Meghalaya, Jammu & Kashmir, Andhra Pradesh and Madhya Pradesh had CAL in less than five per cent of elementary schools. The dropout rate of ST girls is particularly high at all stages of schooling (MHRD, 2018). National Achievement surveys by NCERT also records moderate gaps between class X average achievement scores among different social groups and urban and rural population.

6. English, Language, Mathematics, Science and Social Science

2.3 Variables in STEM for girls

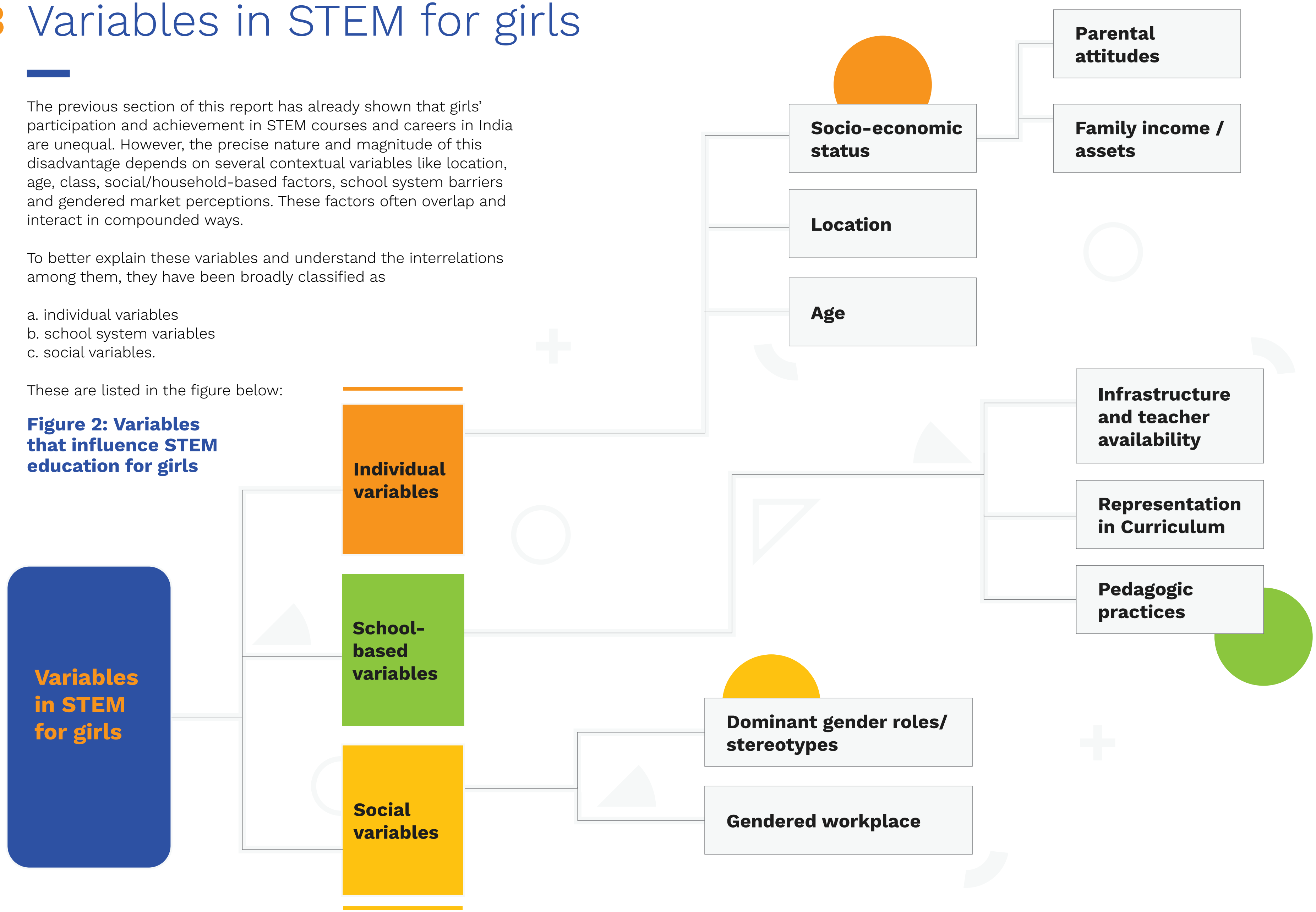
The previous section of this report has already shown that girls' participation and achievement in STEM courses and careers in India are unequal. However, the precise nature and magnitude of this disadvantage depends on several contextual variables like location, age, class, social/household-based factors, school system barriers and gendered market perceptions. These factors often overlap and interact in compounded ways.

To better explain these variables and understand the interrelations among them, they have been broadly classified as

a. individual variables
b. school system variables
c. social variables.

These are listed in the figure below:

Figure 2: Variables that influence STEM education for girls



Individual variables:

Studies among women scientists in India have found that most of them come from privileged backgrounds, largely urban and educated class, where parents have favourable gender attitudes (Dogra and Jayaraj, 2016). A study on women scientists supported by Niti Aayog found that the socio-economic and educational status of 97 per cent of its sample had educated parents and siblings and 55 per cent reported at least one parent or sibling in the academic profession (SSESS, 2017). The study records over one-third of scientists reporting that at least one of the parents offered 'unconditional support' towards their education and career in science. Likewise, a study by Jugaad lab (undated) found that besides economic status, gender attitudes of parents had a decisive influence on girls pursuing STEM. Corroborating this, participants of this study also suggest that socioeconomic status, location and age are the three most important individual-level factors in girls' access to and achievement in STEM education.

Socio-economic status:

Socio-economic status impacts all children, but is of particular consequence for girls, given the traditional gender roles and patriarchal setup. While socioeconomic status includes a host of interrelated variables, like religion, caste, class, parents' education/occupation and so on, the two of these that stood out in the discussion with respondents were: parental attitudes and family income and assets.

Given that education is a family decision in India, girls may be dissuaded or discouraged to opt for STEM courses and careers. Parents might not consider higher education and investing in their girl's education a priority. Thus, unfavourable parental attitudes can lead to loss of opportunities and exposure for girls, even where they may be otherwise available. An ATL coordinator from DLF school shared that their community outreach program has often faced high absenteeism, particularly from girls. Citing an incident, she stated that for a workshop in their ATL, where they had invited children from the neighbourhood school, none of the girls were present one particular day. When they sent out volunteers to motivate girls, they found that it was because it was the kanjak day (9th day of Navratri festival, when girls are worshipped). Parents preferred to make the girls a part of the festivity rather than prioritise the workshop. This could be a result of their limited understanding of the benefits such opportunities bring to their girls in the long run. Some respondents cite intra-household disparity in allocation of resources to girls, where parent's hesitation to invest in coaching classes for girls was a key reason for fewer numbers of girls' clearing competitive entrance exams for engineering courses. Besides, safety concerns also made parents restrict girls' mobility, and limit them from accessing coaching/remedial classes and other opportunities and exposure to STEM, unlike boys.

Family income and assets is another factor that has a substantial impact on girls' education. Based on their analysis of IHDS data, Patel et. al. (2018) show that girls from poor communities are three times more likely to drop out than others. This increases to 70 per cent higher if they belonged to communities which had generally low literacy among mothers. Poverty often overlapped with caste, poor education, low occupational standing of parents and less exposure to messages of gender equality. Conversely, parents with higher educational qualifications are likely to have more positive attitudes towards STEM education for girls. Neither of the two elite urban schools covered in the study reported experiencing gendered attitudes from any parents with regards to their girls' participating in STEM.

Location:

According to the District Information System for Education (DISE, 2016-17), of the total 8.4 lakh primary schools in India, 90 per cent (over 7.5 lakhs) are located in rural areas. Likewise, the bulk of upper primary schools (92 per cent of over 1.3 lakhs of the total 1.4 lakhs) are in rural areas. The numbers, however, sharply decrease both in absolute terms and in proportion to urban school availability at the secondary and higher secondary stages. At the higher secondary stage, only 52 per cent of schools (5970 of the total 11436) are located in rural areas. Thus compared to primary schools, there are only 4 per cent secondary and 1.3 per cent senior secondary schools available in rural areas. Also important to note is that a high majority of schools (about 79 per cent) in rural areas are government schools, compared to 36 per cent in urban areas. Nearly half of the urban schools are private unaided schools, whereas these amount to only 15 per cent in rural areas. At the higher education stage, All India Survey on Higher Education (AISHE, 2018-19) finds that 60 per cent colleges are in rural areas, with 11 per cent of them being exclusively for women. About a third of the total universities (394 out of 993) are in rural areas.

Thus what appears from data is that at the secondary stage, availability of schools declines sharply in rural areas, before somewhat increasing again at the tertiary stage. This resonated in the expert interviews as most participants in the study cited 'location' or 'remoteness' is one of the key barriers for girls. Urbanisation was seen to enhance exposure and opportunities and bring about modernization in attitudes. Conversely related to girl's access to STEM education, rural residence was marked by a sort of 'information poverty', fewer opportunities and regressive social attitudes. Rural parents were also found to be less likely to invest in girls' education and poor mobility further distanced girls from any opportunity that existed in the vicinity. Schools in rural areas had fewer teachers, particularly science teachers, and were more likely to be short of facilities like separate toilets for girls and science/STEM labs. Vimala Ramachandran, a retired professor from NIEPA, contended that in her research evaluations of Rashtriya Madhyamik Shiksha Abhiyan (RMSA) in 2018 she found that schools in tribal areas were particularly deprived of science and mathematics teachers.

Respondents also caution that the disadvantage of rural background although being very significant in its own right, is also contextual. Within this location, there are layers of marginalities like that of caste, class, inter-state factors which further impacts on girl's access to STEM education. Thus, rural areas of tribal Jharkhand are likely to be much worse than rural areas of Kerala. Likewise, rural girls of Maharashtra, given that it is an economically strong state, with a history of popular civil society movements, are likely to meet with more favourable mindsets and better opportunities, compared to states where women are generally accorded a much lower status. Thus, a connection can be established between the human development indicators especially those related to gender and the opportunities that are presented to girls with respect to STEM education.

