QUEST ALLIANCE

Building STEM Mindsets:

An Ecosystem Approach

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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.

STEM FOR GIRLS

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Executive Summary

This study is the second part of a two-part enquiry on STEM mindsets, career and gender. The first part of the enquiry provided us with a set of key skills and attitudes that were widely recognized as constitutive of the STEM mindset. It further highlighted the importance of the STEM mindset across careers.

In this second part of the enquiry, we attempt to identify gaps in government-run secondary schools in India in inculcating the STEM mindset in students. A qualitative study using surveys, interviews and focus group discussions were conducted with students, teachers and parents from Gujarat, Telangana and Odisha. The study examined the extent of STEM mindset among students and teachers, the perceptions and practices of science and math teachers and the extent of parental support for girls to pursue higher education and careers in STEM. Based on the empirical findings from the study, review of relevant literature and interviews with curriculum developers, the report makes a number of recommendations for developing the STEM mindset and preparing students for the fast-evolving world of work in the future.

The student survey tried to elicit the emotions that students associated with science and math. 80% of the students associate the word ‘curiosity’ with science compared to 64% in math. The word ‘fear’ is comparatively more associated with mathematics (16%) than with science (3%) by students. The first part of our enquiry had pointed to the importance of mathematical and data handling skills for new-age careers. We looked at how students apply the STEM mindset in their day to day lives—students from the government schools open up things, tinker, repair, build apps and products, work with soil and plants and experiment in the kitchen, but there are differences across states. The percentage of girls who open up things, tinker, repair, build apps and products was always lesser than the percentage of boys, except in the kitchen. The focus group discussions indicate that students are not able to reason, argue or justify their responses and explain the science behind phenomena (eclipses, Covid-19, falling bodies).

Girls are less likely than boys to have access to computers or to play video games or use learning apps. However, one encouraging aspect is that more girls noted that the reason for their poor performance in science and math is due to lack of encouragement from parents and teachers and boys noted the lack of support from the peer group as the important reason, so neither gender thinks they are cognitively not equipped for math and science and attribute failure to lack of support from peers and parents.

Teachers do recognize the importance of STEM in the contemporary world and are fairly aware of the way in which science and technology have positively impacted human life in many fields. However, we find that there is no deep understanding of the new age careers that were identified in the first study. Seventy-nine per cent of teachers from Gujarat, and 74% of teachers from Telangana thought that logical thinking was the most important skill from the learning of science and math, while 25% of teachers in Odisha associated math and science learning with factual knowledge, and 25% thought looking for evidence was the most important skill. Seventy-nine percent of teachers said that science and math is needed for all jobs, and nearly 97% felt that science and math is useful for all students. However, teachers' own STEM mindset needs work. From the focus group discussions, what we could infer was that the teachers did not seem to analyse, reason and justify their responses in a systematic and scientific way as would be expected from those with a STEM mindset.

Teachers from Gujarat and Telangana are quite tech-savvy and used technology in classrooms, but technology use was relatively lower among the teachers interviewed in Odisha. The use of technology is mostly as an add-on to existing ways of teaching (Diksha apps to provide engaging material relevant to the school curriculum, videos for explaining concepts, Microsoft Teams during Covid, apps for school administration like attendance), rather than in transformative ways. While teachers do focus on application of science and math in real life, teachers still view students as users of technology, rather than creators of technology. Math is recognised as the key skill for a STEM career (shown by previous study) and with respect to math curriculum, 31% teachers thought that many children find math difficult, and 36% thought the syllabus should be made simple. Forty-five per cent of teachers from Telangana and 46% of teachers from Gujarat thought that the science curriculum is vast and there is not enough time to explain everything well. Biases about gender continue to prevail: 49% of teachers felt that girls are more suited for biology, and 42% of teachers felt that boys are more suited for physics, and some felt that certain occupations are better for women.

Among a list of occupations, engineering is the occupation that was given the most preference in Telangana(33%) and Gujarat(27%). In total, 46% students from Telangana, 57% students from Gujarat and 16% students from Odisha reported an interest in jobs directly related to STEM (such as engineering, software professional, doctor and scientist). Parents in Odisha and Gujarat were less aware of STEM careers (medicine, engineering, scientist), while parents in Telangana were more aware of options (perhaps due to higher levels of academic qualifications). Careers in Artificial intelligence (AI), machine learning, big data specialists, internet of things specialists, and software application developers are projected as important careers of the future (mentioned in the first report) were not specifically mentioned indicating a lack of awareness about these.

The willingness of parents to support science and mathematics-related careers for their children is high and there is a strong belief that the same will lead to prospective careers. Although many parents expressed willingness to support their children's education irrespective of their gender, when faced with limited finances, preference is given to boys' education and not girls.

Based on our findings, this study report concludes with recommendations to improve the quality of STEM learning for children, especially girls, studying in government schools in India. We hope that these recommendations will be useful to various stakeholders such as policymakers, CSOs, educational organizations and program designers working in the intervention space to facilitate STEM mindset development and interdisciplinary learning. The main recommendation is to help teachers develop their own STEM mindset and their Technological Pedagogical Content Knowledge (TPCK[1]) for the STEM mindset. This will in turn help students develop a STEM mindset. Additionally, it is recommended that awareness about future career opportunities and the increasing relevance of STEM mindset in careers is provided to schools and teachers. Gender sensitization and awareness training should form part of both pre-service and in-service teacher training to correct for covert biases that may hold girls back from succeeding in STEM as much as boys. Career counselling support to provide pathways to current and cutting-edge STEM careers should be provided to the schools. Another important recommendation is for educational officials and resource persons to be involved in the transformation to create a system-wide impetus for change.

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Parental Support for STEM Education

The context of the families deeply influences how students view and relate to science. This section explores the parents' understanding and perceptions towards STEM mindset and careers along with emphasizing the gender gap with regards to parental support.

6

Inculcating the STEM Mindset - Expert Perspectives

This chapter attempts to present the gap between what industry suggests and what is being done in schools with a focus on importance of nature of science, process validity and growth mindset

7

Conclusions and Recommendations

This section concludes the findings of the study with recommendations to better inculcate STEM mindset in the school ecosystem, with a focus on developing curriculum and assessment, teacher capacity building, orienting parents to support girl students and collaborations needed to build STEM mindsets.

Appendix

References

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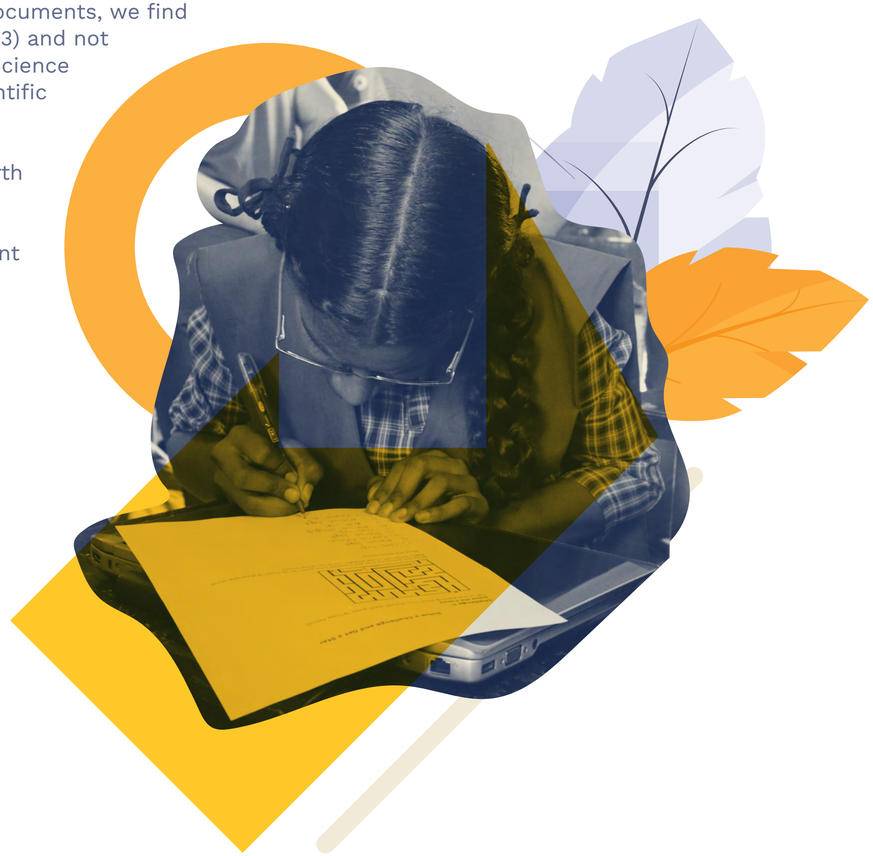
1 Introduction

There is one duty that is unique to India under Article 51A (h) that encourages the citizen to “develop the scientific temper, humanism and the spirit of inquiry and reform” (Ramachandran, 2020). India’s National Education Policy, 2020 speaks of development of scientific temper as being essential for all students. The MHRD Conclave on School Education (September 2020) listed scientific temper as one of the 21st century skills along with other skills like digital literacy and creativity. In the NEP, scientific temper is placed along with values such as empathy, liberty, equality and justice. It is not envisaged as a subject to be taught, but rather as a habit of the mind that needs to be inculcated.

A “Statement on Scientific Temper” prepared by a group of scholars in 1981 —including P N Haksar, Dr Raja Ramanna and Dr P M Bharganva—mentions that the method of science provides a viable method of acquiring knowledge and that human problems can be understood and solved in terms of knowledge gained through the application of the method of science (Prasad, 1982). A person with a scientific temper will be logical and rational in their thinking.

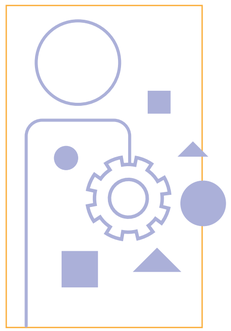
Such an individual would employ the scientific method of decision-making in daily life. This idea is echoed in the definition of the STEM mindset that was put forth in the Quest Alliance report: STEM Mindset, Careers and Women—An India Study. In the report we had stated that a person with a STEM mindset would use a scientific approach to enquire into everyday problems. The scientific approach or attitude is emphasized in the articulation of the scientific temper and also in scientific mindset (SMS). In many Indian policy documents, we find reference to the scientific temper (Raza et.al, 2013) and not the STEM mindset per se. In 2014, the National Science Day was dedicated to the theme, “Fostering Scientific Temper”, by The Government of India, through the National Council for Science and Technology Communication (NCSTC). In this context, it is worth noting that Knowledge and Awareness Mapping Platform (KAMP) is the first initiative taken by CSIR-NISTADS[2], to assess students on their current level of scientific temper, and to advise students, as per the outcome of the assessments, on ways to improve their scientific temper.



The notion of STEM mindset overlaps with the idea of scientific temper which continues to be one of the important aims of education in modern India. As science and technology play ever greater roles in our lives, a STEM mindset is important for everyone and not only for those engaged in STEM-related careers (Murphy, 2019). The STEM mindset has a crucial role in the workplace, especially in the current scenario, where technological advances are altering the nature and scope of work in almost every field. Law (2002) has articulated how various STEM skills and attitudes are required in different careers and everyday decision making in life. This is also corroborated by the first part of the current study by Quest Alliance (Vijaysimha, Sundararaman & Aravamuthu, 2021).

It is important to think of the similarities and differences between scientific temper and STEM mindset for two reasons:

The similarities between the two ideas will enable STEM educators to build on a powerful idea that is already familiar to many teachers and policymakers.



By articulating the between the two ideas it will become possible to expand the scope of what is needed in education to develop the STEM mindset.

By explicitly pointing to the similarities between the idea of the scientific temper and the STEM mindset, teachers could be encouraged to strengthen the pedagogical strategies common to inculcating a scientific temper and STEM mindset.

It is equally important to articulate the differences between the two ideas. STEM mindset goes beyond what is posited as the scientific temper, by bringing in the technological, engineering and mathematical dimensions in an explicit manner. The STEM mindset also includes general skills and attitudes that are part of 21st century skills and the growth mindset (Vijaysimha, Sundararaman and Aravamuthu, 2021). These do not find mention in the discourses around scientific temper (Nehru, 1946/1989, Bardapurkar, 2020, Rampal 2020, Ramanujam, 2018) Further, the STEM mindset places equal emphasis on technological and mathematical skills along with application of these skills to solving real-world problems. We do not find such an explicit reference to these skills in the discourses around scientific temper.

To arrive at a clearer articulation of the STEM mindset, its relevance in the world of work and the gaps in education when it comes to inculcating the STEM mindset in the Indian context, a two part research study was conducted. The first part of the study aimed at getting a real-world perspective of STEM mindsets from people working across several fields such as pure science research, medicine, manufacturing, electronics, computer technology, pharmaceuticals, math and statistics, banking, finance, HR, social work, art and design, and journalism.

Skills that were described by professionals as part of the STEM mindset such as creativity, communication and critical thinking are also considered to be 21st century skills. Attitudes associated with a growth mind-set[3] such as patience, perseverance, hard work, learning from failure and open mindedness were also emphasized. Although necessary for STEM careers, neither the growth mindset nor the 21st century skills are specific to STEM (Murphy, 2019). Similar to the description of the STEM mindset given by Murphy (2019), the Quest Alliance study gave this definition:

Persons with a STEM mindset would believe that asking and answering questions using a scientific approach and drawing conclusions based on data and evidence will help them to understand phenomena around them, to identify opportunities and risks and to make decisions and to take action and predict the outcomes. They would have an appreciation for the complex role of technology in various walks of life. They would believe in the potential of science, engineering and technology used responsibly and ethically, to solve local and global problems (Quest Alliance, Vijaysimha, Sundararaman & Aravamuthu, 2021).

Broadly speaking, the STEM mindset can be said to comprise skills and attitudes (attitudes for the purpose of this report also includes ethical values) along with a specific orientation towards STEM as a way to make sense of the world, help in decision making and solve problems. The study further found that there is an increased need for STEM skills and STEM mindsets across various sectors in the workplace of today.

Against this, the second part of the study attempts to identify the gaps in understanding and development of the STEM mindset in the prevalent school practices, as well as the role of parents in supporting girl students to take up careers requiring STEM Mindset (SMS).

Based on the findings of the study the report offers:

1. **Recommendations for teacher capacity building towards understanding STEM mindset and career counselling inputs**

2. **Curriculum suggestions to weave in and build STEM mindset and link them to career opportunities**

3. **Pointers for parents on how they may support girls to build a STEM career pathway**

4. **Suggestions for funders on programs and collaborations needed to build STEM mindsets.**

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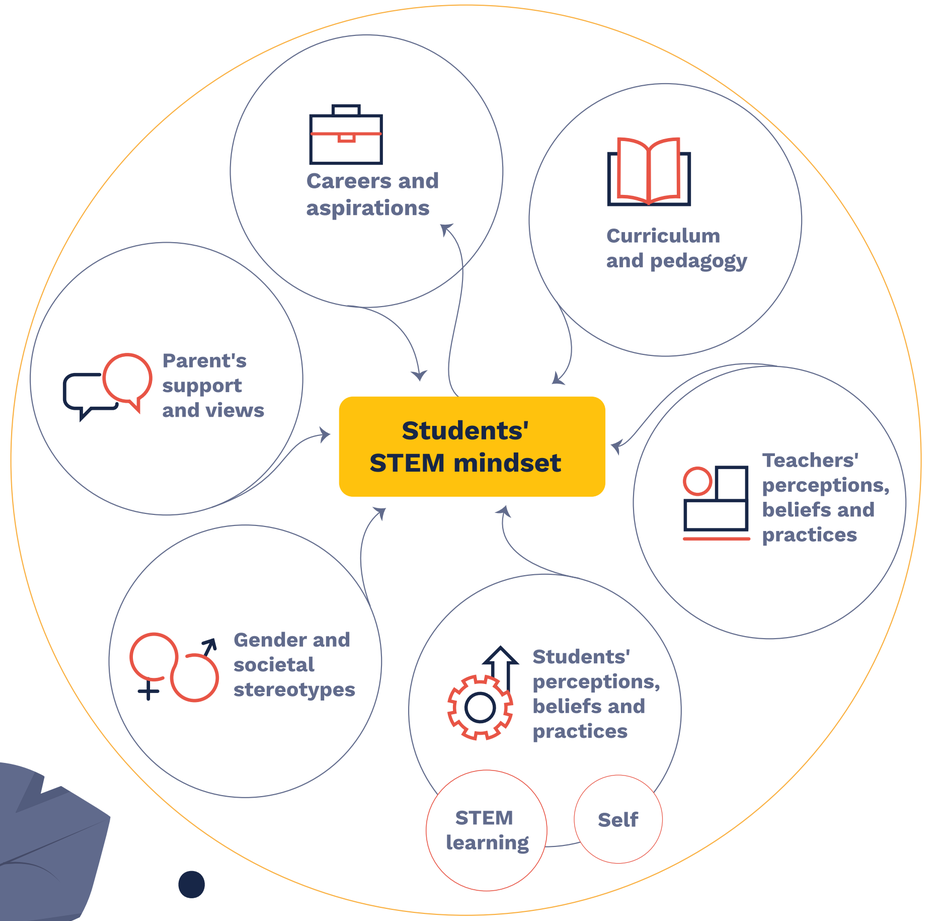
2 Methodology

The study adopted an interpretative research approach using mixed-mode design including qualitative surveys, interviews and focus group discussions (FGD) to provide empirical data around developing STEM Mindset (henceforth SMS) among students. The empirical findings were used to provide a situational analysis of secondary education related to STEM in the states of Gujarat, Odisha and Telangana. The primary data analysis was supplemented with relevant research literature to arrive at a more comprehensive understanding which could then yield pointers and recommendations to build SMS among all students and increase participation of girls from public schools in STEM careers.

2.1 Conceptual framework

The underlying assumption that forms the basis of the empirical study is that Students' STEM mindset is influenced by the following factors: students' own perceptions about self and STEM learning, teachers' perceptions of STEM and their beliefs and pedagogical practices; school curriculum and assessment practices; gender stereotypes and parental support. Careers and aspirations have a two-way effect, in the sense that they influence STEM mindset and are influenced by STEM mindset. The following schematic captures the relationship between the various factors and student SMS.



The key objectives of the empirical component of this empirical research were to study:

- Extent of SMS and self-perception among students with a special focus on gender and SMS
- Teachers' perceptions on STEM, SMS, gender and STEM learning and pedagogical practices
- Teachers' awareness and guidance to students regarding STEM careers
- Parental awareness and support to girls regarding STEM studies and careers
- Curriculum support for SMS

2.2 Tool design

In the first part of the study undertaken for Quest Alliance, a set of skills and attitudes that are constitutive of SMS had been identified. For the second part, we examined the factors influencing student SMS by focusing on the following key skills—logical reasoning and problem solving, mathematical thinking and technology skills; and important SMS related attitudes such as curiosity, risk-taking and resilience in the face of failure and environmental awareness.

To examine secondary school students' SMS and career aspirations, a qualitative survey and focus group discussions were conducted. In order to gauge teachers' SMS, their understanding of the relevance of SMS for future careers and their pedagogical strategies, a qualitative survey tool, a semi-structured interview tool and a focus group discussion tool were developed. Parents of secondary school students were administered a qualitative survey to understand their perception about supporting their daughters to pursue higher studies and take up STEM-related careers. Themes, questions and sub-questions under those themes and the appropriate tools for data collection were designed.

This table provides an indication of the research objectives and corresponding tool used for garnering data.

Student Survey

Students SMS, attitudes towards STEM and gender, aspirations, risk-taking and response to academic failure

Student FGD

Extent of SMS among students

Teacher interview (semi- structured)

Pedagogical practices, STEM careers and Student Guidance

Curriculum experts' interview (open-ended)

Curriculum development and possible changes needed for developing SMS

Teacher Survey

Teacher understanding of SMS & relevance and importance of SMS; perception about students, gender and STEM; opinion of science and math syllabus; teacher training needs

Parent survey

Support to STEM education and STEM careers

Teacher FGD

Extent of SMS in terms of thinking logically, critically and applying available scientific understanding about the topics discussed

The survey with students helped to capture the perceptions about STEM learning, self, careers and aspirations and gender stereotypes. Selected skills and attitudes that represent the STEM mindset were examined through focus group discussions.

One of the objectives of the study was to examine teachers' capacities towards developing SMS related skills and attitudes among students. To get a nuanced picture of teachers' capacities, we looked at teachers' SMS, their understanding of SMS and their pedagogy for inculcating SMS in students. Interviews were also conducted with a small set of curriculum developers and resource persons. During FGD with teachers, their understanding and ability to explain the reasons for the cause and spread of Covid-19 were probed and additional discussions were held on how they are preparing their students for digital literacy, future jobs and for changes in the environment.

Parents were surveyed, the aim was to broadly understand their perception towards STEM education, their willingness for their children to pursuing STEM education and careers, understand gendered responses and concerns towards STEM education and also understand the reasons for barriers in entering STEM education. The genders, as well as the occupations of parents, were noted to determine any influence of the same in the responses as well.

2.3 Location and context

After considerable discussion, it was decided that the study would be conducted in the states of Telangana, Odisha and Gujarat. The mandate was to cover government schools in these three states. Given the linguistic diversity of the study areas, the various tools had to be translated from English to the respective state language and the qualitative data from the respective state languages to English.

It is useful to examine some of the basic education statistics in each of the states considered as part of this report.

The Human Development Index (HDI) of Gujarat stood at 0.672 as of 2018 (Global Data Lab, 2018).

82.4% **Male**

74.8% **Female**

In Gujarat, as of 2018, the literacy rate stood at male literacy rate of 82.4% with male and female literacy rate of 74.8% (Census 2011, n.d).

93% **Male**

97% **Female**

The Gross Enrollment rate (GER) of Gujarat from first grade to eighth grade was 95% while the female GER stood at 97% for girls compared to 93% for boys (statistica.com, 2020).

21.8% **Male**

19% **Female**

The drop out rate as of 2018 for students at the secondary education level stood at 19% for girls and 21.8% for boys.

The HDI of Telangana was 0.669 as of 2018 (Global Data Lab, 2018).

80.5% **Male**

65.1% **Female**

As of 2018, the literacy rate of Telangana stood at 66.52% with a male literacy rate of 80.5% and female literacy rate of 65.1% respectively (Telangana State Portal, n.d).

94.4% **Male**

94.4% **Female**

The total GER of students from the first grade to eighth grade across Telangana was almost 94.4% for male and female both, as of 2018(statistica.com, 2020).

19% **Male**

15.2% **Female**

The dropout rates from secondary school education stood at 15.2% for girls while 19% for boys as of 2018.

The HDI of Odisha was 0.606 as of 2018 (Global Data Lab, 2018).

84%
Male

70.3%
Female

The literacy rate of Odisha as of 2018 is 72.9%. The male literacy rate is 84% whereas the female literacy rate is 70.3%.

91%
Male

85.54%
Female

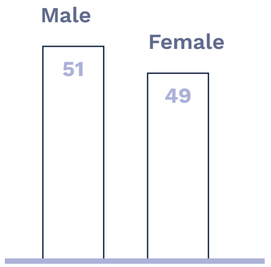
The GER of the elementary level in Orissa was 88.28% with 91% for male and 85.54% for female as of 2018.

28.7%
Male

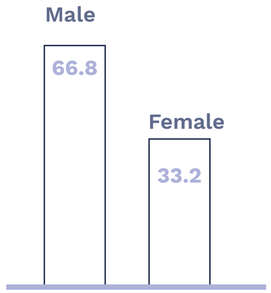
27.8%
Female

The dropout rate at secondary level, 2017-18 for boys is 28.7% and for girls is 27.8%.

Taking a look at the Male-Female ratio at each level educational level, it can be observed that the ratio of male is higher than female at almost every level except M.Phil, Post Graduate and Certificate.

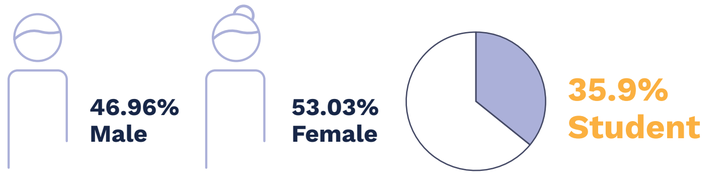


Student enrolment at undergraduate level has 51% male and 49% female.



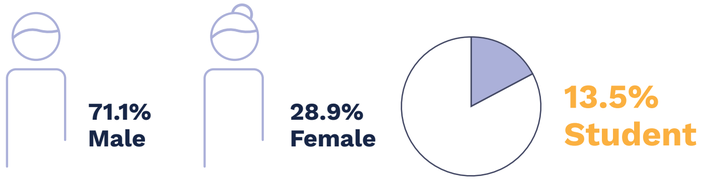
Diploma has a skewed distribution with 66.8% male and 33.2% female (AISHE, 2019).

At a national level, there has been a shift in the number of students pursuing science or STEM-related courses from their undergraduate education. A 2015 survey found that one out of every four students aspiring for a college degree prefers to choose humanities (Pednekar, 2015).

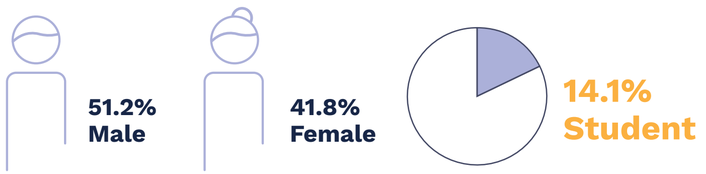


According to the AISHE (All India Survey on Higher Education) in the academic year 2018-19, at the Undergraduate level, the highest number (35.9%) of students are enrolled in Arts/ or Humanities/ Social Sciences courses of which (46.96 % are male and 53.03% are female);

followed by Science (16.5%) of which (49% are male and 51% female),



Engineering and Technology (13.5%) of which (71.1% are male and 28.9% are female) and



Commerce (14.1%) of which (51.2% are male and 41.8% are female). (AISHE, 2019).

Further, the choice of STEM education and careers for women has come with barriers that emanate from a societal and cultural perspective. As of the academic year 2018-19, women constitute nearly 43 per cent of the total STEM enrollments in the country, however, the disparity becomes starker with subsequent qualifications (AISHE, 2019). Women are likely to be constrained by their societally mandated roles, wherein professional decisions are largely affected by their household responsibilities. Women are also not exempted from biases in the workplace. About 81% of the Indian women in STEM faced gender bias in performance evaluations and a large proportion felt that their companies would not offer a top position to women (Jain, 2020).This is an important area to reflect upon given that there is a growing demand for individuals trained in STEM across fields.

The following section indicates the breakup of students, teachers and parents from each of the three states.

The study reached out to 104 students and 101 teachers. Sixty-two students participated in the surveys - 21 from Gujarat, 19 from Orissa and 22 from Telangana. The gender breakup was as follows - 33 girls and 29 boys. 42 students participated in the FGDs (9 in Telangana, 8 in Gujarat and 25 in Orissa).

Seventy-seven teachers: 26 from Gujarat, 31 from Telangana and 20 from Odisha were surveyed on their STEM mindsets, comfort with technology, and perceptions of gender and STEM learning. Interviews of 24 teachers (8 from each state) offered a more detailed exploration of their ideas on STEM mindsets, pedagogy, and the challenges they face. Focus group discussions were conducted with groups of teachers in Gujarat and Telangana. However it was not possible to hold FGD in Odisha as permission from the concerned district educational authority was not forthcoming.

Parents of students from grade 8 to 10 were surveyed across Telangana, Gujarat and Odisha based on a common questionnaire. Around 30 parents participated in the survey.

Students

104 | 42 | 62

Teachers

101 | 24 | 77

Parents

30 | 30

Stakeholders reached

- Total Number
- Through qualitative Survey
- Through FGD/Interviews

2.4 Limitations

The scope of the study was limited due to the ongoing pandemic situation and it was not possible to conduct direct observations of classroom teaching. Instead, the pedagogical strategies used by science and math teachers were probed using survey and interview tools.

We decided not to develop an objective tool to gauge the extent of the STEM mindset among participants (teachers/ students). The time available for the study was not sufficient for the development and standardization of such a tool. The study relied on interpretation of FGD data to gauge the extent of SMS among students and teachers. The FGDs were conducted by field researchers in the three states and this involved the translation of tools from English to the local language and subsequent translation of discussion data from the local language back to English. This process of double translation could have led to loss of some of the finer nuances of what was said by the participants.

Further, in Odisha, the data was collected from the more remote districts which have considerable tribal populations whose languages differ from the state language. The field worker in Odisha spent considerable effort to elicit interview data from both students and teachers, but expressed that there were difficulties in getting a more detailed response. Further, teacher FGD could not be conducted in Odisha because permission was not given by the educational officials. The researcher in Odisha had also tried to contact teachers from the list provided by Quest Alliance, but found that the teachers were not willing to participate in this study.

Finally, it needs to be mentioned that the first part of the study provided us with detailed narratives of a multitude of skills and attitudes that are associated with the STEM mindset. In the first report, we had pointed out that many of the skills associated with SMS were common to those identified as 21st Century Skills and also the Growth mindset. For the purposes of the second study we deliberately narrowed the list of skills to a smaller subset of skills and attitudes (mentioned under the Tool Design section). The focus was on skills and attitudes more specifically associated with STEM and SMS. The growth mindset was probed to a very limited extent by examining student response to academic failure. Thus, the scope of the present study does not cover a detailed exploration of the development of the growth mindset or 21st century skills. This tailored focus was necessary, given the constraints imposed by the pandemic, multi-state design and time availability. At the same time, the narrower scope allows for a sharper focus on skills and attitudes more specific to SMS.

The findings of the study, based on the qualitative methods above, are described in the next four sections. The first section presents the extent of SMS among students, the second section describes the findings related to teachers' perceptions about SMS, and the third section gives a picture about parental support for STEM education of girls. The last section elaborates the views of curriculum developers on the approaches to STEM learning.

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2 Students and STEM mindset

A STEM mindset is essential for people to adapt to the rapid changes brought about by technological advances. Innovations in automation and AI are impacting almost every field as findings from the first part of the study show. This will bring opportunities to those who can find their way in the new age. Innovations due to advances in automation and areas like AI do not automatically benefit all alike. Notably, innovation does not benefit women and men equally (UN Women, 2017). While men and women will be equally affected by the changes, for women the new challenges will come on top of existing barriers towards gender equality in the workplace (Madgavkar, Krishna & Ellingrud, 2019). The next sections of the report focus on the extent of STEM mindsets among students, SMS and self-perceptions with issues related to girl students and SMS.

3.1 Extent of STEM mindset among students

Curiosity, exploration, tinkering and risk-taking

Most students seem to open up things, repair, use materials such as drill, pickaxe, magnet, mirror etc. Most students have reported that they worked with soil and played around in the kitchen with materials. There are some variations in the states- for example- fewer students (36%) from Telangana reported that they have built something in comparison to students from Gujarat (76%) and Orissa (68%). More students from Gujarat seem to be repairing, drilling, using magnets and other materials, building or making and playing with materials in the kitchen such as Soda, turmeric, lemon etc. when compared to Orissa and Telangana. More students from Orissa (94%) reported to be working with soil and plants when compared to the other two states.

The students seem to explore, tinker, repair on their own and schools do not seem to provide many oppurtunities. The teachers in the interviews mentioned projects involving survey and data collection and did not specifically mention tinkering, repairing, creating or making things. However, there is a marked difference between genders as is detailed in the subsequent sections. Boys are more likely to tinker and repair than girls.

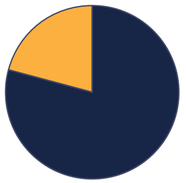
The responses from the different states are as follows (in percentage).