Age:

It is well established that girls' education suffers the most around the age of puberty. This is when they are most likely to drop out of school due to socio-cultural norms, like menstruation taboos, misogynistic notions on safety and devaluation of education for their lives ahead. Insights from rural areas show that at the primary level, girls may have an edge over boys. Their gross school attendance ratio is better, as boys are the ones to bear the brunt of child labour and often go to work in fields or cattle grazing. In the sowing and harvesting seasons, attendance of boys in some areas sees a particular dip while many girls continue to attend schools. Although girls do housework, these are often managed before and after school hours. However, once girls reach around grade 8th-9th, their disadvantages surge. They either get married or are pulled out of school simply for the belief that education is of no use to them, as managing the husband's home and rearing children are their inevitable predicaments.

For urban middle-class girls, respondents suggest that this vulnerability was more likely to start after marriage and childbirth. Thus, despite receiving higher education, the disadvantage is experienced in the form of a disproportionate burden of gender roles like household and care work and glass ceiling at the workplace. Gargi Datta explains eloquently, "we have engineers who apply for the position of science teachers. When I interview them, and they say it is because of their love for teaching, I don't believe them. I know they opt to teach in schools because they want a manageable career while looking after family, in-laws, children and so on. But schools have now become corporates, it is not like before that you can leave in half-day and attend to other errands. However, social perceptions remain the same. Unless those are challenged, girls will only be able to partially benefit from what we are doing with them in schools".

Thus, girls seem to be most vulnerable to disadvantage at two crucial stages: first around puberty, as they enter the secondary level of schooling, which is more likely to have an impact if they belong to a poor family and reside in a rural area where conservative social norms are more prevalent. Second, around the transition from junior to the mid-career stage, when marriage and childbearing coupled with gender role expectations mean that care and housework are prioritised, often resulting in dropping out of paid work or seeking under-employment.

School-based variables

School-based factors include several aspects like availability of infrastructure and equipment, availability of female teachers, curriculum content and pedagogical practices which includes classroom interactions, teachers' beliefs and expectations, domain knowledge and assessment practices. These are elaborated below:

Infrastructure and teacher availability:

With SSA and RTE, availability of basic infrastructure in schools have received a boost. According to UDISE, in 2017-18 (provisional), there were 31,799 (or 2.91 per cent) government schools without girls' toilets. However, this is less than the number of schools without boys' toilets which stands at 58,035 or (5.31 per cent) (Unstarred question 2286, Lok Sabha, 8th July, 2019). Despite these, the availability of teachers as well as specific infrastructure and resources for STEM education remains a concern, particularly in government and low-cost private schools. According to the latest MHRD data, the share of female teachers is 50 per cent at the primary level, but this reduces to 43 per cent at the secondary and 39 per cent at the tertiary level (MHRD, 2018). Official estimates acknowledge that elementary schools have a shortfall of over 9 lakh teachers, with Jharkhand being the state with the highest deficit. Although subject-wise disaggregation of male/female teachers is not available, some respondents in the study maintain that science, mathematics and sports are subjects which are primarily taught by male teachers.

In terms of infrastructure, DISE data (2016-17) show that only 14 per cent of schools in India have a functioning computer. This is again marked by regional imbalance where the figure for states like Delhi is 67 per cent, followed by Punjab and Tamil Nadu at 42 per cent. However, some other large states like Uttar Pradesh and Odisha have a working computer in only 3 per cent of schools. Amidst a general lack of infrastructure, girls are further marginalised as it is mostly all-girls' schools which are denied science teachers or labs, or options of choosing elementary mathematics (against home science) under the pretext of lack of relevance or suitability (CABE, 2005; Mehrotra, 2006; Ramachandran; 2018). Vimala Ramachandran, based on her evaluations of RMSA for World Bank (2018) stated that many all-girls' schools in Rajasthan and UP have no science teacher. When she confronted an official, an education officer told her, "ladkiyan science padhkar kya karengi?" (what will girls do with studying science?). Thus when resources are limited, differential access becomes the unsaid norm and girls bear the brunt of disadvantage.

Poor infrastructure impacts girls further as they are also poorly represented in the curriculum and lack out-of-school familiarity in science and mathematics. Participants explain that boys generally get more opportunities to hone their spatial and mathematical abilities in everyday tasks and are also given the opportunity for more exploratory and experimental play than girls, who are bound to homes or in the neighbourhood even while at play.

Representation in Curriculum:

A study by UNESCO found that girls' achievements are impacted by the nature of learning material and assessment modalities. They tend to learn better when the curriculum takes into account their experiences and relates to their lives whilst including hands-on activities (UNESCO, 2018d). However, a review of the national curriculum framework found that in Indian mathematics and science textbooks, only 6 per cent of the illustrations at the primary level showed exclusively female characters (Benavot, 2016). Moreover, there was a stark absence of women in all commercial, occupational and marketing depictions as well as representations of engineers, executives or traders.

During the interviews, none of the companies or non-profit STEM education providers felt that they need to customise learning material for girls. However, the inclusion of girls in the curriculum was emphasized as an important enabler to their inclusion in STEM. Krupalini Swamy, who is Vice president of Evobi automation and also a Niti Aayog mentor for change, argued that when implementing a STEM curriculum, there must be efforts to relate to girls' innate ways of learning. According to her, boys are spatial learners while girls are visual learners. These differences are a result of an evolutionary process where men were hunters and women were gatherers. Thus, she elucidates, that when both are asked to draw cars, boys would draw a moving car and girls would draw an intricate, detailed car, paying attention to aesthetic details. In the same tangent, Mathura Govindarajan, Lead Developer at peblio.co, contended that a curriculum for STEM education should include girls' interests. She illustrates that instead of focusing mostly on robotics, more inclusive narratives of doing STEM through arts, gardening, fashion accessories and so on may enhance girls' interests. However, while there is no harm in exploring such viabilities, caution must be exercised so that these help in overcoming stereotypes, not reinforcing them.

Pedagogic practices:

General contention of respondents was that Indian classrooms are purposed to transfer factual knowledge to students effectively. This coupled with parents' expectation of good examination performance, makes the entire system oriented to rote learning with little scope for exploration, self-reflection and integration of knowledge. This leaves girls without further scope to display agency in the classroom. A few participants also made references to discriminatory classroom practices where girls' contribution were unrecognised or devalued and curriculums were gendered.

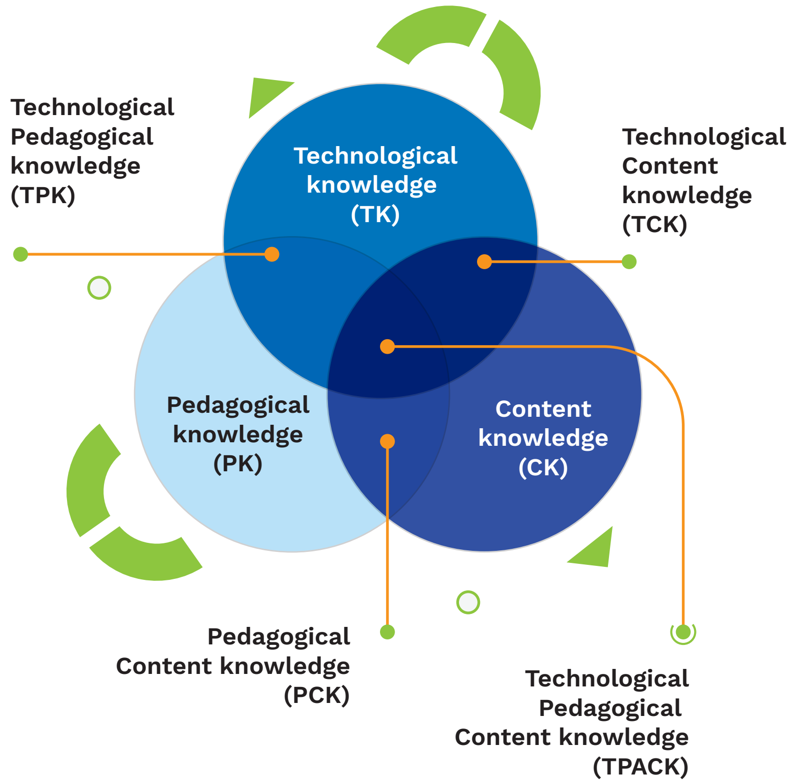
Issues around gender and curriculum have been systematically investigated by many researchers, across contexts. Studies have found that teachers interacted more with boys than girls, expressed greater acceptance of boys' contributions and answers, engaged in higher-order questions with them, and offered them greater praise and reinforcement (Dube, 1998; Karlekar, 2000; Rathnam, 2002; Mehrotra 2006). Girls were discouraged from participating in class by a number of non-verbal and verbal communication. Verbal communication included biased interpretations of textbooks, use of gendered language, stereotypical references to abilities and girls' inevitable future predicament of marriage, childbearing and housework. Non-verbal communication like gaze aversion, withholding of active listening responses like nods or requests for elaboration, and delayed verbal feedback and interruptions have all been found to limit girls' classroom participation (Tulsyan, 2018). Gautam (2015) captured a gendered division of labour in science where boys usually conducted experiments and girls did the associated writing work (maintaining the practical file) which was later simply copied by the boys.

However, there was evidence that some change is around the corner, particularly in urban, elite schools. On the one hand, teachers have been oriented towards concepts of active learning, and on the other, students have increasingly found diverse sources of learning, like online libraries, YouTube videos or Google search engines.

Gargi Datta gives an example from her class:

"I am a science teacher, but one day I asked my students if they have any musical instruments that they can bring to school so that we can have a concert in class. Someone got a tabla, someone guitar, someone flute and another one harmonium. First, they will play it. Now you must be feeling where do musical instruments in a science class belong? This will be answered when the discussion begins. I will ask students questions: why did you tighten the strings of the guitar? How did it change the pitch? What will happen if we close all holes of your flute and keep only the last one open? How will the sound change – using these I will explain to them about scientific concepts like frequency, amplitude, pitch and so on? Gradually they will start getting curious and ask questions. This is how our classrooms have changed."