Yes No

STEM Mindset

Opened up something to see how it works

	Yes	No
Gujarat	85.7%	14.3%
Orissa	60%	40%
Telangana	86.4%	13.6%



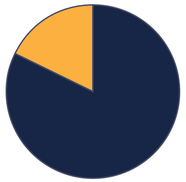
Across the three states

79.3%

20.7%

Used a drill, pickaxe, shovel, hammer or a screwdriver

	Yes	No
Gujarat	85.7%	14.3%
Orissa	89.5%	10.5%
Telangana	72.8%	27.3%



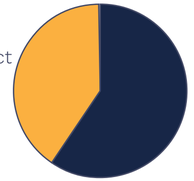
Across the three states

82.3%

17.7%

Tried repairing or building something - for example an app, or a physical product

	Yes	No
Gujarat	76.2%	23.8%
Orissa	68.4%	31.6%
Telangana	36.4%	63.6%



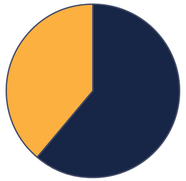
Across the three states

59.4%

40.3%

Use of pulley, or a magnet, or a set of mirrors or some electronics on their own

	Yes	No
Gujarat	85.7%	14.3%
Orissa	47.4%	52.6%
Telangana	50%	50%



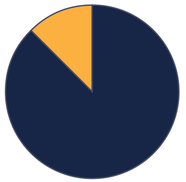
Across the three states

61.3%

38.7%

Working with soil, water, compost, seeds to grow your own plants and flowers

	Yes	No
Gujarat	90.4%	9.6%
Orissa	94.7%	5.3%
Telangana	81.8%	18.2%



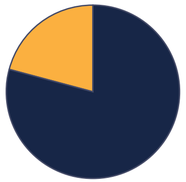
Across the three states

88.7%

11.3%

Play around in the kitchen with soda, lemon, turmeric, yeast etc. to see how they behave

	Yes	No
Gujarat	80.9%	19%
Orissa	78.9%	21.1%
Telangana	77.3%	22.7%



Across the three states

70.1%

20.9%

As seen in the above table, the students survey explored the individual growth-oriented mindset, curiosity, ability to persevere and willingness to take risks. Questions such as “Have you ever opened up something to see how it works?” and “Have you used a drill, pickaxe, shovel, hammer, or a screwdriver?” were asked to interpret the students’ curiosity and to a minor extent the risk-taking ability as well, given that breaking things open could get them into a confrontation with adults. Response to failure was checked by asking students how they dealt with academic failure. The ability to persist was reflected to a limited extent by the student’s response to what they would do if they failed in an examination for which a majority of students from all the states responded that they would approach their teacher or peers to study the concepts better and improve their performance.

Logical thinking and critical thinking

The FGDs explored in depth the student's ability to reason, analyse and justify. Questions revolved around a solar to understand if students question or blindly follow some superstitions. The other questions were on COVID and falling objects. The questions on falling objects helped elicit alternative conceptions (misconceptions) that students have regarding mass, gravity and air resistance. The questions on COVID explored their ability to reason and analyse and think logically.

Most students from Gujarat reported that they do not believe in the myths regarding eclipses. Some students have attempted to observe the eclipse in school. Some students reported that their parents follow the rituals and beliefs with respect to an eclipse. There were many students who noted their parents' superstitions and few students mentioned that they had tried questioning their parents' beliefs, but their parents didn't encourage them to do so. In Telangana, students explained how eclipses occur and mentioned that they have tried to observe the eclipse through cooling glasses and films. However, they have not tried to question their parent's beliefs.

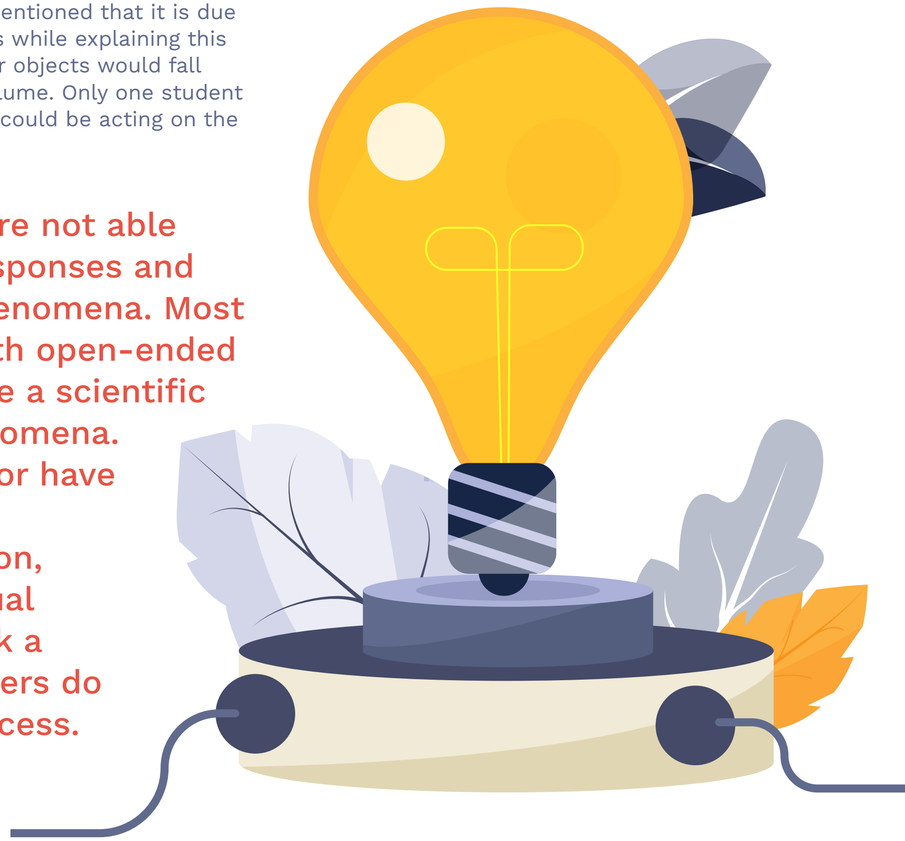
Contrastingly in Orissa, students seem to follow the rituals around the eclipse. They are not allowed to go out or eat and they have not tried to question such beliefs. They noted that an eclipse is observed through a mirror kept in a plate of turmeric water in villages.

Though in Gujarat and Telangana, many students reported that they do not believe in superstitions concerning the eclipse, students do not seem to have sufficient understanding of how eclipse can be viewed as they reported that they watch through sunglasses, cooling glasses or through X-Ray sheets and films. One of the students said that Aryabhatta and other scientists have explained how eclipses occur. Many students have a lot of misconceptions and could not sufficiently explain how a solar eclipse occurs and the methods to view the eclipse safely.

Similarly, on the question of COVID and whether washing the hands with soap solution is effective in preventing the virus, the students could not explain and give reasons on how soap solution might be effective. Some felt that viruses would not be killed and some responded that viruses and bacteria can be killed with the help of soap solution.

With respect to falling objects, almost all the students agreed that crumpled paper would fall faster than uncrumpled paper and mentioned that it is due to weight. The students seem to have misconceptions while explaining this phenomenon. The students mentioned that all heavier objects would fall faster and related it to gravity, weight, density and volume. Only one student mentioned that an 'air force' (probably air resistance) could be acting on the plain uncrumpled sheet.

The FGDs indicate that students are not able to reason, argue or justify their responses and explain the science behind the phenomena. Most of the students did not engage with open-ended questions and do not seem to have a scientific understanding of the various phenomena. Students know some information or have heard it or read it in the book.
The students do not seem to reason, analyse and have deeper conceptual understanding. They appear to lack a scientific mindset and often teachers do not encourage such a thinking process.

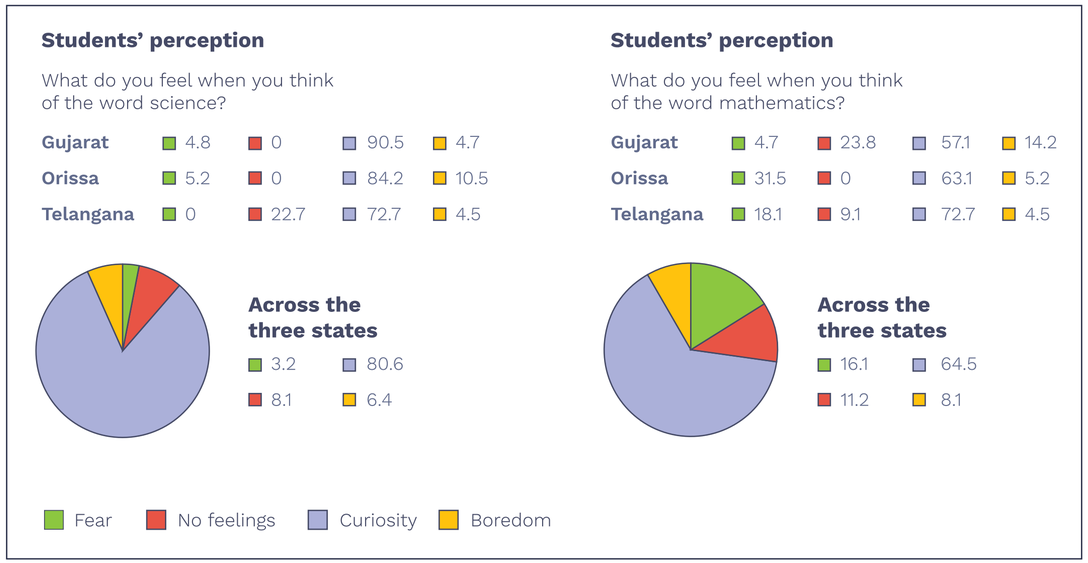


3.2 STEM mindset and self-perception

The students' perceptions about themselves, their abilities, about science and mathematics has an important relationship with the STEM mindset. "Self-efficacy is a critical component of STEM mindset because of its links to perseverance in STEM" (Wieselmann, 2019). The survey explored students' perception of science and mathematics as a subject, how they relate to it, their abilities and if they would choose STEM careers and pursue science and mathematics after class 12.

Perceptions around science and math

It is interesting to note that 80% of the students associate the word curiosity with science compared to 64% in math. The word fear is comparatively more associated with mathematics (16%) than with science (3%). More students from Orissa report fear (32%) in mathematics compared to Gujarat and Telangana. Few students find math (8%) and science (6%) boring.



STEM aspirations

Eighty-four per cent of students across all the three states are willing to pursue science and mathematics after class 12. However, this willingness does not relate to the STEM mindset but to jobs in STEM fields that are considered lucrative by parents and students. In Telangana, 96% of students reported that they will pursue math and science, which is not surprising. Research studies (Gilbertson, 2014; Kamat, 2011; Prasad, 2017) find that more and more students from Telangana aspire to become software engineers and many schools are geared to prepare the students for the same. The general notion among parents is that jobs in IT are lucrative and offer social mobility. (Prasad, 2017; Sundararaman, 2019).

Among a list of occupations, engineering was given the highest preference in Gujarat (27%) and Telangana (33%). In total, 46% students from Telangana, 57% (Gujarat) and 16% (Orissa) reported being interested in jobs directly related to STEM (such as engineering, software professional, doctor and scientist).

Orissa seems to present a different case with respect to aspirations. Teaching (47%), police (21%) and then farming (10%) are the most common aspirations in Orissa.

Police and armed forces are not a middle-class dream and more a working-class aspiration (Macleod, 2009). The dreams of the students seem to be located and stemming from socio-economic status. In Orissa, the students who participated were from the tribal communities, whereas the students from Gujarat and Telangana were from semi-urban towns and rural areas. This could probably be one of the reasons behind the differences in the aspirations among the students of the three states. Gujarat and Telangana are also better with respect to HDI[4] when compared to Orissa.

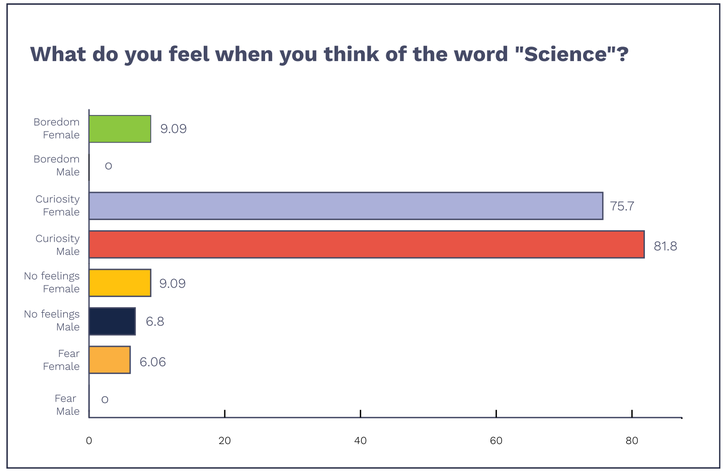
Though there is a positive attitude towards pursuing science and math and interest in these subjects, this does not necessarily correlate with the STEM mindset among students, especially as seen from the focus group discussions. During interviews, some teachers noted that most of the teaching and learning is focused on preparing the students for examinations. Given this context, STEM mindset such as reasoning, analysis, logical thinking, rationality, scientific temper, perseverance, risk taking and so on appear to be a big ask.

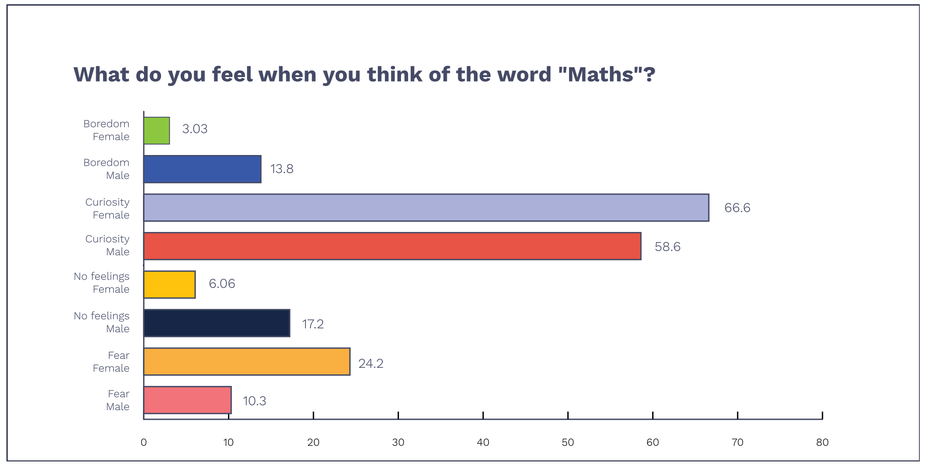
3.3 Gender perceptions and STEM mindset

The survey helped to elicit the perceptions regarding science, access to materials, repairing, tinkering, creating and the gender differences.

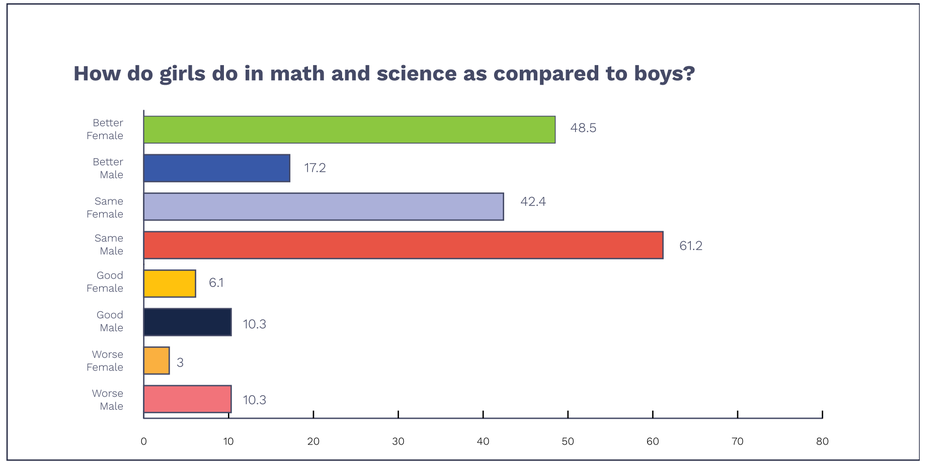
Who can or cannot do science and mathematics ?

Eighty-two percent boys reported that they associate the word curiosity with science compared to 76% girls. A few girls (6%) associated science with fear and none of the boys associated fear and science. Similarly, in math, more girls (24%) compared to boys reported fear (10%). However, more girls (67%) associated curiosity with respect to math when compared to boys (59%).