While there is greater recognition that rote learning needs to be replaced by active and experimental learning, this development has not been uniform. In a large majority of schools, it is much less understood. Prof. Padma Sarangpani feels that this is because while the government has made some improvements in pre-service teacher training, in-service training has continued to be neglected. It will thus take a long time before all teachers are replaced by a new generation of teachers who have received training in interactive pedagogies. Moreover, given the increasing relevance of technology in everyday life and workplaces, teacher training must use the conceptual framework of Technological Pedagogical Content Knowledge (TPACK). TPACK framework contends that technology integration in any educational context needs careful alignment of content, pedagogy and the technology, and it, therefore, requires teachers who are competent in all these three domains. This framework is commonly represented by figure 3, as follows.



Source : Mishra. P. (2018) Revised version of TPACK image

The dotted circle in the figure above represents the contextual knowledge of the teacher. The three overlapping circles within this represents three domains of teacher knowledge: Pedagogical knowledge (PK), Technological knowledge (TK) and content knowledge (CK). This TPACK image thus presents two very crucial aspects of teacher training for STEM education: first, that the technological knowledge of teacher is as significant as content and pedagogical knowledge and has a much larger role in facilitating student's learning than before and second, that contextual knowledge has a strong influence on teacher's knowledge and practice of the other three domains.

Assessment practices:

Our education system places a disproportionate emphasis on 'assessment of learning' while often neglecting 'assessment for learning'. The former is a summative measure of the performance of students, often based on standardised tests once the teaching-learning process is complete. This later, however, refers to an ongoing assessment to understand the learning process and adjust instructional strategy accordingly. To promote STEM, there is a need to record and make sense of day-to-day descriptive data and develop feedback practices which can make way to classrooms. For the development of skills required for the 21st century skills and the 6C's, both these formative and summative assessments must gradually integrate and promote 'assessment AS learning'. Assessment as learning is a process where children are actively involved in setting up their learning objectives and assessment design, and are guided by teachers in their personalised learning paths.

Social variables

Social factors that influence girls' participation in STEM include dominant gender roles/stereotypes, gendered market and lack of role models and mentors.

Dominant gender roles/stereotypes:

Stereotypical gender roles, which typify women in domestic roles, coupled with a lack of role models hold back girls from pursuing STEM. They often internalise these messages and expectations from within family, society and media and this affects their interest or motivation in STEM. Respondents point out two significant areas were social barriers become significant: first is the ability stereotype, where girls are seen as naturally less capable in STEM than boys, and second is the cultural fit stereotype (Master and Meltzof, 2017) where girls feel they do not belong in STEM. These stereotypes get learnt early in life, starting with the toys that babies are given to play with. Boys are given blocks to play with and girls are given dolls, resulting in a) early differentiation in learning and opportunities and b) naturalization of these stereotypes, which get continuously reinforced in a myriad of ways as they grow up. Girls also face differential access to technological devices (like laptops) within the home and even if they make it to scientific institutes or engineering colleges, they continue to face gendered attitudes of lab assistants, restrictive timings of hostels (unlike boys) and lack of informal networks.

Gendered Workplace:

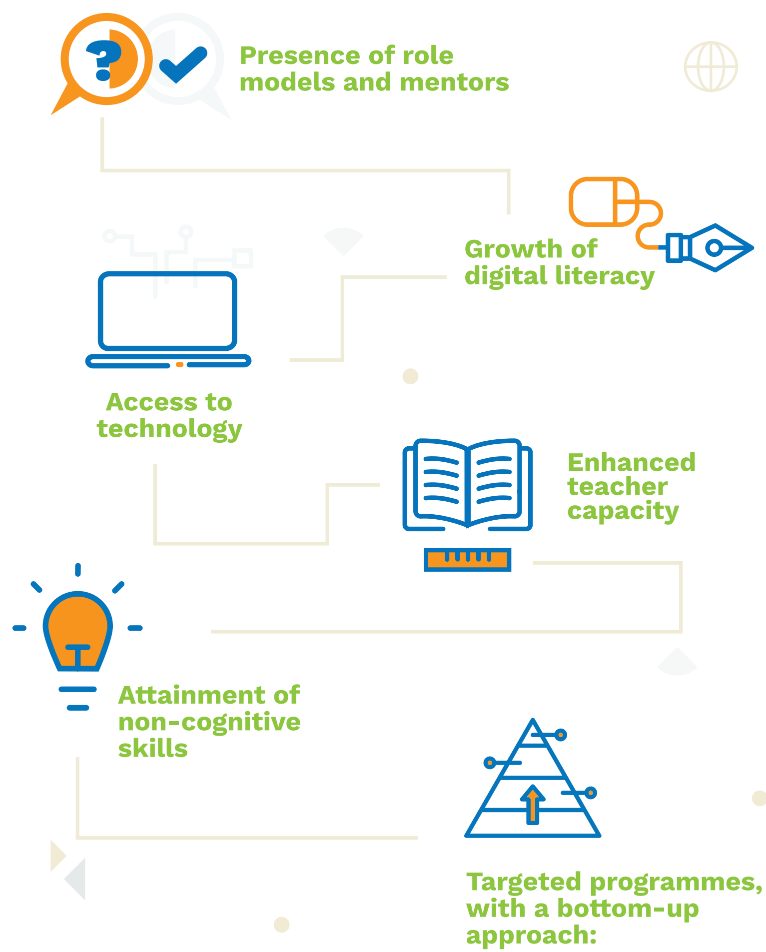
Both primary and secondary findings suggest that a range of market-based factors contribute to push women out of the STEM fields. These include hiring and promotion bias, male-dominated work culture, poor work-life balance, safety at workplace, lack of women-friendly policies and avenues for re-entry.
According to Valian (1999), women are held back in careers because of two key reasons: gender schemas and accumulation of advantage. The first, gender schemas, refers to the implicit notions about gender differences that makes employers overrate men and underrate women by presuming certain stereotypical traits and capacities for each gender. This often leads to a hiring or evaluation bias. The second, accumulation of advantage, refers to both the small and big advantages that men pile up over a time which contribute to unequal career advancements. This has led to a concentration of women in junior and middle-level positions, with a conspicuous absence of women in the senior leadership roles. This phenomenon has been described as a vertical segregation (Caprile et al., 2012).

A survey by MasterCard and Incite found that 45 per cent of women respondents who worked in STEM-related fields did not wish to pursue these in the long term. The reasons for their dissatisfaction ranged from; the need for frequent upskilling (46 per cent), long working hours (39 per cent), male-dominated work culture (36 per cent) and unequal pay (24 per cent) (Economic Times, 10th February, 2018). Another survey with adolescent girls (12-19 years) further revealed that as many as 38 per cent had decided against STEM careers (ibid). Thus, a gendered marketplace further contributed to excluding women from STEM courses and careers by reducing their aspiration in such fields.

Above mentioned individual, social and school-based variables put together tend to create psychological inhibitors among girls like greater anxiety, poor confidence and low motivation among girls. Resulting in reduced self-efficacy and aspiration in STEM, these factors contribute to actualising of the stereotype threat, where girls may themselves choose to move away from STEM citing lack of interest or competence or both. However, it is important to point out that these preferences or interests are neither innate nor absolute, but are constructs of social conditioning and experiences.

2.4 Enablers of girls' access to STEM

There are certain factors that improve girls' access to STEM curricula and careers. These are expanded on below:



Presence of role models and mentors

The presence of and interaction with role models and mentors which can help dispel stereotypes break and instil aspiration in STEM careers were reported as one of the key enablers of girls in STEM. If these role models are relatable i.e. belonging to their caste/class/geography, they become even more effective by instilling confidence in girls and making them think: 'if they can do it, so can I'. Thus respondents point out that the strategy must gradually shift from using urban-based, privileged background role models and mentors, to identifying and developing a cadre of girls who can then also serve as relatable role models to the next generation of girls. The focus should be on celebration of their achievements, their inclusion in the curriculum, as well as opportunities of engagement, which can provide both practical guidance and psychological stimulus for girls.

Growth of digital literacy

All respondents of the study felt that digital literacy is a strong enabler of STEM education. It opens up a whole new world, allows for an exchange of ideas, and helps in understanding and solving problems that students may encounter in their pursuit of innovations. Thus, although science and experimentation can happen without digital literacy, in the contemporary and future world, digital literacy is practically a necessary prerequisite to STEM education. Some respondents articulated that this is a bi-directional relationship where each one contributes to greater understanding and fluency of the other. For girls, in particular, digital education can help them overcome barriers like lack of facilities and exposure, mobility and lack of role models. Digital literacy thus enhances girls access to content, keeps up their interest and motivation and builds aspiration.

Respondents further add that the role of digital education has also grown due to increased access to smartphones, however, this is only one of the multi-pronged strategies and works best when combined with other enablers. They maintain that focus on digital literacy cannot dilute the need to fix basic infrastructure and teacher capacities in education.

Access to technology

Technology can be used to enhance access to online knowledge repositories like MOOC (Massive Open Online Course) and OERs (Open educational resources) several of which are freely accessible, diverse and creative content and are useful for teaching, deeper learning and doubt clarifying. When students are connected to these, it promotes personalized learning and helps overcome barriers of geographical remoteness and lack of adequate exposure. However, merely improving access to technology is not enough in itself. Unless the school ecosystem is geared to support active learning, technology will not be optimally utilised to fulfil what it truly can. To give an example, the distribution of tablets/laptops to students is meaningless if it is not supported by a teacher to guide its usage. Thus, technology alone cannot solve the problem but technology combined with teachers is the changemaker, respondents emphasised.