Another interesting trend to note is that girls feel positive about their abilities in math and science when compared to boys. Girls - 49% reported that they do better than boys whereas 62% boys felt that both boys and girls perform similarly.



More girls noted that the reason for their poor performance in science and math is due to lack of encouragement from parents and teachers and boys noted the lack of support from the peer group as the important reason. The table below highlights the different reasons (in percentage) in detail.

The table below highlights the different reasons (in percentage) in detail.

If girls perform worse, why do you think it is so?

1. Girls are not encouraged by parents and teachers to do math and science

39.1% Female **12.5%** Male

2. Girls and boys perform similarly

26.1% Female **18.8%** Male

3. Girls are not good at school work

8.6% Female **12.5%** Male

4. Girls do not have friends who think math and science is important

8.6% Female **18.7%** Male

5. Girls are not naturally gifted in math and science

17.4% Female **25%** Male

If boys perform worse, why do you think it is so?

1. Boys are not encouraged by parents and teachers to do math and science

3.8% Female **6.3%** Male

2. Girls and boys perform similarly

23.1% Female **12.5%** Male

3. Boys are not good at school work

30.7% Female **12.5%** Male

4. Boys do not have friends who think math and science is important

26.9% Female **43.8%** Male

5. Boys are not naturally gifted in math and science

15.4% Female **18.8%** Male

More girls (91%) expressed willingness to choose science and math after 12. However, engineering appears to be a male domain as more boys than girls reported that would like to be an engineer in future. Interestingly, willingness to be a computer professional amongst girls is a little higher compared to boys. The table below presents the aspirations of students.

What job do you imagine yourself doing when you are 30?

Female		Male	
Engineer	12.1%	Engineer	34.55
Police	15.2%	Police	17.3%
IAS	12.1%	IAS	0%
I.T	9.1%	I.T	6.9%
Lawyer	3%	Lawyer	0%
Doctor	12.1%	Doctor	0%
Teacher	18.2%	Teacher	13.8%
Business	3%	Business	10.3%
Farmer	3%	Farmer	3.4%
Scientist	3%	Scientist	3.4%
Others	9.1%	Others	10.3%

Who takes more risks, repairs and tinkers?

Though there is a positive attitude towards science amongst girls, more boys than girls have tried to repair, tinker or build and play with materials such as pulley, magnets and electronics. Opportunities to access science related materials and resources are more for boys and girls are often discouraged from handling drill, pickaxe, hammer, electrical and electronics materials, repair and building something.

The table below indicates the gender differences with respect to repairing, tinkering in detail.

STEM Mindset

Yes No

Opened up something to see how it works

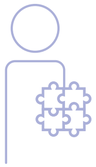
	Yes	No
Female	66.7%	33.3%
Male	89.3%	10.7%

Tried repairing or building something - for example, an app, or a physical product

	Yes	No
Female	48.5%	51.5%
Male	72.4%	27.6%

Working with soil, water, compost, seeds to grow your own plants and flowers

	Yes	No
Female	87.9%	12.1%
Male	89.7%	10.3%



Used a drill, pickaxe, shovel, hammer or a screwdriver

	Yes	No
Female	78.8%	21.2%
Male	86.2%	13.8%

Use of pulley, or a magnet, or a set of mirrors or some electronics on their own

	Yes	No
Female	45.5%	54.5%
Male	75.9%	24.1%

Play around in the kitchen with soda, lemon, turmeric, yeast etc. to see how they behave

	Yes	No
Female	81.8%	18.2%
Male	71.9%	14.1%

3.4 Discussion

In a white paper brought out by Quest Alliance (2020), three levels of barriers to participation of girls in STEM were identified. At the social level, these barriers include gender stereotypes and a gendered job market. At the level of schooling, girls meet barriers in the form of lack of infrastructure and teacher availability, pedagogic practices and curriculum representations. Finally, factors at the individual level such as socio-economic status, location and age influence the ability of girls to participate in STEM.

The stereotypes seem to be coming from the home and influencing boys and girls strongly with regard to being manipulative, skilful and experimenting or otherwise (Sundararaman, 2019). Teachers are also reported to be providing fewer opportunities to girls to experiment and engage with STEM-related activities. The surveys with teachers indicate a strong bias among teachers with respect to subject abilities — where biology is considered a female domain and a softer subject and physics is suitable for boys.

Gender gap is noted among students with respect to access to technology - such as access to computer/ laptop and online learning resources. Seventy-nine per cent boys reported access to computers compared to 46% girls and 72% boys reported that they access online learning apps compared to 46% girls. The digital gender divide manifested more during the COVID pandemic and reports suggest that girls are at the losing end (Aggarwal, 2020).

Many career fields across the world are dominated by men, and this is even more true in STEM areas. The under-representation of women in STEM sectors puts them at a high risk of being displaced by technology. IMF's study in 2018 indicates that women, more than men, perform more routine tasks — jobs that are prone to automation. (Brussevich, 2018). Women form only 28.8 per cent of the world average of STEM workers. In India, this number is still lower at 14 per cent. Worryingly, the female labour force participation rate (FLPR) in India has steadily declined to 26 per cent in 2018, against a global average of 48.5 per cent (ILO, 2018). It is evident that women in India are failing to reap the benefits of economic development.

It is especially important to develop SMS in girls to increase their participation in the workforce. Almost all professional work requires SMS (Vijaysimha, Sundararaman & Aravamuthu, 2021) and if women are to reap the benefits of economic development, they need to overcome various barriers by developing SMS. Underachievement and unequal participation of girls in subjects like science and mathematics has been pointed out in a white paper brought out by Quest Alliance (2020). 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 from 2011-15, the study found that only 11% of girls accounted for top-level scores in math, compared to 89% of boys. In science, only 18% of girls received top scores, compared to 82% of boys (Makel et.al, 2015).

Gendered stereotypes on the students’ science abilities have been found to be an important reason for the ‘leaky pipe’ effect and widening gender gap in STEM careers in the western context. In the Indian context researchers (Mukhopadhyay and Seymour, 1994; Sujatha, 2015; Sujatha, 2017) note that the gender gap in STEM may not be due to stereotypes on cognitive abilities but due to domesticity, familism and patrifocal family structures. The survey also confirmed that the girl students have positive self-perception about their abilities in science and math and reported that if they do badly, it is because they are not encouraged by parents and teachers.

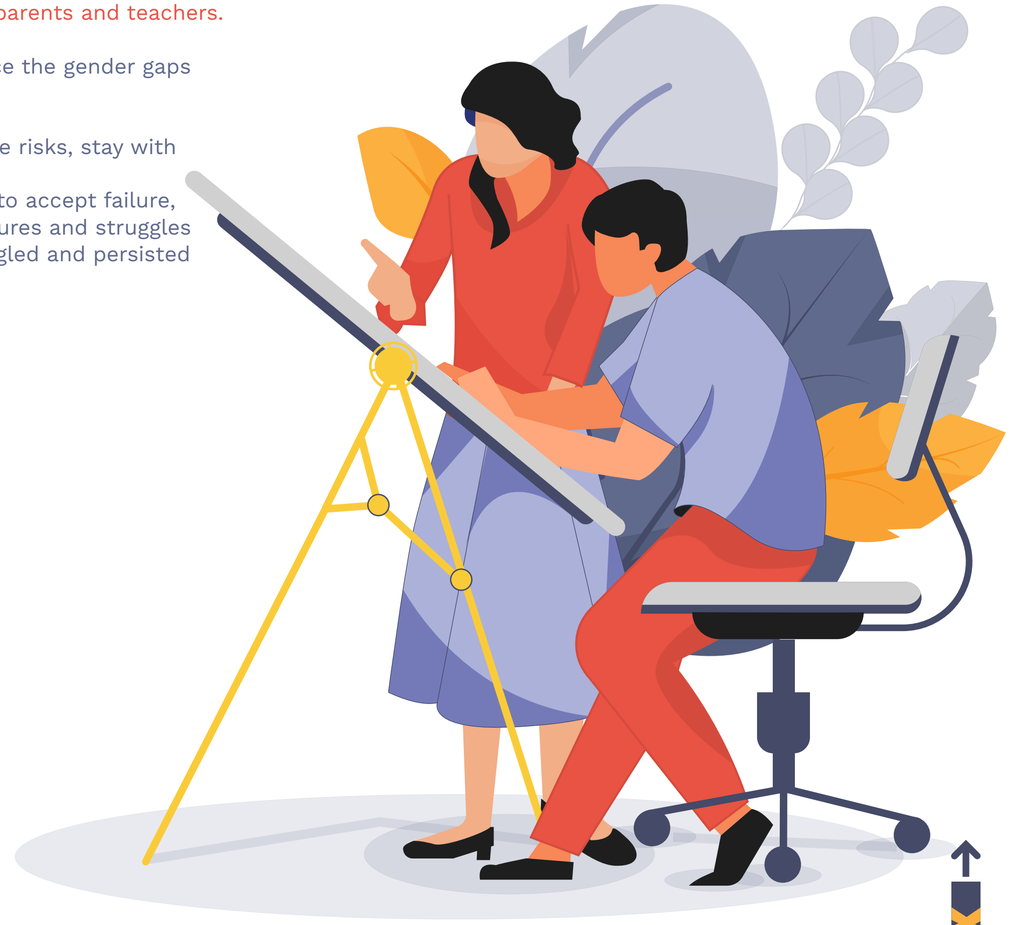
Wieselmann (2019) offers interesting recommendations to reduce the gender gaps and nurture STEM mindset among girls,

- Providing open-ended tasks which encourage students to take risks, stay with ambiguity and try multiple solutions
- Opportunities for design thinking so that it enables students to accept failure, persist, try and enjoy the process and not get deterred by failures and struggles
- Engage with role models and ‘coping models’ who have struggled and persisted
- Scope for reflection, self-learning and self-assessment.

These might be beneficial not just for girls but all students according to Weiselmann (2019).

Family decisions regarding girl’s education, discrimination against girl’s education, willingness to spend on boy’s education seem to be an important factors in the Indian context. Though there is discrimination against girls, the participation of girls in higher education has been increasing for various reasons. Reports on labour and employment indicate that more and more girls are accessing higher education and professional courses in STEM; however, the participation rate of women in the labour market is low (Agarwaal, Kapur and Tognatta, 2012). This highlights the role of parents and families in bridging the gender gap in STEM education and labour participation in STEM careers. This necessitates working with families and parents. We highlight some of the emerging needs in the coming sections.

The next section discusses the findings on teachers’ STEM mindset, their perceptions about STEM learning, gaps in curriculum, pedagogy and assessment, gender and careers.



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4 Teachers and STEM mindset

Teachers play a critical role in how students perceive themselves and how curriculum is implemented. The teacher's SMS and their perceptions of learning and teaching STEM leaves an impression on STEM among students. Lederman (1992) indicates that the teacher's view of science necessarily translates into classroom practice and teacher's views of science and students' view are related. Considering the crucial role that teacher's play in learning, this section attempts to describe the teacher's SMS, their perceptions about STEM learning and their understanding of evolving STEM careers. It articulates the gaps in the curriculum, pedagogy and assessment as identified by teachers.

4.1 Teachers' SMS

Teachers do recognize the importance of STEM in the contemporary world and are fairly aware of the way in which science and technology have positively impacted human life in many fields. Several teachers spoke about how science has made life easier. Many of the teachers also spoke of how technology could be used to improve education.

Questioning given beliefs

While the majority of the teachers identified logical thinking as an important skill learnt through science/math, less than three per cent of the teachers identified the questioning of traditional beliefs as important. Across states, traditional customs are followed by many teachers. Teachers did mention that they ask the children to question customary taboos and beliefs, while also saying that the taboos and beliefs came from some logic and that one must search for the rationale behind the taboos. A few teachers offered a pseudo-scientific explanation for following some customs.

There is a scientific relation to the "sravan masa snanam" (ritual bath during on a specific calendar day). "While taking a bath there is a relation between the body's magnetic particles and Earth's magnetism, and so a tank bath has a positive effect" - Ratna[5], Teacher, Telangana. The teachers did not seem to analyse, reason and justify their responses in a systematic and scientific way as would be expected from those with SMS. In many instances, their responses during FGD discussions were not well thought out and some teachers did not seem to critically evaluate the information they received. During a discussion of what caused Covid-19, one of the teachers from Telangana noted, somehow this is because of the attitude of the human beings, their view of getting the upper hand over nature. Another teacher noted, "I have no specific idea of the way the coronavirus is transferred, whether it is transferred from animals to human beings or not". Except for the above reasons cited by the teachers, the other teachers discussed lack of cleanliness and neatness, negligence and so on. A discussion of the same topic in Gujarat, likewise, did not spark a discussion of the virus; instead, the focus was on non-vegetarianism as a reason for the spread of the coronavirus. The teachers in the FGD in Telangana also discussed that misinformation was spread due to a commercial or political outlook. Teachers in Gujarat and Telangana discussed building immunity using traditional recipes for Covid-19 – a teacher in Telangana talked about sesame seeds and jaggery as a recipe for immunity against the virus and brushing with neem sticks as a good way of cleaning the mouth and the saliva. This is all the more surprising, given that the school curriculum includes content on micro-organisms and their role in causing diseases.

It therefore appears that teachers themselves do not have strong SMS and that they could be provided specific opportunities to read and reflect about current issues using a scientific lens.

Understanding of STEM

When it came to the term STEM, 40% of teachers across the three states understood it to be an acronym for Science, Technology, Engineering and Math, 40% of teachers associated the term with an integrated way of teaching across disciplines, and 21% of teachers were not clear about the term. Teachers mostly equated STEM with technology skills, which seemed relevant during COVID and the requirement to teach online. Despite not being very clear about the term, STEM, teachers were quite clear about the importance of science and math in developing key skills of SMS like logical thinking and problem-solving. Teachers and curriculum developers had clear perceptions of the mindsets for science and math learning and teaching.

As mentioned in the first part of the study, there is an overlap between the concepts of scientific temper and STEM mindsets. Teachers referred to the former and not to the latter while discussing the aims of science and math teaching. Teachers also mentioned curiosity, creativity, independent thinking, rational thinking and critical thinking while discussing the aims of teaching science and math.

Eighty-seven per cent of the teachers surveyed recognized that the importance of teaching science and math was to develop a scientific mindset

Sai Teja
Telangana

I am thinking that STEM mindset is a kind of way of thinking for children. The program that drives the child to think in a logical way and to understand the technology and engineering, that is the scientific mindset".

Ruchika
Gujarat

To develop a scientific attitude, a child must develop an interest in science around him. He or she can understand science is everywhere: that is the main aim of science education. All the small things from boiling the milk to any other activity, science is there. So, they should understand that".

Ninety-seven per cent of teachers surveyed were aware that STEM is needed for all jobs, and 79% of teachers surveyed said that science and math are useful for all students.

Logical and analytical thinking and problem-solving

This study shows that teachers are aware of the importance of developing the skills of logical reasoning and problem solving through math and science. Seventy-six per cent of the teachers believe that logical and analytical thinking is needed for success in STEM and 83% believe that to be good at STEM a student needs to apply knowledge to real-life situations. Sixty-eight per cent of the teachers identified logical thinking as the most important skill learnt by studying science and math. The skills gained by studying science and math (as seen by teachers from the different states) is given below:

Skills Gained by studying science/math

Thinking logically	Looking for evidence	Factual Knowledge	Questioning traditional belief
Gujarat 79%	Gujarat 0%	Gujarat 10%	Gujarat 0%
Orissa 45%	Orissa 25%	Orissa 25%	Orissa 5%
Telangana 74%	Telangana 13%	Telangana 10%	Telangana 3%

Answer to question: What is the most important skill that you learn by studying science/math?

Many teachers, especially in Gujarat and Telangana, pointed out that the aim of teaching science was to inculcate logical and analytical thinking and problem-solving. In the case of Odisha, the teachers focused more on the importance of helping students gain scientific knowledge. Some teachers from Odisha mentioned that students should understand how scientific knowledge is applied to solve problems. Thus it appears from this study, that teachers in Odisha give more importance to factual knowledge compared to those from other states. Overall, it is interesting to note that a very small percentage of teachers identified the questioning of traditional beliefs as an important skill learnt through science.