Enhanced teacher capacity

Investments in teachers was cited as another critical enabling factor for promoting girls in STEM. This included three things: first, to enhance teacher's domain knowledge; second, to train them into interactive pedagogies and third; to develop them as change agents. Enhanced domain knowledge will help teachers to clarify concepts more comprehensively within classrooms, further enhancing the capability of students to apply this in different contexts. When pedagogies are revised, they will make experiential and blended learning more central to the school ecosystem and build scope for greater student agency in the classrooms. This means that besides textbooks, much of teaching will happen through activities, projects and exposure trips. There is also a need to make learning contextual, to draw examples from everyday realities and experience of girls. Finally, when teachers become conscious of their behaviour and actively promote a positive hidden curriculum, the entire education can be geared to the end of the empowerment of students. As teachers are sensitised to fulfil their role as change agents, they start encouraging girls into atypical courses and vocations, and generally express a higher expectation of them in all fields.

Attainment of non-cognitive skills

There was a near consensus among respondents that education needs to be reimagined from the perspective of promoting life preparedness, besides near acquisition of subject knowledge. Thus, skills like critical thinking, problem-solving, creativity and other soft skills are crucial for future life success on a personal, occupational and social level. It is important to teach students how to develop themselves as learners, how to collaborate meaningfully with each other and how to embrace failures. For girls, two sets of skill-sets were articulated: first, personal skills like social and general awareness, training in self-defence, negotiation, assertiveness and resilience. Second are the employability skills like communication, teamwork, time management, leadership, problem-solving and so on. These skills will go a long way to translate educational success into success in the workplace and later life.

Targeted programmes, with a bottom-up approach

It was found that government programmes, like ATLs, have been a huge enabler for the STEM education programme. Many of the urban schools, which were previously sourcing STEM education products from private vendors, now with the ATL grant have immensely benefitted by being able to purchase more equipment, without passing on the financial burden to parents. This covering of costs has also allowed them to make STEM accessible to all their students, rather than only those who could afford to be a part of the robotics club.

Respondents also discussed some other targeted, bottom-up initiatives that have encouraged participation and representation of girls in STEM. For instance, tech companies like CapGemini have committed themselves to hiring and training programmes for girls from rural areas. To identify talent from underprivileged backgrounds and nurture their growth as trainees and employees. Such awareness and commitment from companies not only has a direct impact on the girl being hired but also creates role models for others in similar situations.

Another example cited in the study was that of The Honeybee Network (HBN) which collects information on pro-poor inventions and innovations from the grassroots and disseminates it to the wider ecosystem. This not only popularises such ideas and products by diffusing the gains to larger areas, but also stimulates affordable and practical solutions to local problems.

Such programmes developed by government, companies or civil society/ non-profit groups go a long way to support and encourage STEM among students. When they are targeted at girls, particularly from less privileged backgrounds, they become even more valuable.

03 STEM Policy environment in India

3.1 Policy support to STEM in the NEP (National Education Policy)

The recently passed New Education policy has both hits and misses for STEM education in the country. The three most significant proposals include: a. expansion of RTE to include free and compulsory education till secondary level b. setting a target of 2030 for achieving 100 per cent GER till secondary stage and 50 per cent in higher education by 2035 and c. mainstreaming of early childhood care and education (ECCE), in acknowledgement of the scientific fact that maximum development of brain occurs from birth to 5 years of age. Its proposal to extend the Right to Education (RTE) to secondary stages is likely to result in a boost to school access and retention of girls in the secondary grades, around when the gender gap in science and mathematics are known to widen. This will not only serve the goal of social inclusion but also economic inclusion, allowing girls greater success and choice in the technology-driven occupations of the future. Besides, ECCE will provide formative skills and make a lasting difference to child's aptitude, building a strong foundation for future participation in STEM activities.
Other positive features include listing girls as a disadvantage group in need of inclusion and the need to adapt and keep education system flexible in view of changing Future of Work. Multiple reference is made to reduction in syllabus and promotion of experiential learning, based on hands-on activities. It also engages in technology in detail – mentioning both, studying through technology and studying about it. Expanding the scope of technology from learning apps and online libraries for students, it discusses the need to teach coding and robotics to all and develop a scientific temper. However, it has dropped the target of making available personal computing devices to all students by 2025, from its draft.

The NEP does not directly address STEM. From its about 500-page predecessor draft, the finalised policy includes about 60 crisp pages. It mentions STEM only once in the document, in a generic context. Any mention to Atal Tinkering Mission is omitted. Hence, one can argue that despite the mention of Future of work and the need for hands-on learning, NEP does falls short of creating space for STEM in educational budget, in strategic partnerships or in a large scale nation-wide programme. STEM education thus continues to remain a policy blind spot in India.

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The only silver lining is that there some suggested measures which may have an indirect impact by a. creating STEM infrastructure and b. creating STEM mind-set. The big push for digital infrastructure like physical as well as virtual laboratories, use of open source software, spoken tutorials, computer rooms and other scientific equipment will allow students to access technology, learn through its use. Creation of school complexes will allow sharing scare resource in a short supply. This coupled with activity based experiential learning will improve the quality of education, including science and mathematics teaching-learning. Moreover, with a complete overhaul of teacher training, which will include training in child centered pedagogy and use of technology, one can hope that they will promote development of 21st century skills among students. Semester wise assessment system will allow continous learning with flexibility.

Thus, despite the above-mentioned initiatives that may have a related impact on STEM education in the country, the Indian policy scenario is far behind some countries who have taken active policy measures. For instance, Germany has formulated a High-Tech Strategy and a National Pact for Women in STEM Careers[7], specifically aiming to address gender disparities in STEM education and employment. In 2016, Australia committed to an expenditure of 8 million Australian dollars in projects to inspire girls and women to study STEM[8]. Japan introduced National STEM frameworks 2020. Likewise, the Malaysian government has started a STEMForAll[9] (STEM4ALL) initiative particularly targeting rural areas. They also set up residential science schools for girls and are strengthening the STEM curriculum with the help of multilateral agencies like the World Bank and UNESCO. Most recently, the U.S. Senate Committee on Science, Commerce, and Transportation passed a Building Blocks of STEM Act which particularly focuses on equitable distribution of STEM-related education in early childhood stages. Relatively, STEM education in India continues to lag behind both in policy and practice.

However, despite lagging at the national level, there have been some state government initiatives that have achieved substantial outcomes and recognition. One such case study from India's southern state of Kerala is detailed below.

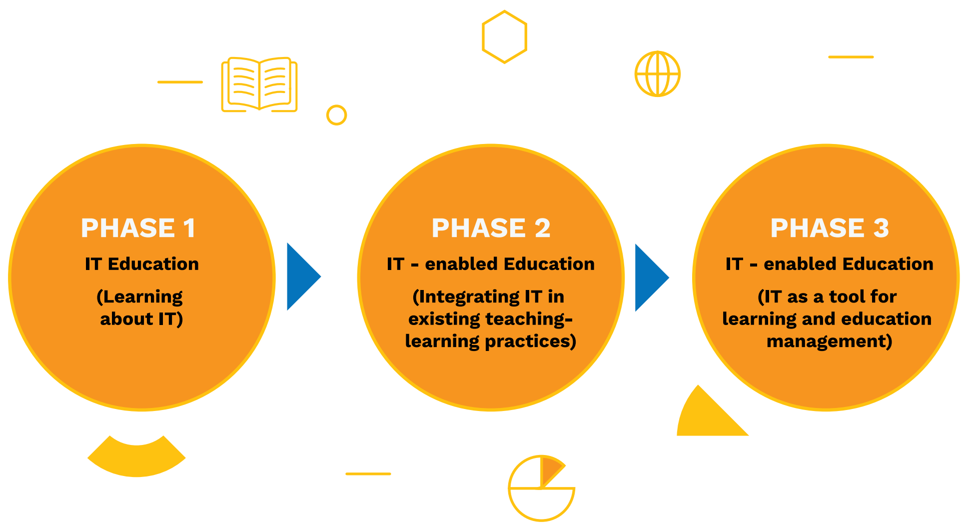
7. https://www.komm-mach-mint.de/english-information National Pact for Women in MINT[STEM] Careers, 2008
8. https://www.minister.industry.gov.au/ministers/hunt/media-releases/8-million-support-women-stem-and-entrepreneurship $8 million to support women in STEM and Entrepreneurship, 2016
9. https://news.microsoft.com/en-my/2019/03/12/transforming-malaysias-education-system-with-stem4all/ Transforming Malaysia's education system with STEM4ALL and Artificial Intelligence, 2019

Case Study: Kerala IT@Schools

In 2000, the Department of General Education of Kerala constituted an IT task force under Prof. U.R. Rao to define the scope of ICTs in schools. This task force recommended that IT must be leveraged in classrooms to promote better, deeper and faster learning. It also noted that Kerala, "with its unique academic, social and technological environment is ripe to tap the benefits of the IT revolution to enrich its education". This paved the way for creating an ICT-enabled education system in the state.

This was achieved in a phased manner (see figure 4). In the initial stage, the focus was on setting up a vast and transparent infrastructure system to gear up the program for future success. Schools were supported with equipment like computers, printers, netbooks, and generators; along with broadband connectivity and detailed usage norms to ensure safe and secure browsing. These were procured through funds available with local institutions or MLA/MPs development funds. Alongside, in 2002, IT was introduced as an optional subject for grade 8. The very next year, it was made a compulsory subject, and in the following year, it was expanded to include grade 9 and 10 as well.

Figure 4: Phases of IT@Schools in Kerala



Source : Adapted from Parkavi Kumar, CIPS (2013)

In phase 2, the focus was on simultaneous content development and capacity building. Smart classes were introduced in schools, along with the revision of curricula of other subjects to include components on IT education. Teachers were oriented to enhance their capacities to remodel their conventional pedagogies and use educational applications in classrooms. Over 2 lakh teachers were trained, with specific modules for teachers of specific subjects. A hardware clinic programme was launched to solve technical problems and promote maintenance, repair and up-gradation needs of the equipment.

In phase 3, a full-fledged ICT enabled delivery in classrooms was achieved. Building capacity of teachers gradually did away with the dependence on outsourced ICT trainers. The project covered 12,000 schools in the state, benefitting nearly 5 million students. A ratio of 1:15 was maintained between students and computers. IT@School has a network of 160 master trainers and 5,600 school IT co-ordinators, who are all school teachers. Another remarkable feature is that the entire platform, including the operating system and applications for IT education, has been developed in-house. All of the content deploys Free and Open Source Software (FOSS).

IT@school was changed to KITE (Kerala Infrastructure and Technology for Education) in 2017, which is a Special Purpose Vehicle Company under the Department of Education. KITE not only manages all IT-enabled e-learning projects but also supports e-Governance initiatives of the State. Thus from learning support, the programme has moved on to include IT-enabled governance of schools and education department.

Some of the initiatives under IT@school (now KITE) include:

- **'Little KITEs' which are IT Clubs for school children with a membership of over 1 lakh students. These clubs participate in activities and training in areas such as Animation, Cyber Safety, Malayalam Computing, and Hardware and Electronics.**
- **The Hi-Tech school programme where schools will have well-equipped classrooms and IT Labs. These are in a network through a central server, which would allow sharing of information.**
- **Samagra eResource Portal which is a repository of digital resources for all subjects from K1 to K12. Teachers across the schools contribute to a variety of content which can be accessed by all students.**
- **Sampoorna which includes services such as student information and school management systems.**
- **School wiki for better sharing of information and decentralised incorporation of information. Spark, which contains teachers' databases and stores management support and records of training support provided to teachers.**
- **Portals for Kallolsavam, Sastrothsavam & School sports which help in better organisation and visibility of events.**
- **SIET's Digital content development for the creation of audio-visuals and their dissemination.**

There are three remarkable aspects of the IT@school project:
First, the program has been largely successful in achieving the issues of access, equity as well as quality. Girls, who faced discrimination with respect to their access to technology at homes could now access it in schools. It thus led to a sort of democratisation of technology.

Second, is the in-house capacity building, particularly of the teachers alongside infrastructure provisioning. This included female teachers who developed their capacities and played an important role in taking tech in classrooms. The project also facilitated peer learning, both among teachers and students.

Third is curriculum reform, development of extensive digital content and exclusive deployment of open source technologies.
Despite these successes, the state faces some challenges particularly in areas of expansion and evaluation. Expansion of the programme to primary and upper primary grades with limited financial resources will be a real test of political will and efficiency. Besides, there is also increasingly realisation of the need to evaluate the curriculum and establish a rigorous feedback loop between content development and learning outcomes. Both of these will ensure that content is continuously updated and adjusted to meet the changing needs of students and the programme objectives.

3.2 Effectiveness of Atal Tinkering Labs

Aiming to 'Cultivate one Million children in India as Neoteric Innovators', Niti Aayog has initiated a flagship programme called the Atal Innovation Mission (AIM). AIM encourages the establishment of Atal Tinkering Labs (ATLs). Under this programme, schools (both public and private) are provided grants to set up tinkering labs to promote creativity, curiosity and innovation among young minds. These labs are dedicated workspaces which have been equipped with do-it-yourself (DIY) kits of modern technologies, such as 3D printers, robotics, Internet of Things (IoT), and miniaturised electronics; to enable students from middle and secondary grades to learn and work on innovative solutions.

One of the biggest achievements of the programme is that it has widened the participation base in terms of hands-on learning and experimentation in science and mathematics. The schools whose representatives were interviewed in this study had been part of robotics clubs where only the interested children participated. These schools bought limited equipment from private vendors. However, with the establishment of ATL, it became a compulsory activity for all children above grade 6 and the level of innovation got elevated from ideation only to building actual products. Also, of particular significance is the word 'tinkering', which supports the idea of exploring, making small changes and seeking to improve or innovate. 'Tinkering' promotes experiential learning and application of concepts learnt in classrooms in an integrated manner.

It is a demand-driven programme where interested schools have to make an application and undergo a screening process before grant approval. Each school is given a grant of 10 lakhs as establishment cost and 10 lakhs for the next five years as operational costs. To further support the initiative, each school is provided support of 'mentors for change' recited by Niti Aayog and assigned to schools as enablers. The program design includes an elaborate application and screening process, followed by several checks on utilisation, like documentary compliance and audit. Gargi Datta from DFL school explains that one of the first questions she faced in her interview with the screening committee was 'if you are granted an ATL, what will you do for the community?'. Thus the agenda of wider community outreach and problem-solving through ATLs is high in the programme.

Once the grant is finalised, schools have to share regular real-time data on several aspects: equipment purchased, number of participating children, number of classes/activities/events, number of community outreach activities, number of visits by the mentors, details of innovations done and so on. These need to be adequately supported by documents, like bills, receipts and photographs. Besides, mentors also need to send school progress reports. On the whole, participants of the study agree that this is a well-monitored programme and has an in-built mechanism to ensure that grants are purposefully utilised and ATLs are operational.

However, despite getting the approach right, some concerns were expressed with regards to implementation. First, most of the ATLs seem to have been granted to urban, elite, private schools or some of the better performing government schools like the Kendriya Vidyalayas. This means that while it is good for optimisation of top-line growth, efforts to make the opportunity accessible to all continues to remain the need of the hour. Second, the community outreach component has been limited to schools holding workshops and events for neighbourhood schools. Thus, children from outside the grantee school come only when invited, for programmes which are highly structured and do not enjoy the opportunity to freely work on projects alongside the school's own students. Prof. Padma Sarangpani from TISS recommends that AIM should provide a) targeted opportunities for deprived areas and sections of people, b) ensure the operational success of the labs by providing additional infrastructure and human resource support and c) build motivation through local, relatable mentors and role models. This points out a need for a thorough assessment of ATLs on parameters of accessibility, inclusion, innovation and impact.

3.3 Other Programmes and Schemes

The Indian government has strived to bring more women to science through its various incentive-based programmes and schemes. In 2014, the Department of Science and Technology (DST) restructured all its women-centric programmes bringing them under one umbrella called the Knowledge Involvement in Research Advancement through Nurturing (KIRAN). With the aim of achieving gender parity, the KIRAN programme focuses on gender mainstreaming by encouraging women scientists back in the labour market by offering fellowships and internships. Besides this, KIRAN also has a component of supporting Science and Technology infrastructure in women-only universities through CURIE i.e. Consolidation of University Research for Innovation and Excellence in Women Universities programme which seeks to attract and retain female researchers. DST is also involved in training and capacity building activities, particularly setting up Women Technology Parks (WTPs) which are a hub for convergence of diversified technologies, like agriculture, fisheries, animal husbandry, horticulture, forestry and so on.

Yet another scheme called Vigyan Jyoti was announced in 2017 by the Ministry of Science and Technology which focuses on encouraging girls in secondary school by providing them with opportunities for interaction, coaching and mentorship with role models i.e. women scientists from IITs and Indian Institutes of Science Education and Research. This was accompanied by the redesigning and renaming of a national programme called Innovation in Science Pursuit for Inspired Research (INSPIRE) to Inspire-MANAK (Million Minds Augmenting National Aspiration and Knowledge), whose aim is to attract gifted young boys and girls to pursue science as a subject and future career trajectory. However, the actual impact of how these schemes translate to increasing women in science beyond students attending a few camps is unknown, as the schemes do not entail the provision of long-term monitoring and follow up (Wire, 5th September, 2018).

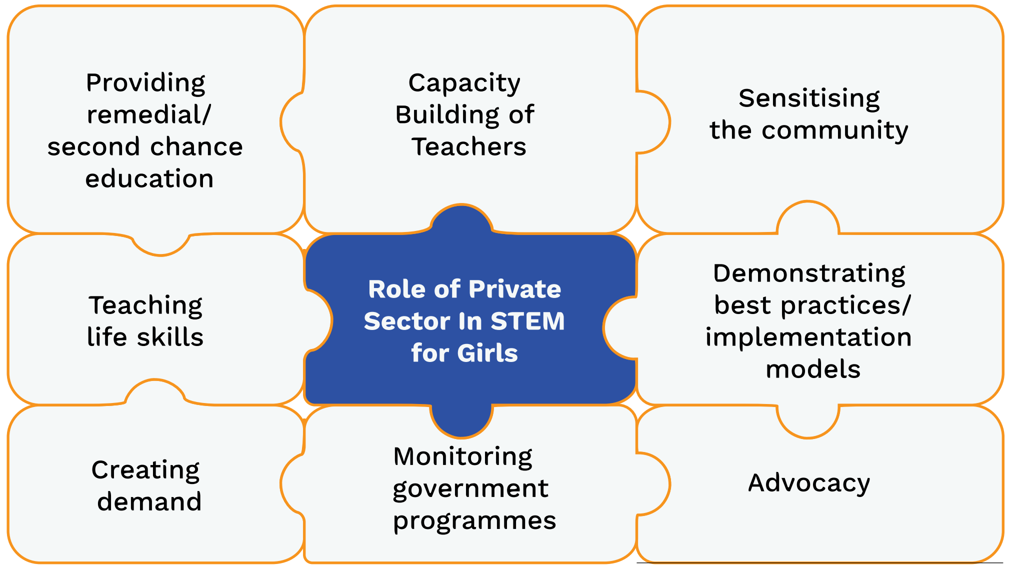
Some other fellowships and grant-based programmes like the Indo-US STEM fellowship, BioCARE programme by Department of Biotechnology (DBT), UGC post-doctoral fellowships and PG Indira Gandhi Scholarship are meant specifically for female children. However, despite these incentive and quota-based schemes, mainly in tertiary education, a lack of long term monitoring and follow up of beneficiaries makes it difficult to assess their real impact.

“In my school [in rural Madhya Pradesh] we have three computers, but no electricity. What’s the use? In my previous school, which was in an urban area (Bhopal), there was electricity as well as computers, but no computer teacher. Due to own limited capacity, we could not use them beyond showing occasional videos. Now ATLs have come. But here we know nothing about it. For us, exposure to STEM is limited to an activity book which has been given to us to engage children who lag behind others so that they can learn with fun.”