However, when specifically asked about how they dealt with superstitious beliefs among students, teachers said that they would provide scientific explanations about the relevant phenomena to help students overcome superstitions. This is discussed in more detail in the section on pedagogical practices.

In addition to the key skills of logical and analytical thinking and problem-solving, teachers spoke about the importance of helping students develop scientific temper, scientific approach or scientific attitude.

Mathematical thinking

One of the curriculum developers, Tarun, who was interviewed for this study, offered a detailed insight into mathematical thinking, an important aspect of a STEM mindset:

Mathematization of whatever topic you are teaching must be the goal of mathematics. What do you mean by mathematization? By studying percentages, data handling etc. the way of looking at the world must change. So, by studying mathematics what are the intellectual faculties that a student will be able to develop? One faculty would be model thinking. How can I come up with some models with which I can study the world? One more is abstract thinking - how can I abstract out of empirical detail? Also, logical thinking. The two most important pillars of logical thinking are inductive and deductive reasoning. We Indians are fantastic when it comes to inductive reasoning, but when we talk of the sample size, it's usually 1! So, teaching proper inductive reasoning is important because a lot of times we make sweeping generalizations. So, if mathematics is taught well, we will be careful in how we generalize.

When specifically probed about the possibility of integrating math and science, several teachers in all three states spoke that this is possible and even desirable.

Rupadhar,
Teacher,
Kashipur, Odisha

Yes, mathematics and science are combined with other subjects for a better understanding of the lesson. Sometimes several examples are given to point out the relation between them."

Teachers from Telangana repeatedly spoke of the importance of integrating math into other subjects. This was equally true of the teachers from Gujarat. Himanshu (Gujarat) emphatically spoke about the importance of math and how it could be integrated with science,

"We generally teach it like this. Suppose the concept of math - bar graph which can be used in science also to show an increase in pollution year by year. Not art but generally we combine math and science. Math we can teach independently. As we say math is the queen of all the subjects. But we have to take help of math while teaching and learning science."

However, when speaking about the aims of science teaching it is interesting to note that none of the teachers across the three states spoke about mathematical thinking or data analysis. What this could possibly imply is that teachers are not explicitly associating scientific mindset or SMS with mathematical thinking even though they acknowledge that it is possible to integrate math and science while teaching. This suggests that teachers could be made aware of the importance of mathematical thinking and data literacy in the careers of tomorrow, and to increase the focus on these areas, while teaching science.

Technology skills

Forty-eight per cent of the teachers believe that learning about computers should enable students to be empowered. When asked about what students should be taught about computers, 47% identified ‘basic electronics’ whereas 34% pointed out that students should learn different applications. Only a minority of the teachers felt that students should learn to create software. This indicates that teachers are more likely to see students as users of technology rather than as creators of the same.

Teachers in Gujarat were perhaps most tech-savvy (comfortable with Microsoft Teams, Diksha app, Gyankunj), and the Gujarat education website had all textbook material loaded with QR codes. There was one mention in Telangana of an augmented reality experiment in class, mimicking another teacher in Kerala who had introduced the idea in her classroom.

Fifty-five per cent of teachers from Odisha said they do not use mobile phones or computers in their teaching at all, 13% of teachers from Telangana said they do not use their phones/ computers at all and 0% of teachers in Gujarat said that they do not use their cell phones at all.

Further research will be needed to probe into the reasons for the state-wise variations in use of technology for teaching. It may be useful to do this using the TPCK[1] framework. For the present study it was not within the scope of the primary objectives to examine this aspect.

4.2 Perceptions about attitudes related to SMS

Teacher perceptions of attitudes related to SMS such as persistence in the face of failure, taking risks, curiosity, ethics and environmental responsibility are elaborated here. Some of the teachers interviewed mentioned that science teaching should spark curiosity among students.

While discussing the aims of science education

Suresh,
Head Teacher,
Gujarat

To teach how to learn, how to observe, connect with the outside life, to understand the role of each part of nature in the earth, how to design our thinking- being curious... From the third standard, we are trying to connect life and the learning of Environmental Studies(EVS)as a subject. Then we eventually make sub-divisions of science as a subject. Here we are trying to make students understand how nature, systems and things work - that is the main aim of science. By doing this, they will develop several abilities as a by-product - like problem-solving and having patience. It will develop the understanding about the “cause and effect” relationship of nature.”

In response to a question about the attitudes and skills required for success in STEM, 76% of the teachers identified the skill of logical and analytical thinking and only 14% identified “to take risks and try out new things”.

In the present research study, teachers were not asked in a detailed way about how they would inculcate attitudes common to SMS and the growth mindset - persistence in the face of failure. However, students were asked about how they would deal with academic failure and several of them responded that they would approach their teachers. It is heartening to note that students did not mention dropping out or giving up when faced with academic failure. This is a positive indication that teachers may be supporting, to a small extent, the growth mindset by being open to helping students learn from failures.

Teachers could be explicitly trained about the importance of the growth mindset and encouraged to support it by pointing out some of the positive aspects of their existing practices, such as helping students deal with failure. Teachers could be supported to document and expand their strategies for helping students deal with failure and further develop their capacities to inculcate other aspects of the growth mindset.

The role of teachers in supporting growth mindset needs to be researched in much greater detail to develop appropriate strategies to enhance teacher capacities in this direction.

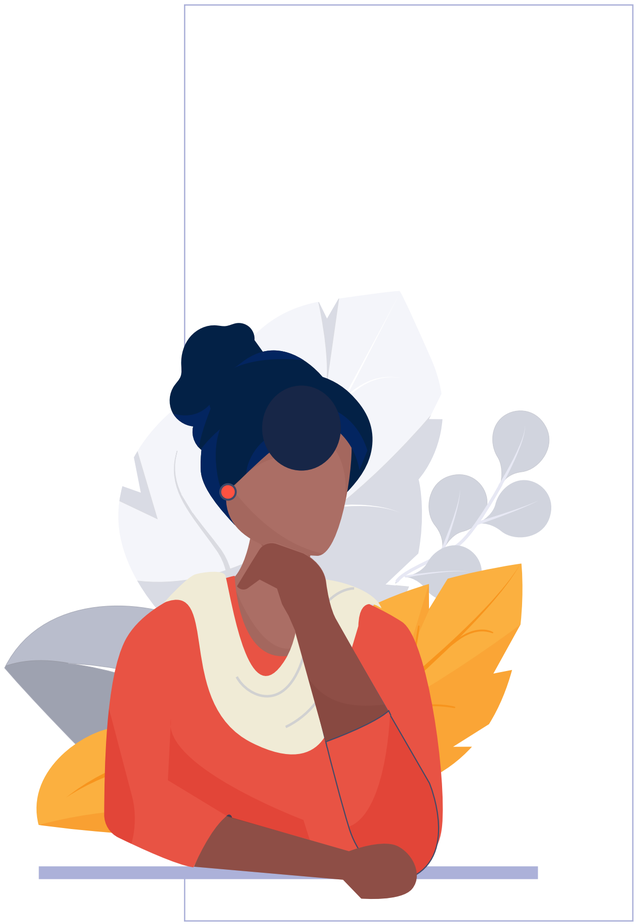
To gauge teachers’ perception regarding developing environmental responsibility and orienting students towards emerging green jobs the following question was posed:

Continuous increase in usage of natural resources is leading to many problems like pollution and climate change. This means that new jobs will emerge that require which of the following:

- Ecological understanding;
- interdisciplinary thinking;
- Strong ethical values;
- All of the above.

In response, 86% of the teachers selected the last option, indicating that they had a good understanding of what needs to be inculcated in students in terms of environmental responsibility and preparedness for the future. However, further research is required to gauge whether teachers are actually inculcating the knowledge, skills and attitudes required for green jobs. As mentioned in our earlier report, (Vijaysimha, Sundararaman and Aravamuthu, 2021) the green job sector is likely to be a fast growing one and it would be highly desirable if students are suitably prepared for these jobs.

4.3 STEM and Gender



Gendered perception about abilities

Teachers seem to have gendered perceptions with regard to students' abilities in science (42% thought boys do better in physics and 49% thought girls do better in biology, 75% thought both can do well in chemistry). Teachers did not hold such a bias with regard to math learning; 87% of teachers thought that both genders can do well in math. It is interesting to note however that it did show that learners feared math as detailed in the previous sections. There were also biases regarding occupations that were more suited for girls (no such restrictions were mentioned for boys). B.Ed., fashion designing, jewellery making, home science, and medicine were suggested as suitable careers for women. A few teachers said that mechanical engineering was not suitable for women. During his interview, one teacher from the Kutch region mentioned that the women are expected to perform household chores, look after younger ones and do embroidery to be able to marry well, but there are no such expectations from men. Questions on considering gender in lesson planning elicited answers ranging from being inclusive of gender because both boy/girl names were used in lessons, to including images showing women and men doing all kinds of tasks to build a more equitable society.

Teacher awareness of girls' unequal access to technology

Student surveys carried out for this study show that girls are less likely to have access to computers, to install video games, or to use learning apps on their phones. The gender stereotypes and societal expectations seem to deter girls from taking risks. As mentioned in the earlier study, the push from society to be "good" and to be approved is greater for girls, and this goes against the STEM mindset which needs risk-taking and resilience in the face of failures. Girls tend to appropriate the behaviour as expected and set by the parents, teachers and society in general. This is possibly an area that requires awareness at every level (school, government, and family).

A research study conducted in the US (Luongo, 2012) showed that teachers who were actively made aware of the gender disparity in students' computer and technology usage through professional development training sessions were more likely to exhibit gender-equitable teaching behaviours than they did prior to the sessions. The implications of this research are that teachers should receive explicit awareness training regarding the inequitable access to technology by girls and on ways to redress this.

4.4 Pedagogy for SMS

The study tried to understand whether schools are changing in accordance with the changes in occupations. In the previous report, industry experts had articulated the STEM mindset in terms of both skills and attitudes. They pointed to the importance of an interdisciplinary approach to subjects, and a focus on math, data, and computing skills. More importantly, problem-solving, analytical and logical thinking, critical thinking, creativity, communication and collaboration emerged as core skills for a STEM mindset. (Vijaysimha, Sundararaman and Aravamuthu, 2021)

In this study, what emerged was that teachers had internalized the ideas of hands-on and activities based learning. Nearly half the teachers surveyed for this study feel that students could be helped to develop scientific thinking by doing experiments and that science and math should be taught through hands-on activities.

Forty-three per cent believe children must do data analysis by collecting data and analyzing themselves, and 36% believe they should write problems based on their own experience.

70%

say they allow children to do experiments, while 21 % do experiments to show children

82%

were confident about performing experiments

Teachers were actively thinking about student learning: Ratna (Telangana), talked about preparing different methods before going to class, thinking of introducing easy problems, and then moving on to hard problems, writing a diary, and being ready with alternative methods. She mentioned keeping in mind different standards of children – speed learners versus slow learners, while entering the classroom. Another teacher talked about forming groups of 10-15 children based on where they live, gender, and cultural background so students can collaborate on projects. A third teacher mentioned that she uses the CCE methodology, writes her lesson plan step-by-step, has teaching points, and scientific terminology in mind as she goes into class. She starts with an introduction, and moves to teaching points. She interconnects with the child's life situations. At the end of the class, she allocates a minimum of 3 minutes for a recap and allows the child to read the text and identify new words (for example, Photosynthesis). At the end of the class, she asks them to recite. Yet another teacher (from Gujarat) mentioned that for a chapter on solid shapes, children had made cubical solid shapes from paper. They could elaborate/imagine 3D shapes while he drew 2D shapes on the board. They justified Euler's equation by making a model. Once they were clear about the concept, they showed the activity or justified it in the morning assembly. Thus, questions on lesson planning generated responses that show that the idea of activity-based learning is recognized by teachers on a conceptual level.

Teachers across all the three states spoke of student projects although teachers in Odisha were not able to substantiate or elaborate what was done in their schools except in one or two cases. In Gujarat, teachers spoke of regular participation in science meets, about a student making a robot from scrap, "aushadhi" gardens, science day celebration, annual life skill programs, and a mention of collaborations with IIT Gandhinagar, Agastya foundation, and VASCSC (Vikram A. Sarabhai Community Science Centre).

Teachers in Telangana also mentioned doing projects – ones that helped children collect information on household expenditure, midday meals, a project to look at the viability of certain crops for commercial production, projects involving building on knowledge of local plants and creating herbariums, and a “water auditing” project. Teachers from Odisha also mentioned doing projects and participating in science exhibitions. Since many of these teachers were new appointees, they were not able to give details.

While project-based learning is happening, there are instances of these being gamed. One of the teachers discussed how projects are done by engineering students:

In the final year or half-year or semester, they must do some project. How many of these final year students are doing projects of their own? How much percentage of those students are purchasing the projects from the internet centers.

This narrative shows the problems of teachers while dealing with students lacking ethics and gaming the system. At the same time it points to other lacunae in the education system such as an inadequate way of assessing project-based learning. We would like to argue that a clear mapping out the learning objectives of project-based learning would lead to more robust ways of assessment based on the objectives. Further research is needed to study the effectiveness of project based learning to achieve the stated objectives and develop SMS/scientific temper. As the report based on the first part of this two-part study shows, project-based learning has been identified as a significant contributor to the development of SMS (Vijaysimha, Sundararaman and Aravamuthu, 2021).

4.5 The gaps that derail STEM education

Scarcity of resources

Government teachers mentioned the challenges that they face in terms of resources (people and material)

Nila,
Teacher,
Gujarat

Right now I can only read and explain the book. There should be three science teachers in our school, but I am the only person here. Time is short and information is plentiful. I have a lot of admin work also, and I can't include more than one activity in a unit plan.

Nomita,
Odisha

There is a shortage of space to do projects or experiments. No projects have been done after my joining.

Suresh,
Head teacher,
Gujarat

The course is lengthy, so we cannot give opportunity to each and every child to express themselves in the class when the class strength in the government school is 40:1 (student to teacher ratio).

The teachers in Telangana pointed out lack of funding and non-availability of lab materials as challenges while implementing project-based and activity-based learning. One teacher mentioned that the supplies in the lab are not replenished on time and grants being released at the end of the year is a major challenge. Economic inequality was cited as a hurdle in learning during COVID-19 times, when a smartphone was not available to all parents.

Lack of awareness of the best use of technology

The lack of depth in understanding how to use technology well was another gap that was explored. One teacher complained of having costly equipment lying around in school, but lacking knowledge on how to use it. Vanshika, a resource person from Gujarat, mentioned that expensive LG projectors were lying around in their packing, since no one had come in to install them, or teach teachers on usage and that she took the initiative to get it usable. She also said teachers use technology to punch in every day, update attendance, marks, activities in the class etc., but they do not go beyond using technology for these administrative tasks. Some teachers in interior areas mentioned a lack of internet coverage or intermittent connectivity as another issue. One teacher also mentioned that having access did not automatically mean sensible usage. He mentioned that when they went to homes to install the Diksha app, they found student smartphones flooded with Tik-Tok and Free Fire, which he deemed a bad use of technology.

Diversity of Students, language issues and contextualization

Government school teachers have to deal with students who may have migrated from other districts or even states. In many instances, teachers said that migrant students don't sufficiently understand the language used in the classroom. Migrant students may also have discontinuities in their schooling leading to gaps in their learning. Lastly, migrant students at times do not continue in the same school long enough for teachers to work on remedial learning.

Vanitha,
Teacher,
Telangana

Many of the children migrated to our village, they come from various places to work at the quarries and granite industries, sometimes from Bihar, Bengal and from other states. They speak only Hindi; we are facing a lot of problems with those children.

Rekha,
Teacher,
Telangana

There are certain gaps at primary level, quality is less, teachers are not concentrating on basics, and that is affecting the work at the higher level.

Migrant labour children who come in from different states face language and comprehension issues, especially with technical words being too heavy and unintelligible for children. This was highlighted by Sravan, a teacher in Kutch, Gujarat.