- Amita Singh

3.4 Role of Private Sector

Besides the government, the country has witnessed several private companies/academies/start-ups, corporate social responsibility groups and not-for-profit initiatives with a focus on STEM education. Earlier, IBM has also initiated the Teachers Try Science program, the main focus of which was to onboard teachers on it’s online website hosting STEM resources for teachers to create and customise hands on learning material. For outreach, this has been made available in nine Indian languages. SAP has partnered with Niti Aayog to adopt 100 Atal Tinkering Labs. The government of Uttar Pradesh is currently upscaling a model developed by CARE India, supported by ORACLE to set up Teachers’ Resource Laboratory. This project focuses on improving the domain knowledge of primary school teachers in languages, science and mathematics. Likewise, some other notable private sector initiatives for STEM education for the underprivileged sections of the society are listed below:



- Indian Girls Code, an initiative by Robotix, is a free hands-on coding and robotics education programme for underprivileged girls in Tamil Nadu. The company has also partnered with Ford Motor Co., CISCO Systems and Amazon, to extend STEM, Robotics and Coding to more underprivileged girls. One of the important achievements of Indian Girls Code is to develop a contextualised curriculum which is translated in regional language for better learning and access.

- Bandhan Konnagar which works with rural women and girls for poverty alleviation and livelihoods promotion. It is currently being supported by the World Bank to reach 3 lakh families in the states of Rajasthan, Bihar and Jharkhand.

- The Royal Bank of Scotland launched a forum called WomenInTech which aims to adopt a multi-pronged approach to address women's under-representation in STEM. For example, it can access a corpus of funds to finance the higher education of talented girls from economically weak regions at top STEM universities in the UK or USA.

- Project DEFY (Design Education For You) in Karnataka has set up self-learning spaces called Nooks where students learn to tinker with the help of essential resources and internet access, guided by volunteers (not teachers). The project challenges the very design of conventional education which is school-based and teacher-centric; and recreates a model based on experimentation and collaboration.

- Tata STRIVE which aims to develop the skills of youth from financially challenged backgrounds.

- TRRAIN (Trust for Retailers & Retail Associates of India) a public charitable trust which specifically focuses on the up-skilling and workplace preparedness of persons with disabilities.

Thus, besides the government, the private sector including tech companies, education start-ups, non-profit and civil society organisations working at the grassroots level have come together to enhance the accessibility of STEM. They have created successful intervention models and demonstrated best practices which can be replicated and scaled up. Their community outreach programmes go a long way in sensitising the community and creating a demand for such activities and accomplishments at the grassroots level. Even sporadic events, such as competitions, quizzes and one-off workshops helps in much-needed awareness generation and information dissemination. Civil society initiatives like training of teachers, running remedial or second chance education programmes, facilitating life skills or leadership programmes for adolescent girls and community-based monitoring of government schemes go a long way in having a concomitant impact on STEM education of girls. In addition to these, there are other public spaces like museums, libraries and theme parks which can reinforce, educate and stimulate students and serve as additional resources.

A case study to illustrate how the private sector can work with the state to enhance accessibility to STEM education is given below.

1. Case Study: Agastya International Foundation

Agastya International Foundation is a public charitable trust which is working towards transforming education through one of the world's largest science education programmes. Agastya's activities are spread across India and are catered towards teachers and children with a focus on grades 5 to 10. The organisation takes a hands-on pedagogical approach to address several gaps in the public education system including the lack of spirit of inquiry, stimulating interaction, opportunities to learn through real-world application of knowledge and a dearth of well-trained science teachers.

The core activities of Agastya International Foundation include science centres, mobile science lab programs that take STEM education to areas that do not have access to it, science and art fairs, summer and winter camps, competitions, peer learning and teacher training programmes. Initially, children are engaged in hands-on learning through observation and interaction. This is followed by activity-based learning and project-based learning to promote deeper understanding and aim at igniting Curiosity (Aah!), nurturing Creativity (Aha!), and instilling Confidence (Ha-Ha!). Through this process, the aim is to trigger five key shifts: 'from yes to why', 'from looking to learning to observing', 'from being passive to learning to explore', 'from being textbook-bound to being hands-on', and 'from fear to confidence'. Several students further move to the 'explorer' stage where they are encouraged to innovate and create models and participate in school-wide competitions and fairs. Those who show exceptional motivation and abilities go on to become Young Instructor Leaders, who assist teachers and inspire peers while developing their leadership and communication skills.

To achieve this, Agastya has its creativity lab near Kuppam in Andhra Pradesh which caters to nearly 650-750 students per day and 90+ science centres spread across 21 states. It has 202 Mobile Science Labs which have travelled more than 1 million kilometres, covering more than 3,000 schools across 165 districts in the country. Its 83 Labs-on-bikes have covered more than 800 schools.

The number of its Young Instructor Leaders (YILs) which has created a successful model of peer learning has reached 18,000 students. Of these, about 45 per cent are girls.
Its more recent initiatives include the Curiosity Carnival, a mega innovation fair that showcases STEAM-based interactive exhibits and the Banao Bus, a mobile maker space that encourages design-thinking among children. In total, Agastya works with 8,600+ government schools in 126 districts across more than 21 states of India.

Agastya initiative currently benefits over 1.2 million children and more than 250,000 teachers directly every year and has reached to over 10 million children and 300,000 teachers since its inception in 1999.

Agastya has established a successful model of public-private partnership in states like Karnataka, Andhra Pradesh and Chhattisgarh. A crucial systemic impact of Agastya's educational interventions lies in its complementing and working within the mainstream government school system and demonstrating that creative, interactive and hands-on approach to scientific learning can be promoted in an affordable and scalable way.

In the next few years, Agastya aims to create integrated content including science, art and the humanities and leveraging digital technology to deliver a unique blended learning experience for millions of teachers and children. It also plans to begin to target children between grades 1 to 4 as well as beyond 10, going up to university level.

Stories from Agastya

Jahnavi,
Aged 14, Grade 8:

“I have always wanted to see a microscope…. We read about its uses and how scientists use it to identify different diseases, find unidentified parts of cells and make so many other amazing discoveries…All I have seen are pictures in our textbooks. I would sit around and imagine what things might look like under a microscope lens. When the Agastya van pulled up outside my school, I stopped imagining and got to see first-hand what cells look like. The Agastya instructors put a few drops of red dye on a slice of onion and placed it on a slide….. I couldn’t wait to look through the eyepiece.”

Her experience of looking into the microscope gave her a newfound love for science.

“I have made a pinhole camera, we made our own litmus paper and we have also made our own slides for the microscope.”, Agastya classes have made her feel like a scientist.

“We do experiments just like how scientist do them on TV. We get to make observations and discuss our findings. What better way is there to learn?”

Of all the experiments she has gotten to participate in, Jahnavi says that making a rocket out of PVC pipes and an old plastic bottle has been her favourite experiment.

“I didn’t know it was so easy to make a rocket out of things we have lying around in our house.”

Arthi,
Aged 11, Grade 6:

“My favourite experiment was learning how to separate liquids. We mixed water and oil in a glass bottle and learnt about why they don’t mix and how to separate them using funnels and filter paper.” Arthi says she recognizes the importance of doing experiments in order to learn. “When we do experiments with our own hands we learn so much more.” She says that even her teachers have been inspired by the way the Agastya instructors conduct their classes. “Our teachers sit in on all the Agastya classes and they act like students, listening intently and being as fascinated as we are. My teachers have even started trying to do small experiments in class now. One day our science teacher brought a magnet to class and we all went outside to check and see if there were ant iron particles in the sand.”

Arthi says that her entire schooling experience has been enriched because of the Agastya International Foundation. “There is also so much of connection between what we learn at school and what the Agastya instructors teach us. It’s like we are learning everything twice. We get so much more clarity and I feel like, because of the experiments we do, I will never forget anything I am learning.”

Arthi says that she wants to be able to inspire children to learn and pursue science the way she has been inspired.
“I especially want to ensure that girls study science. There is nothing boys do that girls can’t.”

3.5 Converging points: Secondary Education for Girls, STEM and Integration of Technology in Education

1. **Initiatives in Secondary Education for Girls:**

There have been several initiatives in India by the government or non-profit organizations to address the barriers to girls' education at the individual level, socio-cultural level and institutional level and to support Girls for STEM.

The Rashtriya Madhyamik Shiksha Abhiyaan is focused towards providing universal access to secondary education and removing gender related barriers at the institutional level. Several schemes have also been initiated to ensure girls come to school and parents do not pull them out for economic reasons. Under the National Scheme of Incentive to Girls for Secondary Education, a sum of Rs. 3000 is deposited in the name of an eligible girl as a fixed deposit. State governments efforts include schemes like the Free Bicycle Program in Bihar or the Ladli Lakshmi Yojana in Madhya Pradesh. Often parents and girls are not aware that such schemes are available for them.

NGOs have addressed different barriers to girls' education through focussed partnerships with state governments. Large scale programs like Educate Girls in Rajasthan focuses on bringing girls back to school at elementary level and ensuring their retention to move them up in their school journey. They do this through community volunteer efforts in the form of 'Team Balika' and institutional efforts towards strengthening SMC accountability to ensure retention and a supportive school and community. There is also a focus on improving learning outcomes through interventions in classrooms like Creative Learning Teaching that enable girls through life skills sessions.

Room to Read works through supporting girls with minimal material support, an intensive life skills curriculum, mentoring support through social mobilizers and family and community engagement. Girls are engaged in the program at elementary level and the support is provided up to 18 years of age to ensure that the girl completes school education.

Initiatives like Gender Equity Movements in Schools (GEMS) by ICRW, CORO for Literacy and TISS work towards promoting gender equality by encouraging equal relationships between girls and boys, examining social norms that define men and women's roles and questioning the use of violence. There are many other initiatives across India which address different barriers to girls' education. Some focus on bringing girls to school, some engage with schools to create an enabling environment, some focus on improving the quality of classroom interactions to make them more gender responsive. Others work with communities to address barriers presented by the family of a young person. There are also initiatives for strengthening vocational and employability skills among adolescents especially girls from marginalized communities (for e.g. Etasha Society). A study by Going to School[10] suggests that 'offering skill training to girls in secondary schools increases their interest to remain in school – they tell their parents that they do not want to drop out of school. They negotiate with grandparents to share housework. They tell their fathers they do not want to marry early and instead convince them to take a loan for their education. Skill building is critical particularly for girls as they are unlikely to get many opportunities after their schooling to develop income generating skills.

2. **STEM and Girls Education**

To enable the STEM mindset in girls and to push them towards STEM careers, only a multi-pronged approach that addresses all barriers can work. At the same time, however, one cannot wait for an issue to be met with in order to move to another. Many initiatives and efforts have also been made to enable STEM mindset for girls. A study by Feminist Approach to Technology reveals that girls don't take up STEM because they feel they may not be good at it and not because they aren't performing well. For boys, on the other hand, such doubts do not arise. This is a common scenario even when girls have been outperforming boys in STEM subjects. The study recommended creating interest in STEM for girls through simple and creative methods; building interest early in their education journeys and targeting teachers to ensure long term engagement. Microsoft found that through good role models and through strengthening the belief that men and women are treated equally in the workforce, more girls are likely to take up STEM[11]. A larger, critical question however remains unaddressed. Is our current education pedagogy enabling a STEM mindset in schools?

10. https://www.dasra.org/resource/keeping-girls-in-secondary-schools Up Grade: Keeping Girls In Secondary Schools, Dasra.org, 2016

The New Education Policy stresses the need of developing a scientific temperament however, the finer steps are not called out in a way that would directly address this issue on the ground.

At the beginning of this paper, in section 1.1, we open with a holistic understanding of STEM – a cross-curricular approach, taking learning beyond classrooms to link it with the larger community and global issues, going beyond textbooks and subject knowledge to create linkages with technology to prepare children for the future. Addressing this at a pedagogical level itself has been difficult not just in the case of girls but all children. Our schools are still struggling with pedagogic practices that place examinations as the main drive to engage with the curriculum thereby pushing away the need to develop a critically engaged, questioning child who can move beyond classroom learning and engage with a wider spectrum of knowledge.

Several initiatives have consciously designed programs towards improving the classroom transaction on a day-to-day basis addressing different subjects or the learning process, supporting TLM, strengthening teacher input and making classrooms more child centric. Textbooks have also been modified to guide teachers and enable them at the classroom level. Integration of technology with education initiatives has also been enabling teachers as professionals and enriching subject/ domain specific knowledge through materials/resources.

3. Initiatives of Integrating Technology with Education

The Connected Learning Initiative (CLIx) is a technology enabled initiative at scale for high school students. Seeded by Tata Trusts with Tata Institute of Social Sciences, Mumbai and Massachusetts Institute of Technology, Cambridge. CLIx offers a thoughtful pedagogic design leveraging technology adapted to the Indian context. Resources for students are in areas of Mathematics, Sciences, Communicative English and Digital Literacy designed to be interactive, foster collaboration and integrate values and 21st century skills. CLIx also offers Teacher Professional Development through professional communities of practice engaged in blended courses such as Reflective Teaching with ICT. Initiatives like CLIx have expanded to use the word 'technology' in education from replacing chalkboards to smart boards or merely digitizing print to creating deep learning engagement for children and teachers while also grappling with infrastructure availability, subject teacher availability, multilingual context and student readiness challenges.

Azim Premji Foundation's CALP (Computer Assisted Learning Program) started with children's need to speak English and learn computers. The program later grew to other states as a Teacher Assisted Computer Based Learning Program for children. A study of CALP in 2006 reveals a positive interest towards technology enabled learning. However, there were challenges of incorporating it to the school timetables and teaching-learning process and not as separate sessions.Both the above programs do not target girls specifically. These programs sight the challenge of infrastructure availability to implement such programs to enable their sustenance in school's overall learning processes, even though they happened at a gap of several years. And both also report how children engaged enthusiastically with such programs.

Of late, the government has also come up with several apps and ideas towards integrating technology encouraging teachers to take up such professional learning as well as bring them into practice. The new NISHTHA modules by NCERT also has a module on ICT in education encouraging teachers to explore the use of technology in classrooms through sample lessons. CIET, NCERT and MHRD host the ICT curriculum (https://ictcurriculum.gov.in/) offering courses for both students and teachers on the platform also linking them to several other initiatives. There are several resources and even 'Discussion Forums' that can be accessed here.

TESS India created many resources now available as Open Education Resources to enable pedagogies that align with the idea of STEM as outlined here. EY recently created a mobile platform on STEM for girls for Delhi Government to engage girls in age group 13-18 years. This will be implemented with 6000 girls and we are yet to see its impact. It offers several reward levels for every task/activity/completion that girls engage with.

Overall when we look at all these efforts and initiatives; in girls education, STEM for girls, integrating technology and engaging both teachers and children with technology for learning, developing interactive classrooms or changing pedagogical practices, there seem to be several good efforts. Most of these efforts, however, have been unable to come together to enable a STEM environment for girls and impact their growth mindset. To move towards improved outcomes, it should be our concern to see how these efforts may inform our understanding and planning as we set out to create enablers for Girls in STEM and within that , the inclusion of girls from some of the most vulnerable communities in India.

04 Looking Forward

4.1 Recommendations

Systemic push to partnerships enabling access, resources and translation of policy into action:

- Systemic issues in education, including fewer schools in rural areas at the secondary stage, the paucity of laboratories and computers must be addressed and technology must be integrated into learning experience.
- Education policy must explicitly articulate the need to promote STEM education. Once intent and goals are expressed in policy, its process and steps must be outlined in Plan of Action.
- Government programmes must have a strong component of long-term monitoring and follow-up to assess real impact. Any schemes (like computer or tablet distribution) must be accompanied by operationalisation support.
- Enabling the environment at school - in the form appropriate infrastructure (availability of functional computers and lab maintenance, internet and appropriate guidance) to ensure meaningful interaction between children and technology.
- Public awareness campaigns on various schemes promoting science education among girls. At the grassroots, these schemes should be made readily accessible, free from bureaucratic hassles and poor convergence among various departments.
- All government schemes and programmes must have a component of interaction and support by female mentors. As far as possible, local relatable role models must be identified and encouraged.
- STEM interventions must start early on in a girl's school life to enable her interest and self-belief by the time she reaches secondary school.
- Strategic partnerships between the private sector and state governments must be promoted. These partnerships should be based on cost-effective, sustainable and scalable models, keeping in mind the cultural contexts and local needs. There is also a need to leverage CSR resources, wherever possible.

Parents and community as key influencers

- The roots of poor representation of girls in STEM lie in both social perceptions and cultural barriers. These need to be targeted with active social campaigning aimed at attitudinal change. Inclusion of informal leaders, schoolteachers and school management committees in such programmes will be crucial.

- Role of the school management committee (SMC) must be strengthened at the secondary level. Adequate representation of women must be ensured in SMCs, and the STEM agenda must be articulated in school development plans.

Localising STEM education

- Targeted programmes with a bottom-up approach must be used to close regional imbalances and promote social equity in access to STEM education.
- Further research must also provide insights into how STEM needs to be framed in local contexts.

Curriculum and pedagogy with a gender lens

- School curriculum should integrate STEM activities for developing 21st century- appropriate skills and inculcating the 6C's among students. Curricula must also represent women, in text and illustrations, as well as by celebrating their achievements.
- Pedagogy must include experiential and blended learning opportunities. Assessment practices which make women less anxious must be used, coupled with psychological surveys to understand pathways to developing self-efficacy.
- Life skills courses at all levels must be offered in schools. Additionally, for girls, non-formal curricula to cultivate agency and leadership, as well as socio-emotional skills, must be offered.
- There is a need to conduct further research endeavours to understand what teaching strategies and dialogue frameworks work best for girls.

Teacher development to break STEM biases

- Teachers are the single most important link in the process of improving the educational experience of girls. It is crucial that quality teachers (particularly female teachers) are made available, are oriented in using progressive pedagogies and are able to recognise their role as change agents.
- Pre-service and in-service teacher training must use TPACK framework while including sessions on gender as well. Assessment for learning must be conducted periodically and these must inform teacher training modules regularly.

4.2 Conclusion

Despite unprecedented access to education for girls, the goal of gender equality both within and through education remains elusive. In fact, there is a growing realisation that mere participation in conventional education is not enough to attain equal participation of women in the workforce.

Our findings show that there are two crucial stages where barriers become insurmountable for some girls: around puberty (secondary education stage), and during marriage and childbearing (during the transition from junior to mid-level career). Supportive programmes specifically targeting these stages in a woman's life cycle can lead to sustainable impact both at the individual and community level. There is also a need to develop targeted programmes for girls who face additional barriers of poverty, social group and location. Among enablers, the presence of role models or teachers who function as change agents has a central role to play. This is closely followed by the acquisition of digital literacy and access to technology. Also significant is changing parental and community perceptions. The latter can go a long way in providing girls with supportive home environments. Expanding RTE to secondary level and an overhaul of teacher education and training, if implemented with rigour, will also provide a much-needed impetus to STEM education across the country.

We thus conclude that formal education, coupled with adeptness in 21st century skills and life preparedness, combined with interventions to address social constraints can lead to long-term sustainable impact on the lives of girls and the communities they belong to. Hence, despite the challenges, the Indian scenario holds several possibilities for engaging girls' in STEM, which when harnessed will result in much-needed benefits of individual empowerment, social equity and sustainable economic growth.