Children who speak Kutchi are confused with words solenoid and electricity,

Sravan felt that the curriculum should be more contextualized to people, culture, and the region:

When I talk about oxygen and carbon dioxide, they feel it is not something relevant to their lives, but if I will talk about dairy farming or hydroponics, they feel it is relevant and something that can solve their problems. The problems which are relevant to them- they find it interesting.

In NCERT textbooks, they learn about Sundarbans, which they will probably never visit in their life. They will not be able to see the impact of climate change there. But when they learn about the history of their own region, types of weather and landscapes in the past and what are the changes right now in a deeper sense, then they can realise the need to learn it, the need to be a problem solver and the need for awareness. NCERT textbook gives the idea about the whole country, but there is a lack of attention to the solution of regional problems.

Assessment Challenges

Nila,
Teacher,
Gujarat

The biggest reason why every new batch that is coming in the last two to three years is very bad is because the government has decided that no child will fail in one to eight standard. The thing to do is when the child is not examined he does not know what he does not know and the teacher has so much work that he does not even have time to take care of every child. The child keeps moving from one class to another and he doesn't even know how to do math and doesn't even read. 40% of students come under this category. Now when I expect from such children that they can do science experiments, it would be an exaggeration.

The implementation of Continuing and Comprehensive Evaluation (CCE) is not the focus of this paper, however, this observation shows that the pendulum swings from one extreme to another: from assessment as the raison d'etre for schools to not doing assessment at all, and a middle path that uses assessment to improve learning outcomes has to be found. Several teachers asked for a more practical assessment, rather than a pen-paper assessment.

Burden of syllabus, textbooks and marks

The need to focus on the syllabus, textbooks and marks is an issue. In the teacher survey, one question was: In order to develop students' scientific thinking the teacher should focus on a) building understanding b) syllabus completion c) give students challenging problems d) make students do experiments. No one chose b) as an answer. This shows that teachers do not believe that syllabus completion is a priority for developing a student's scientific thinking.

However, in interviews, the syllabus, textbooks and marks show up as quite central to the teachers' lives. A teacher in Telangana remarked:

...Sometimes children will talk about ghosts or the devil but I have no time to deal with all these things, especially in the math class. I always concentrate on academics, and scoring good marks.

What this shows is that there is a difference between what teachers believed to be good and what they actually practised. There is a considerable body of science education research about the relationship between teacher belief and teacher practice. Some studies (Cronin-Jones,1991; Haney & McArthur, 2002; Hashweh, 1996; Levitt, 2002) found that teacher beliefs are consistent with classroom practice, while others found that teacher beliefs do not necessarily influence classroom practice (Lederman, 1999). The context of teaching should also be considered because studies indicate that teacher practice is context-dependent.

Field interviews conducted as part of this study provide a picture of the context in which teachers are working. Vanshika, the resource person from Gujarat, said that due to lack of time or interest, teachers gave out answers directly, rather than allowing children to construct answers in their own words. She also cited paperwork and field-work as other reasons for teachers not having time to plan lessons properly, except when under observation. Nila, a teacher from Gujarat, complained that examinations and the related paperwork interrupted regular classwork, and that in the name of the test, the teachers and students are so bound that they cannot look outside the textbook.

Earlier studies focused on the Indian education scenario corroborated that the textbook holds a center-stage in classrooms (Vijaysimha, 2013, Aravamuthu, 2018). The gap between teachers' understanding about good pedagogy and what is actually practised in the classrooms has been pointed out by several studies (Nargund-Joshi, Vanashri & Park Rogers, Meredith & Akerson, Valarie, 2011; Vijaysimha, 2013; Nargund-Joshi, Vanashri & Park Rogers, Meredith & Bhagwate, Deepali, 2019).

Education resource persons in Gujarat opined that the NCERT syllabus was heavy on knowledge and that the Gujarat syllabus that was earlier developed by the Gujarat Council of Educational Research and Training (GCERT) had a greater focus on activities as compared to the NCERT syllabus that is now being followed in Gujarat. Another teacher, Ramnath, clearly spoke about how having flexibility in the curriculum and assessment can help individual students who are performing poorly in a conventional way.

A child may not be interested in learning all these subjects. If we give a computer to that kid, then he can remove all the parts and he can reset all the parts. His brain is having that idea of how an instrument can be set and assembled. Why can't we give training to such a type of student in this field? If we train that student in that field, he can come up. He may be able to improve his knowledge. He may be performing in his life in a better way. If we go on teaching from 1 to 10 classes through written examinations and giving failed certificates as proof that his brain is not getting used, he will not pass 10th class examination. If we give training in his interested area, and if he will be certified, that will be useful in his field.

It is pertinent to inquire into why teachers do not find ways to flexibly adapt the curriculum. Part of the reason could lie in the prevalent pedagogical culture. Clarke (2003) explored the impact of the reform process on teacher thinking and classroom practice in Karnataka, using both qualitative and quantitative methodologies. The study analysed the impact of four cultural constructs, which frame teaching and learning in India: holism as a shared worldview that encourages openness to regulation; the hierarchical structure as a regulative social framework; knowledge as discovered and attested collectively; and the 'sense of duty' that defines the role of the teacher (and student). The study concludes that both teachers' openness and resistance to reform are embedded in the cultural construction of teaching and learning. In such a pedagogical culture, a teacher would not easily make changes at the individual level unless there is a larger collective and formal mandate towards it. This means that curricular changes and assessment reform must be introduced in formal ways through higher-level functionaries embedded in the educational system. Collaborating organizations interested in bringing about the changes required for inculcating SMS would need to find ways to work closely with the public education system and get an official buy-in into the required changes.

In the survey, teacher's opinion about the science and math curriculum was elicited and the table below indicates their responses state-wise,

Regarding science syllabus (Teacher opinion)

Telangana	Odisha	Gujarat
45%	**75%**	**46%**
thought the science syllabus is vast and there is not enough time to explain everything well.	thought the science syllabus is vast and there is not enough time to explain everything well.	think the science syllabus is vast and there is not enough time to explain everything well

Regarding math (Teacher opinion)

Telangana	Odisha	Gujarat
32%	**10%**	**38%**
thought that math was difficult for children, 26% thought it should be made simple and 29% thought it was good	thought the math syllabus was good, 40% thought many children find math difficult, and 50% thought syllabus should be made simple)	think the math syllabus should be made simpler

Discrepancy between situations during training, and the pressures of the curriculum while working in the classroom were highlighted by a teacher: trainee teachers will teach one lesson a month, but teachers have to teach a lesson within 3 to 5 Periods.

The responses to the survey questions regarding training needs are given below:

What kind of training support would be useful to you? (Training needs)

Telangana	Odisha	Gujarat	Consolidated
79%	**90%**	**76%**	**81%**
want training on how to make science and math more interesting for students	want training on how to make science and math more interesting to students	want training in making science and math more interesting to children	wanted help in making math and science interesting

When a new syllabus is introduced what are your expectations? (Training needs)

Telangana	Odisha	Gujarat	Consolidated
58%	**65%**	**70%**	**49%**
thought a change in syllabus will mean you have to study it yourself.	think they have to study topics by themselves	want an orientation when a syllabus is changed, while 27 % think it will introduce new topics that you have to study yourself.	think that if a new syllabus is introduced, they will have to learn it themselves, while 40% think that there must be an orientation

Regarding having an interdisciplinary approach to teaching science, teachers acknowledged the difficulty in weaving different branches of science into one lesson. They felt they did not have the time to do this because the course is already lengthy, or there is a need to keep the strands separate due to curricular restrictions in high school, and because each strand needs rigorous treatment. While this should and can be done, very few teachers do this.

Thus, we see that there are formidable gaps in providing an in-depth STEM education due to the inequitable access to resources (material, technological and human), the diversity of students, and the embedded centrality of syllabus, exam, and textbooks in the school system. These have to be acknowledged and addressed systematically to move to the next level of STEM learning.

4.6 Teachers' understanding of STEM careers and career guidance

To the question of emerging STEM careers and associated career guidance provided by teachers, the teachers in both Gujarat and Telangana responded with a fair understanding and were more detailed in their response to career guidance compared to the cohort from Odisha. However, the number of teachers who responded with examples of new-age careers were low to medium across states. In Gujarat, 3 out of 8 teachers interviewed responded to the question of emerging STEM-related careers with specific examples while the rest of the interview cohort opined that training in STEM skills are useful for any career. The careers mentioned included AI, computer programming, development of electronics, Astronomy, astrophysics, physics, Engineering, Scientist.

When asked about career guidance, one of the teachers from Rajula City in Gujarat mentioned making maximum use of technology in class as possible and encouraging students good math and science to do projects and present their ideas. A few teachers expressed the need for vocational training given that not all students are interested in studies, and suggested that training such students in some skills which would make them job-ready and offer a stable livelihood has to be given importance. There was the mention of a "Career Nishta" training which the teachers received. This is a vocational skills-based training that is scheduled to commence from the next academic year. When asked about STEM career guidance for students, Balvant, a teacher of mathematics in a school from Ahmedabad, said:

They can choose any occupation but the point here is because of technology awareness they will be able to access more people and can give their best in any field. They will act smartly, they will know how they can get more output(in milk, crop, business etc) with the use of technology. We do not cultivate here but if technology is developed in this way then children will know how useful drip irrigation systems and hydroponic methods are. Here technology should be developed so children can also use technology for their livelihood and upgrade their own occupation.

Moving to Telangana, 3 out of 7 teachers interviewed responded with particular examples of new-age STEM careers while everyone agreed on the utility of STEM skills in any field according to students' interest. The careers they mentioned included AI, data analytics, ethical hacking, digital marketing, business technology, pharmacy-related careers, other science and technology-related careers especially software, hardware, mechanical, automobile, D-pharma and agriculture-related professions. Regarding the question of career guidance, the responses of four teachers were noticeable. One of the teachers reported guiding average and below-average students towards vocational training which would benefit them after class 10. A teacher from Kothagudem District of Telangana responded that he guided students to think of their future from class 11 or 12 and to explore more of the upcoming opportunities rather than pursue only engineering or medicine. Another teacher from the same district responded that they provided career guidance for students to pursue engineering and related diploma courses. According to her, children from low-income families have low aspirations. She said that their career aspirations are restricted to the professions or lives they see around them. The importance of vocational training and introducing students to STEM careers so that they become independent in life was emphasised. A teacher from Khammam district reported that they provided students with the guidance to start preparing for IIIT from class 7 onwards and provided an orientation to students about the emerging careers in software and hardware.

Finally, in Odisha, 8 out of the 13 teachers interviewed responded with examples of emerging STEM related careers and all except one respondent acknowledged the utility of STEM in all careers.. The careers mentioned included banking, engineering and software jobs, zoologist, wildlife biologist, microbiologist, network and computer administration, health and safety, Artificial Intelligence, digital marketing, geologist, scientist, mathematician and data science. The teachers in Odisha responded with generic statements related to career guidance such as encouraging the interests of students and providing associated guidance, with one teacher not having an understanding of STEM related careers or new-age careers nor providing career guidance to students.

While teachers listed STEM careers, they did not demonstrate an in-depth understanding of cutting-edge careers, nor did they provide pathways to students without the social capital and cultural capital needed for such careers. This is an actionable area for the education authorities. The interview question was an open ended, non-leading question about how teachers advised students about STEM careers. The interviewers recorded what was said by the teachers without specifically introducing any career field like ‘green jobs’. In this way, we can see that there is no awareness about the green job scenario that is fast emerging. None of the teachers mentioned green jobs and this is another area about which awareness needs to be developed among teachers.

4.7 Discussion

Teachers are quite conversant with the idea of scientific temper and could articulate what was needed for the scientific approach. On the other hand, the terms “STEM” and “STEM mindset” were not familiar to many of the teachers. By explicitly pointing to the similarities between the idea of the scientific temper and the STEM mindset, teachers could be encouraged to strengthen the pedagogical strategies common to inculcating scientific temper and STEM mindset.

The findings from this study indicate that teachers do not apply scientific understanding while discussing current issues like the pandemic. Teachers did not use terms like virus, disease transmission or droplet infection while talking about the pandemic and instead focused on some popular WhatsApp messages about immunity etc without critically analysing the statements and the evidence behind these.

The implication of these findings is that teachers need to be given opportunities to develop their own skills of scientific reasoning and apply concepts from the school curriculum to current issues and problems. They also need to develop their own capacities as critical thinkers who can examine various messages that are proliferating on different social media platforms.

Despite the teacher’s positive beliefs about the importance of developing scientific temper among students, there are gaps in students’ SMS. Discussion with teachers indicates that the current assessment practices do not specifically test for SMS. One key aspect of promoting SMS would therefore be developing ways of assessing SMS. To improve quality of teaching, another key to building SMS would be to help teachers develop technological pedagogical content knowledge (TPCK) oriented towards SMS. It is heartening to note from this study, that a majority of teachers are looking for ways to make science and math more interesting and this can be leveraged to provide training to teachers on pedagogy that will promote SMS.

In terms of pedagogical practices and effort for SMS, it needs to be kept in mind that the important skills are math, analytical thinking, programming, creativity, big data thinking, logical thinking, critical thinking, problem-solving, and communication; top attitudes are patience, perseverance, open-mindedness, and attention to detail. Projects, which are already part of school work could be reoriented to promote SMS.

To help teachers develop TPCK for SMS, it will first be necessary for teachers to be oriented about SMS and how it overlaps with the idea of scientific temper that is already familiar to them. Secondly, teachers would need to be explicitly made conversant with the skills and attitudes that are part of SMS.

In this section findings with regard to teacher capacities for inculcating SMS in terms of perceptions, pedagogy and problems were presented. The next section describes the findings regarding SMS and students.

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5

Parental Support for STEM education

Indian families tend to consider education as a key mobility strategy. There is a perception that educational achievement would lead to upward mobility. Families and students often strategize and think of possible ways to achieve their dreams and aspirations (Vincent and Menon, 2011).

"Crucial decisions regarding education are to be made at the secondary school level and these are family decisions in the Indian context. Family members decide whether or not to invest family resources in education, the individual child has hardly any control and the class they belong to plays a major role here. It is so, as it involves (substantial) investment of family resources in education (Mukhopadhyay and Seymour, 1994). In Our baseline study in states of Andhra Pradesh, Karnataka, and Telangana, we find that 48% of our 2743 learners have parents as a key influencer in their career decisions. Additionally Gautam (2015) notes that in the case of middle-class families, the subject choice is usually determined by the male member of the family, especially the fathers" (Sundararaman, p. 19, 2019).

The context of the families deeply influences how students view and relate to science. In terms of science education, parental support in choosing science stream in the upper secondary level, nurturing interest towards science, assistance in improving academic achievements in science and support in choosing science-related careers are considered effective support systems for students pursuing science (Halim et.al, 2018). A strong parental commitment to science education is required especially in the case of girls. As documented by Godbole and Ramaswamy (2008), most Indian women scientists in their autobiographies mention the immense support offered by their parents to pursue science (Sundararaman, 2019).

The way the girls engage in science and science-related activities 'is also a practice that is deeply grounded in the social practices and norms of the contexts in which girls live and grow in' (Barton & Brickhouse, 2006, p. 234). Families also play a crucial role in freeing the child as much as possible from family obligations (taking care of siblings, helping in chores) and providing support by assisting in homework, spending on tuitions, making resources available, motivating and encouraging them through visits to science museums and so on (Sundararaman, 2019). Working-class parents often do not specify a particular career or aspirations for their children (Wong, 2016), however, they view education and schooling positively and acknowledge their importance in a stable career.

The parents from Gujarat belonged to lower economic backgrounds with a majority being daily wage workers, carpenters or tailors. Seventy per cent of the survey participants were men and 60% had sons pursuing their secondary school education. Equal number parents ensured their willingness to educate their children until graduate, post-graduate and doctorate levels while 10% expressed willingness to educate their child up to the school level only. All the surveyed parents reported considering STEM education to be important as well as all were willing to financially support their ward's STEM education. Eighty per cent believed that it will lead to a prospective career for their children. However, apart from "scientist", "computer" jobs, the parents were not aware of emerging STEM jobs. To the question of whether there is a difference in STEM ability between boys and girls, the response was mixed, with an equal number of parents stating "no difference" and "maybe", while 20% reported "yes".

The cohort of parents interviewed from Odisha as well belonged to the rural background, with lower socio-economic capital and all educated up to the school level or uneducated. Ninety per cent of the interviewed parents were males and 80% had daughters, 30% had sons and 10% had sons and daughters each. Ninety per cent of the participants, that is all the male parents were farmers by occupation, while the only female parent was a carpenter. Fifty per cent of the parents reported their willingness to support their daughter's education till degree while only 20% of parents which included the only female parent expressed willingness to educate their daughter up till post-graduation. Here too, the parents were aware of engineering and medicine as the only STEM-related careers that their children could pursue.

In the case of Telangana, the parents surveyed had varying education levels ranging from matriculation, bachelor's in education to masters' degrees. Seventy-five per cent of the surveyed parents were males and 62.5% parents had daughters while 25% had sons. A large majority of the parents surveyed considered STEM as important and felt that pursuing the same would ensure prospective careers for their ward as well as considered the same as important to contribute towards society. Most parents were also willing to support their child's education with 50% willing to support their education until doctorate level.

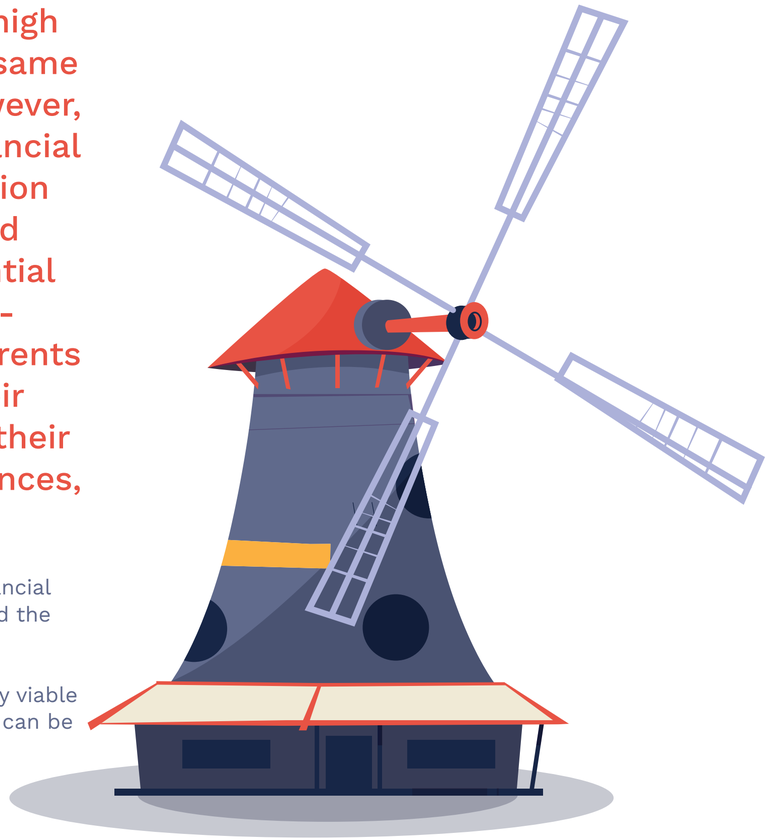
A majority believed that there are no differences in STEM abilities between males and females and found STEM careers suitable for girls. Sundararaman (2019) notes that the middle-class and educated parents seem better informed about the career choices and decide for their wards. This was reflective in the better knowledge of parents related to STEM-related careers choices for their children. The careers mentioned included agriculture, biotechnology, electronics, software, python, machine learning as well as a few respondents mentioned management and doing their own business as prospective careers choices. One respondent also mentioned that students trained in STEM shall take up any profession as well.

Overall, the willingness of parents to support science and mathematics-related careers for their children is high and there is a strong belief that the same will lead to prospective careers. However, when faced with the question of financial constraints, there is also the realisation that STEM education is expensive and this is also the root cause of differential treatment for girls and boys in STEM-related education. Although many parents expressed willingness to support their children's education irrespective of their gender, when faced with lack of finances, the choice goes to the boy mostly.

Mukhopadhay & Seymour (1994) note that if there are financial constraints, the money for education is spent on boys and the progress of the girls are also not monitored.

There is also the need to make STEM education financially viable to all sections. Scholarships to pursue science education can be increased. Information on scholarships that are available to students to pursue science education need to be prepared and made accessible to parents.

Additionally, it would also be beneficial to educate parents on the utility of STEM education and careers to solve real-life problems and challenges rather than being a prospective earning opportunity alone. This would ensure the organic growth of scientific temper, curiosity, creativity, and problem-solving in children and hence cater to the development of a STEM mindset.



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6

Inculcating the STEM Mindset - Expert perspectives

- Nature of science
- Process validity
- Growth-mindset
- Subject choices and subject scores
- Curriculum as a work-in-progress

In the earlier study (Vijaysimha, Sundararaman & Aravamuthu, 2021), we discussed the curriculum and using an old fable, asked the question: is the curriculum sabre-toothed? In other words, are we teaching a curriculum that is in step with the changing times? Industry experts had suggested teaching entrepreneurship, programming and coding, hardware and electronics, mental health and well-being and having arts in the curriculum. Pedagogically, they had suggested connecting learning to the real world, including hands-on practical work, using strategies to develop critical thinking, and developing conceptual understanding and problem-solving. How did this industry view map to the school system view?

Interviews with teachers show that while steps are being taken towards activity-based learning and building technological skills, there is still a gap between what the industy suggests and what is being done in schools. None of the teachers mentioned entrepreneurship or programming or coding as being actively taught in the school.

Interviews with curriculum developers who have been in the industry prior to working in education provided a crucial link between industry and academia. These experts straddle industry and academia and are able to understand the world of work and the greater ideas of science and STEM mindset (related to society and the world). These curriculum experts emphasized that “how you teach” is more important than “what you teach.”

Nature of science

Teachers need to deeply understand the nature of science and mathematics and also improve their teaching methods. For developing SMS it is important for students to learn about the nature of science and mathematics. However, teaching about the nature of scientific knowledge has been less than satisfactory, due to teachers' inadequate understanding about it (Lederman & Lederman, 2019).

The CEO of an Edu Tech Venture, Tarun, explained his understanding about the nature of science as follows:

Science works with potentially falsifiable sentences, so that is the first criteria for a sentence to be scientific. The first most important fundamental principle is potential falsifiability.

The second thing is: I should be willing to change upon finding contradictory evidence. My ego has no role to play in science.

The third thing is in science we have a peer review culture. I might believe that it is potentially falsifiable. But whether it is falsifiable either inductively or deductively, I am supposed to argue about it. What if my logic or argument is wrong? In a peer-review culture, somebody is vetting my logic so that I know I am going in the right direction. So a peer-review culture is very integral to science

The fourth important thing is replicability of results. I am supposed to specify the conditions and under those conditions, the experiment should be replicable. Now over here the humility aspect is very important.

The question of how to improve teachers' understanding of the nature of disciplines such as math and science and then help them develop appropriate pedagogy to teach this is a very crucial one and will need to be dealt with in detail separately through an extensive literature review since a lot of work has already happened in this area. This is beyond the scope of the current report.

Process validity

The National Focus group on Teaching of Science (NCERT, 2006) has written about the importance of process validation in science education in their position paper. “Process validity requires that the curriculum engage the learner in acquiring the methods and processes that lead to the generation and validation of scientific knowledge... Process validity is an important criterion since it helps in ‘learning to learn’, science.” What this means is that children need to be engaged in the process of scientific inquiry and not just taught scientific facts.

Guru (who had a successful career as an engineer and is now a master-teacher and curriculum developer) pointed out ways to develop better mathematical teaching by building understanding rather than focusing on procedures. He gave a vivid example of helping a child think about dissimilar fractions:

For example, if you give someone 2 dissimilar fractions and ask them to add - people will give LCM and give you the procedure to add. So, I was teaching this and I said, let’s take a banana and cut it in parts. Now, I asked, can you add one by two and one by three? He said something is wrong. He had a banana with 2 pieces, and a banana with 3 pieces and he couldn’t add them.

Then he realized they are not the same size. I cannot add them and say it is this much.He took the one with 2 pieces and then in each piece he made 3 pieces. He took the one with three pieces, and then for each, he made it into two pieces.

He is doing LCM. He figured it out ...

Guru says we need to encourage children to build models and solutions to problems:

A lot of the science work is about making models – when you launch a rocket, then you learn about the real aspects of science. Many of the ideas you can get only by creating things with your hand and making models. They cannot just learn by listening to what you are saying. To get everyone to learn science, they have to make some models.

There is this boy who used to do a lot of hands-on work. If you give him any theory, he will get bored. But it is amazing how much he thinks and makes with his hand. In the 8th standard, I was trying to teach them rotational motion. How many times will a top rotate per second? This is the measurement problem I posed. This boy came up with something already done. He removed a magnetic pickup from his bike, and he got a small magnet, he made a small drill on the wooden top and he inserted the magnet and to balance it he created something on the opposite side. Now you rotate the top, and you take the pickup near to that, whenever the magnet goes nearby, it picks up – the calculation is related to the circumference of the wheel. I taught him the math for converting circular motion to translatory motion. It was a rigorous engineering problem. Some children do that, and you should allow them to do it and develop confidence.

In response to the question: How do you show children how to make a hypothesis? Guru mentions using classroom space to help children to put forward a hypothesis, provide evidence and create focus on the ‘what is the truth’ rather than ‘who is winning’:

In a physical class, and even in an online class. I will give a question – somebody will answer, I think this will happen. Somebody else will say, this is what will happen. I say come forward – you put forward your hypothesis, and the second person will find loopholes...and then the first person, s/he will come forward, and s/he will argue for his/her idea and other children will be there, and suddenly, someone will say they support the first person’s argument. All this is done in a very nice manner. Gradually, they realize the argument is about what is the truth, not who will win.

In our previous report, we had noted that many professionals had stressed the importance of fact-checking and developing the ability to discern misinformation. (Vijayasimha, Sundararaman & Aravamuthu, 2021). Curriculum developer, Satya, who has had an earlier research career in NCBS, mentioned reading and discussions to encourage students to look for evidence, check for facts and develop a healthy scepticism:

Interviewer - Sometimes, especially in the TV debates they put forward contrasting views. So how could we encourage children to think about it rather than get……so something like should we get a vaccination for covid-19 and two different views are coming from two newspaper articles. Do we even present them with these contrasting views?

Satya - When we are reading news articles, there are definitely some reliable sources. How reliable they are is a second question but there is at least a point to start with. Go further again and we have to make sure that the source we read has some scientific evidence of what they are talking about. ...Sometimes when I don't know the answer, I don't try to tell them whatever I have in mind. I try to tell them that I don't know the exact facts about it so I will check it properly and come back to you. A lot of reading and discussion is something that might help them to develop this particular skill of getting the evidence and checking the facts and which we should believe and which we need to take up.

All the examples cited above again point to the issue of focusing on the process of acquiring scientific knowledge, as opposed to learning a gospel of facts.

Growth-mindset

The next important aspect is building a culture of exploration where failures are accepted. In the first part of the study, career professionals had emphasized attitudes associated with a growth mind-set[3] such as patience, perseverance, hard work, learning from failure and open-mindedness. Guru says that classroom practices like allowing children to scratch through their work, to put pen to paper, to not necessarily know beforehand what they have to do, help build this:

When I give them math or physics problems, I tell them that whoever makes the most scratches, gets the most marks. If you don't put pen to paper, it will not work. I tell them that when I go to a new place, and I want to know the area, I keep my phone at home, I go walking and get lost, and find the way home. After that, I never get lost. You have to go on the wrong path before you know it is the wrong path. Suddenly, their whole experience changes. They don't have to know beforehand what to do. Fundamentally, your failures should not be punished.

Interestingly, even in a largely pen and paper discipline like mathematics there is a need to encourage risk-taking. In this area too, girls are more risk-averse than boys, as indicated by a study (Sharma, 2015) and as corroborated by this study as well. By creating a classroom environment where it is safe to make mistakes, a lot more students can be facilitated to develop good mathematical thinking.

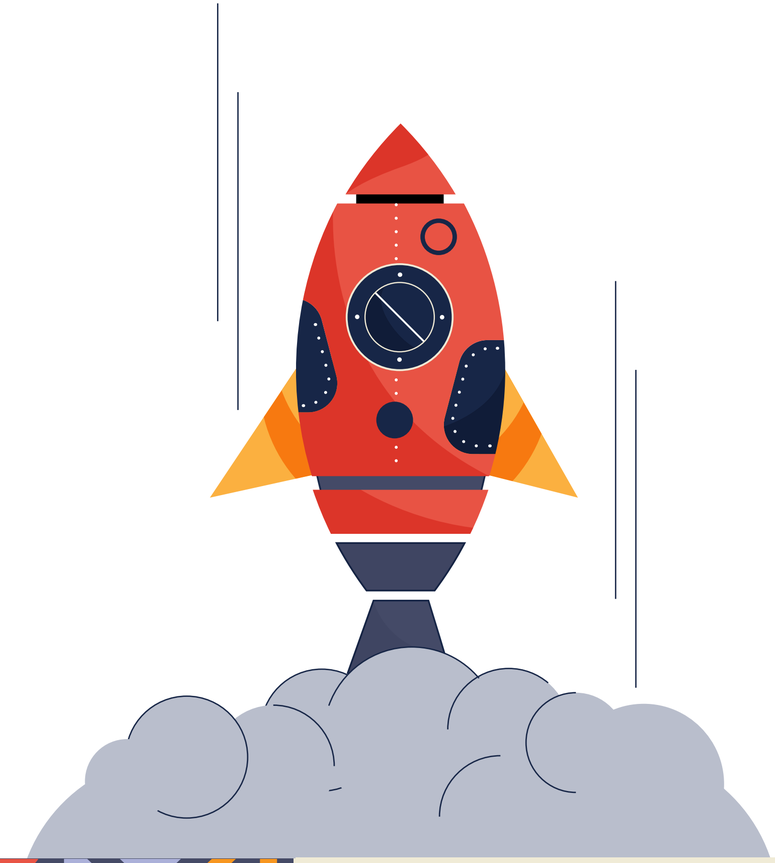
Subject choices and subject scores

There is often a link made with performance or scores in subjects to subjects chosen after class 12. Often students are coerced to study engineering by parents without much consideration for interest and whether the students' have a STEM mindset. Similarly, if students who tinker or create do not score well in exams, they might miss the opportunity to pursue sciences or professional courses.

Satya, Curriculum Developer, noted,

Sometimes I feel that kids get onto engineering, it is because they got the highest marks and from the advice that if you do engineering, you will earn better. Are they really liking a career in engineering? So, if we know what it means through real-life examples by building a small model or computer coding, a project would be good.

Some start-up companies could help in this, starting from the 9th standard.



Curriculum as a work-in-progress

Sathya, Curriculum Developer

We have to design a dynamic curriculum where we can make some necessary additions. We have to develop the curriculum as a continuous process taking into consideration whatever is happening currently. This type of curriculum will help to understand the kind of development we are moving with. Every topic must have something like the current news incorporated every year or every once in two years so that students will be aware of every new thing that is coming up in the particular topic. It will be very interesting for the teachers to teach as well as the students to learn.

As seen in the first part of this study, professionals identified skills such as design thinking and critical thinking, attitudes such as attention to detail, curiosity, risk-taking as well as growth mindsets which include patience, perseverance and hard work (Vijaysimha, Sundararaman & Aravamuthu, 2021). The experts listed here also point out the gaps of the prevailing system which does not focus on developing a scientific temper that encourages exploration and embraces failure but is focused on choosing science as a means to a lucrative career. Dialogue between industry and academia to find and bridge gaps in the curriculum would help to make and keep student learning relevant. A view of curriculum as a work-in-progress would help to address issues of being globally relevant while understanding local issues, as suggested by the teacher from Kutch.