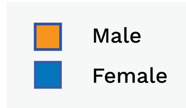
4.3 Epilogue

STEM Mindset, Education and COVID-19: A Gender Lens

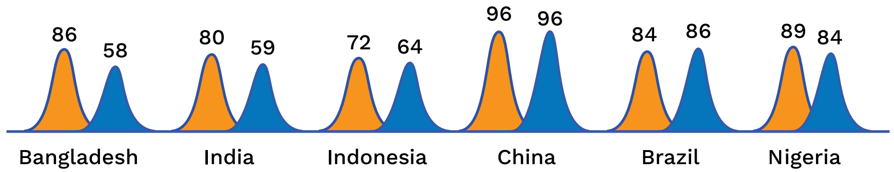
The world is currently reeling under the impact of COVID-19. In India especially, while health and economy are hugely impacted, the lives of people across regions, class and gender are getting affected in different and difficult ways. COVID-19 presents a larger risk to girls from many dimensions. These include:

- Risk of girls dropping out for child labour or housework /sibling care and because of increased child marriage
- Learning loss due to lack of access and limited resources
- Adverse impact on physical safety and mental health given the rise in instances of domestic violence. School in some sense were also safe spaces for girls where they could connect with their peers and teachers and find some form of social support.
- So when the basic schooling and health is threatened – it pushes us decades back in terms of educational gains of girls. During this time, while technology in education has become a buzz, the reality of the digital divide has also become extremely prominent. It has alerted us to the fact that technology is not neutral. A lot of factors affect the likelihood of tech-focused initiatives reaching girls.

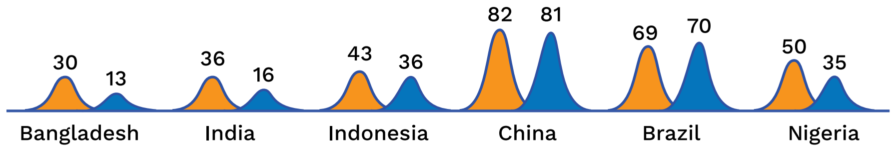
The GSMA Mobile Gender Gap report 2019[12] noted a mobile internet gender gap of 23 per cent across low to middle income countries. This means that 23 per cent fewer women have access to the technology.[13] The above data makes it clear that during the times of COVID-19 too, when education is largely moving online, on mobile phones – the digital divide continues to exclude many-many women and girls. While this digital divide is for all classes, it impacts women particularly.



MOBILE OWNERSHIP GENDER GAP ACROSS COMPARABLE COUNTRIES

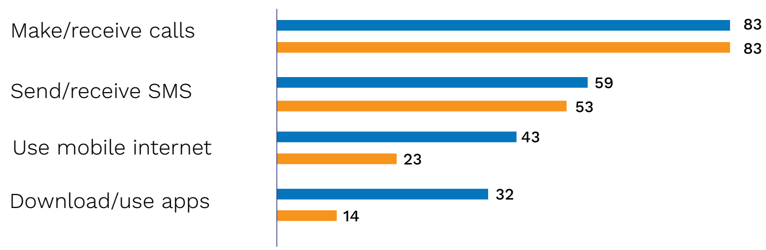


MOBILE INTERNET USER GENDER GAP



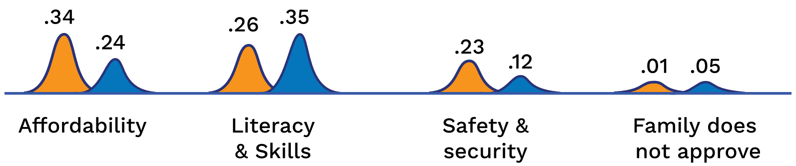
VOICE BALANCE

Among Indians who own mobile phones, usage for voice calls is well balanced, but the gender gap becomes apparent with internet usage. while only 19% of women were aware of mobile internet in 2018, this rose to 42% in 2019



12. https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/02/GSMA-The-Mobile-Gender-Gap-Report-2019.pdf GSMA Connected Women The Mobile Gender Gap Report, February 2019
13. https://www.business-standard.com/article/economy-policy/gender-gap-in-mobile-and-internet-usage-in-india-as-per-gsma-re-port-119030900696_1.html Gender gap in mobile and internet usage in India as per GSMA report, Business Standard, Romita Majumdar, March 2019

BARRIERS TO MOBILE PHONE OWNERSHIP AMONG NON-USERS IN INDIA



The above data makes it clear that during the times of COVID-19 too, when education is largely moving online, on mobile phones – the digital divide continues to exclude many women and girls. While this digital divide is for all classes, it impacts women particularly.

The current education system was not ready for the total cut-off of human physical interaction and as more and more innovation in Ed-Tech comes about, it would need to be mindful of issues of access, agency, context, safety and enablement of self-learning attitudes. This learning cannot be about consuming digitized content. It has to be about learning to navigate the internet and the possibilities it offers.

Finally, STEM mindset as called out in this paper needs to be re-imagined in a post-COVID world. Inequality and inequity on the grounds of gender had already existed and the fear is that this would widen. Women of all class and age groups have been adversely affected. The impact on women and girls across every sphere, be it health, education or livelihood has been huge. Women are losing employment; unpaid work of women and girls has increased exponentially and it is very likely that girls may not be sent back to school or have fallen back into the trap of 'discontinuing education'.

The question of access and staying connected is much larger than what it was earlier. Strategies that offer community solutions to these issues, both tech based and non-tech based, may work in favor of women and girls. More than anything, the need to be mindful of rumors, fake news and irrational beliefs and practices needs to be countered. These have only risen in the times of COVID-19 and many women healthcare workers have been on the frontline, exposing themselves to harassment, pay loss and dangers of health. The focus on STEM mindsets has become a priority now more than ever; to break stereotypes, to enable men and women equally to participate in education and economy, to prevent the biases around unpaid work and make women's struggle more visible. This has to start early on in the lives of girls, to help them live meaningful lives and careers.

05

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5.1 References

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06 Annexure

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6.1 Annexure 1: List of participants

Anitha Bijesh

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Dr. Amit Dhakulkar

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Amita Singh

Principal, a Government school in rural Bhopal

Dr. Arindam Bose

Associate Professor, Mumbai campus Centre for Education Innovation and Action Research, Tata Institute of Social Sciences

Asia Syeda

Co-founder of LEARN
Bhavitha Bhogaraju
India Partnership Coordinator, Girls Who Code

Chintan Joshi

Head of communications, Covestro

Gargi Datta

HOD Science and ATL coordinator, DLF School, Sahibabad

Gayathri Iyer

Technical specialist, Education, CareIndia

Hariharan Ganesan

Agastya International Foundation

Krupalani Swamy

Vice President Evobi automations and Niti Aayog Mentor for change

Mathura Govindarajan

Creative technologist, educator, co-founder of Peblio.co and runs Paper Crane Lab

Nisha Dhawan

Senior program officer, Empower

Nishant Baghel

Director Technology Innovation at Pratham Education Foundation

Osama Manzar

Founder of Digital Empowerment Foundation, New Delhi

Prof. Padma Sarangapani

Chairperson - Centre for Education Innovation and Action Research and Professor, TISS

Rajlakshmi Mallik

Director, Centre for Development Research, Sustainability and Technical Advancement (C-DRASTA), Kolkata & Technical Advisor, SSESS, Kolkata

Ravinder Kaur

Professor, Sociology and Social Anthropology Department of Humanities and Social Sciences, IIT Delhi

Seema Jedarth

Principal of DLF Public school, Sahibabad

Sreehari Rabindranath

Head of Research, Dream a Dream organisation

Renu Seth

Program Head, Pratham Education Foundation

Arun M

General Secretary, Free Software Foundation of India (Also part of curriculum building team at IT@Schools, Kerala)

Vimala Ramachandran

Retd Prof. NIEPA, presently with Educonsultants

6.2 Annexure 2: Interview Guide

General Questions:

1. What is STEM education? How is it different from traditional subjects of science and mathematics, or engineering?

2. Why STEM? In other words, what is the need or usefulness of this concept in the contemporary world in general, and India in particular?

3. What are some challenges and barriers to STEM education in India? Is lack of inclusivity in STEM education a challenge?

4. Is there a need to focus on girls as a disadvantaged group with regards to STEM education? Why? (probe for how STEM education will prepare girls for 21st-century workplace and life).

5. What systemic changes must be incorporated in India's public education system to facilitate STEM education? (probe for infrastructure, teacher training, examination centric teaching-learning).

6. What are the possibilities and challenges of delivering STEM education in India, particularly to the disadvantaged groups, like girls?

7. What could be some innovative solutions to address underrepresentation of girls in science and mathematics in India? Is there any international policy or programmatic initiative that India must learn from?

8. How do we re-purpose or re-imagine our classrooms to facilitate STEM preparedness of children, particularly girls? (probe for technology in classrooms, experiential learning and application of knowledge).

9. What is the relationship between digital literacy and STEM education? How can digitalization of education enable girls' access to STEM education?

10. What other skills will be required by girls, complementing their subject knowledge to prepare them for the world of work (Probe specifically for from marginalised backgrounds). How can these be provided through schools and Tinkering Labs?

11. What are the social and economic costs of underrepresentation of girls in STEM for India? Conversely, what benefits will be gained by furthering their participation?

Selective Questions (Any two for a participant):

Why does underrepresentation of girls in STEM education matter from a. social equity b. sustainable development and c. future of work perspective?

What challenges do schools face in providing STEM education to students, particularly girls? How can schools/teachers ensure the participation of girls and build their motivation and confidence in science and mathematics?

How well does the draft National Education Policy address the need for STEM education in India? what gaps exist?

How effective is Atal Tinkering Labs (ATLs) in taking STEM to girls? How can long term monitoring and follow-up be inbuilt in the scheme to assess its actual impact?

Should educational assessments include measuring non-cognitive outcomes like confidence, motivation and self-efficacy? How will their inclusion help in enhancing the quality of education, particularly STEM education?

Among girls, who are most vulnerable to be left behind from participating in STEM education? What inclusive strategies can government adopt to cover them?

Have you perceived any gender gap or bias in the accessibility or use of your product/service? Do you think girls need customised training, materials, products or support? Why?

How can private STEM education companies and schools form a purposeful partnership to enhance students learning in STEM? Do you see yourself/your company playing a role in providing cost-effective STEM services or products to public schools?

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