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7 Conclusions and Recommendations

By and large, science and math teachers focus on helping students learn facts and procedures without explicitly focusing on cultivating the scientific temper or SMS. The Position Paper on Science Teaching (NCERT, 2006) while discussing the aims of science education mentions knowing ... "the fact and principles of science and its application.." as the first of eight aims, while cultivating the scientific temper is mentioned as the last one. It is not surprising, that the emphases of curricula and examinations are on factual understanding and there is no explicit attention is given to how scientific temper or SMS may be cultivated or assessed. In this context it is worth noting that under the KAMP initiative of CSIR-NISTADS[2], a National Assessment for Scientific Temperament and Aptitude (NASTA) has been designed and developed to identify and promote scientific temper among students. This is one of the primary initiatives under KAMP. It is an Attribute-Based assessment against only Subject Based Assessment. NASTA provides educators, policymakers, and parents with a common measure of student achievement. A similar effort could be collaboratively undertaken to develop curriculum and assessment for SMS.

However, it is not enough to develop appropriate curriculum and assessment for inculcating SMS. A strong and concerted effort to orient teachers towards SMS and develop their capacity for inculcating this among students is required.

In the first part of the study (Vijaysimha, Sundararaman & Aravamuthu, 2021), working professionals had indicated that the pedagogy should focus on providing more hands-on experiences and project-based learning to develop the various skills that constitute SMS. The findings from the second part of the study show that while teachers are reporting that their pedagogy includes activities and projects to some extent, this is not translating into development of SMS among students. The students do not seem to reason, analyse and have a deeper conceptual understanding. They appear to lack a scientific mindset and often teachers do not encourage such a thinking process. Bardapurkar (2020) has argued that "scientific temper can rarely flourish when science teaching emphasizes procedural-prediction and ignores the development of explanatory understanding."

This implies that performing experiments and activities without a rigorous process of analysing observations and developing generalizable explanations will not lead to the development of a robust SMS. Teachers themselves need to develop skills of scientific reasoning and develop pedagogical strategies to promote such reasoning among students. This means that teachers should a) be provided with opportunities to explore phenomena and engage in scientific reasoning and b) supported in the form of curricular material to help students do the same. In other words, teachers should be helped to develop their technological pedagogical content knowledge (TPCK) for SMS and also to make science and math classes more interesting. As an earlier section of this report has mentioned, a majority of teachers expressed a desire to make science and math teaching more interesting and wanted training in this.

The findings of our study indicate that many teachers still have gendered views about STEM disciplines and careers and often assume that certain subjects and (Biology for example) certain careers (Beautician as opposed to Mechanical engineering) for example are more suited to girls than boys. Teachers also lack awareness that girls have less access to technology and devices as compared to boys.

We have earlier discussed that tinkering and risk-taking are important aspects of SMS. In our previous report, we had a director of engineering in chip design speaking about the need for women to be more comfortable taking risks and failing rather than conforming to a so-called perfect version of themselves that could sabotage their careers. The second part of our study appears to confirm that girls are more likely to be 'model students' and are less likely than boys to tinker with stuff or risk trying out new ideas. This form of gender socialization seems to be tacitly encouraged by teachers. Gender sensitization and awareness training should form part of both pre-service and in-service teacher training to correct for these covert biases that may hold girls back from succeeding in STEM as much as boys. Teachers need to encourage girls to make mistakes, be bold and try out new things. Effective ways by which teachers can do this need to be carefully researched and then widely shared.

With regards to teachers' capacity for guiding students towards STEM, there was quite a lot of variation across the three study states. This partly may be due to the broad demographic and socio-economic differences between the states. Broadly, there needs to be a greater awareness among teachers, especially from Odisha, about emerging careers requiring SMS and also the importance of SMS in a wide array of careers. The study showed that teachers did not have specific and differentiated strategies for guiding various students towards STEM careers. These findings are also limited by the study design which did not allow us to explore teachers' capacities for career guidance in a more nuanced way.

The first part of this two-part study emphasized the need for students to discover their individual interest areas and go deep into them. Many successful career professionals were able to identify their interest early and managed to stay with it, while others made shifts and picked up new skills and knowledge while navigating careers. From the second part of the study, it appears that teachers did not have a nuanced understanding of career trajectories and thus were not able to go beyond broadly pointing out some careers to students. One of the respondents in the first study had spoken about the importance of professional career guidance being made available to high school students. The second part of the study supports this conclusion and it appears that high school science and math teachers are insufficiently equipped to provide sound career guidance. This combined with chronic teacher shortages in government schools implies that it may be unrealistic to expect subject teachers to provide sound career advice to students.

Finally, when it comes to changing teacher practices, it has been pointed out by earlier studies (notably, Clarke, 2003) that the pedagogical culture in India encourages teachers to accept regulation from a hierarchical structure and also that knowledge needs to be collectively attested. This implies that expecting individual teachers to make radical changes is unrealistic and that is a good way to bring about lasting changes is to involve educational officials and resource persons and thus create a system-wide impetus for change.

7.1 Recommendations for teacher capacity building

- Advocate for SMS at systemic level so that there is a buy-in at multiple levels in the system to support teachers
- Provide explicit awareness materials/programs for teachers on scientific temper and STEM mindset and their relevance in the fast-changing world of work
- Build SMS in teachers by improving teacher's skills of scientific reasoning and application of STEM concepts to current issues and problems
- Develop teachers' TPCK for inculcating STEM mindset among students and also for making STEM learning more interesting
- Support teachers with classroom material and pedagogic strategies for developing SMS and growth mindsets in students
- Help teachers to make science and math classes interesting for all students, and to become aware of math-phobia in self and children
- Gender sensitization and awareness training regarding the inequitable access to technology by girls needs to be given to teachers
- Expose teachers to career professionals who speak about their own experiences of STEM learning and the relevance of SMS in their work through Role Model interactions and videos

Orienting curriculum and assessment for SMS

Our previous report had indicated that in order to remain relevant, the following areas need to be strengthened in the existing curriculum

- Moving from STEM to STEAM by integrating visual and performing arts
- Communication
- Problem solving
- Critical thinking
- Statistical thinking

The following areas need to find a place in the curriculum

- Systems thinking
- Interdisciplinary skills
- Coding and programming at the school level
- Electronics at the school level
- Self-understanding
- Social skills
- Ethics
- Entrepreneurship

The NEP 2020 speaks of the importance of holistic education, and if this idea is appropriately utilized while framing the new National Curriculum Framework there is scope for building a STEAM curriculum. Needless to say, that unless accompanied by appropriate teacher orientation and training, the curriculum may not be implemented effectively.

From our previous study, it emerged that SMS is required in almost all career fields - from media and theatre to research in pure sciences. However, our study has found several lacunae in the curriculum that need to be resolved so that all students in general and girls, in particular can develop STEM mindsets and pursue careers in fields that require this mindset.

Our findings indicate that interdisciplinary and engineering skills do not form part of the existing school curriculum During the course of this research, it was pointed out by a teacher as well as a curriculum developer that the current curriculum and assessment does not allow students with a strong engineering bent of mind to experience success. (See interview quotes by Ramnath and Guru in previous sections of this report). Muralidharan,(2019) has suggested frequent, granular assessments that let students, teachers, parents and employers gauge a person's absolute level of mastery of any relevant skills. This idea is similar to that of the continuous and comprehensive evaluation (CCE) suggested in the position paper on Curriculum, Syllabus and Textbooks (NCERT, 2006). In order to promote tinkering and engineering skills, vocational training can be integrated with the general academic curriculum (Muralidharan, 2019).

When it comes to preparing students for careers by helping them develop SMS, both parts of our research study have found that the curriculum does not explicitly address this aspect. Experts in various fields who were interviewed during the first part of our research had pointed out the importance of the following aspects when it came to career selections:

7.2 Curriculum suggestions to weave in and build STEM mindset and link them to career opportunities

- Develop a curriculum specifically aimed at SMS. This should include content about the nature of scientific and mathematical knowledge. This can be integrated with the general science and math curriculum instead of being stand-alone
- Assessment for the skills and attitudes that form SMS should be designed based on research. If need be further research could be carried out in this direction.
- Assessment should be flexible so that students who have hands-on and technical skills get recognized
- Modules for coding and data analysis should be developed to allow students to experience the power of technology
- A radical curriculum redesign with STEAM modules replacing the present science and math units could be designed and tested as a pilot
- Vocational training could be integrated with the general academic curriculum to provide opportunities for design thinking, tinkering, problem solving and entrepreneurship. This must also be reflected in student evaluation reports
- Projects, which are already part of school work could be reoriented to promote SMS and evaluated to support SMS as well as GMS (growth mindset)
- Modules on understanding the self, social skills and ethics should be included in the curriculum.

7.3 Support parents to support their daughters to build a STEM career pathway

- Parents need to be informed on STEM pathways and career choices and involved in career counselling
- Develop resources (podcasts and videos) directed towards educating parents on STEM careers and women achievers
- Support parents in accessing the scholarships for STEM programs and provide information on various STEM internships and scholarships
- Organizing STEM fairs where parents can see their children be curious, explore, experiment and communicate

Systemic changes are important, and the curricular, pedagogic and assessment reforms need to go hand in hand with the systemic reforms. Funding for education, and interdisciplinary STEM programs needs to increase. Most importantly, sustaining the programs, with intellectual capital and infrastructure, would help to move the needle on STEM capabilities.

7.4 Suggestions for funders on programs and collab-orations needed to build STEM mindsets.

- Facilitate and sustain role model interactions (meet a data security engineer, data scientist, robotics engineer, plant breeder etc. day) to provide exposure to different STEM occupations, since the conventional schools do not have easy access to industry expertise.
- Offer spaces for visits to labs, short internships for school students
- Work with scientific institutions, R & D labs, and schools and government functionaries to support STEM in schools and bring about systemic changes.
- Build linkages between schools, academia and industry to ensure that students are building STEM mindsets for a good future.
- Support teacher development programs that focu on building SMS
- Support research/development of niche STEM/vocational training spaces
- Work with schools and colleges to research and develop assessments of STEM mindsets.

7.5 Need for further research

Considerable work related to developing scientific temper and scientific literacy has already taken place and a rigorous literature review for the purposes of building linkages with SMS development needs to be done. Being modest in scope, the present study has indicated the need for further research along the following lines:

1. Develop and validate curriculum and assessment of STEM mindsets. This can form the basis of research into factors affecting student outcomes

2. Extent of the different facets of growth mindset among students and how these could be promoted.

3. How project-based learning can be better conducted in order to develop SMS

4. Extent to which teachers are inculcating the knowledge, skills and attitudes required for green jobs

5. The role of teachers in supporting a growth mindset.

Further research will be needed to probe into the reasons for the state-wise variations in use of technology for teaching. The socio-economic background of students is found to have a strong influence on students' academic performance in addition to educational support and this calls for working towards educational equity. Building equitable and inclusive education is the need of the hour as the issue of access and participation in STEM programs can be addressed to a great extent. Equity in education would address the underrepresentation of girls and particular social groups in STEM.

It is critical to conduct thoughtful research on how to encourage greater participation by diverse learners in STEM courses.

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Appendix

Are you familiar with the term STEM? In your understanding?

Telangana	Gujarat	Odisha	Overall
48%	40%	60%	40%
considered STEM as an acronym	said that STEM is an acronym for science, technology, engineering and math	60% said STEM is integrated teaching of math, science, tech and engineering	said STEM was an acronym or an integrated way of teaching. 21% said it was not clear

Science and math are useful for which students

Telangana	Gujarat	Odisha	Overall
100%	92%	100%	97%
believe all students benefit from science and math learning	teachers said that science and math is for all students	agreed that all students need science and math	thought that science and math are useful for all students

What is the importance of teaching science and math?

Telangana	Gujarat	Odisha	Overall
97%	85%	75%	87%
believe the importance of teaching science and math is to develop a scientific mindset	said that the importance of science and math teaching is to help children develop a scientific mindset	said STEM is integrated teaching of math, science, tech and engineering	said that science and math was about developing a scientific mindset

Which of the following jobs need science and math skills?

Telangana	Gujarat	Odisha	Overall
81%	80%	75%	79%
believe that all jobs need science and math, while 19% believe it is for engineering and math students	said that all jobs need STEM	said all jobs need science and math skills	believe that science and math skills are needed for all jobs

What is the most important skill that you learnt by studying science/math?

Telangana	Gujarat	Odisha	Overall
74%	79%	45%	68%
believe the most important skill by studying science and math is thinking logically	said that the most important skill by learning math and science is logical thinking	saith the most important skill is thinking logically, 25% said most important skill is looking for evidence, and 25% said the most important skill is factual knowledge	thought that science and math was about thinking logically

Those who are successful in Science, Technology, Engineering, Math need

Telangana	Gujarat	Odisha	Overall
82%	77%	65%	76%
believe that logical and analytical thinking is needed for success in STEM	of teachers surveyed think that those who are successful in science and math need analytical and logical thinking	thought that logical and analytical thinking is needed for success in STEM	believe that those who are successful in STEM need logical and analytical thinking

To be good at STEM student needs to

Telangana	Gujarat	Odisha	Overall
97%	**73%**	**75%**	**83%**
believe that to be good at STEM a student needs to apply knowledge to real-life situations	of teachers think that a good STEM student applies knowledge to real-life situations, and 15 per cent think they need to keep trying	felt that a student good in STEM needs to apply knowledge to real-life situations	believe that to be good in STEM students needs to apply knowledge to real-life situations

Learning about computers should enable students to

Telangana	Gujarat	Odisha	Overall
77%	**42%**	**55%**	**48%**
believe that learning about computers should enable students to be empowered	said that the most important skill by learning math and science is logical thinking	felt that learning about computers should enable students to understand programming and electronics,20% said it is to use apps and share information, 25% said it is to become empowered	believe that learning about computers enables students to be empowered, while 27% believe that it should enable students to learn about programming and electronics

In order to develop students' scientific thinking teachers should

Telangana	Gujarat	Odisha	Overall
55%	**32%**		**49%**
thought that teachers should focus on making students do experiments, while 29% felt they should give students challenging problems	felt they should make students do experiments, while 31% thought they should focus on building understanding, and 31% thought they should focus on giving students challenging problems	To develop scientific thinking, at least 55% thought that a teacher should make students do experiments, 25% thought they should give students challenging problems, and 20% thought they should focus on building understanding	believe that to develop students' scientific thinking a teacher should make them do experiments

Science and math should be taught

Telangana	Gujarat	Odisha	Overall
71%	**38.5%**	**30%**	**49%**
thought science and math should be taught with hands-on activities, while 29% thought it should be taught by teaching children to observe and ask questions	thought that science and math should be taught through hands on activities, and 35% thought that math and science should be taught by teaching children to observe and ask questions	thought that science and math should be taught in an easy way, while 40% thought that physics, chemistry and bio should be taught separately and 30% thought it should be taught through hands-on activities	believe that science and math must be taught through hands on activities

In science and math classes, children

Telangana	Gujarat	Odisha	Overall
55%	**42%**	**55%**	**47%**
thought that children should be taught to explain what they think, and 45% thought children should be allowed to talk and write using their own words	of teachers thought that in science and math classes, children should be allowed to talk and write using their own words and 35% thought that children should explain what they think	thought that children should be allowed to talk and write using their own words, 20% thought that children should explain what they think and 15% thought they should be thorough with the book	believe that in science and math classes, children should be allowed to talk and write using their own words, and should explain what they think

Teachers can prepare students for the future by

Telangana	Gujarat	Odisha	Overall
100%	**92%**	**85%**	**94%**
thought that teachers can prepare students for the future by making them think independently	of Teachers think they can prepare students for STEM careers by helping them think independently	felt that teachers prepare students for the future by making them think independently	believe that children can be prepared for the future by making them think independently

Nowadays computers are used in all types of work so children should

Telangana	Gujarat	Odisha	Overall
61%	**54%**	**45%**	**34%**
thought that children should learn basic electronics	thought children should learn about apps in school, and 35 per cent thought that they should learn basic electronics	thought that children should learn to learn about different apps in school and 40% thought children should learn basic electronics	thought that children should learn about different apps in school, and 47% believe they should learn basic electronics

It is very important for students of secondary school to

Telangana	Gujarat	Odisha	Overall
50%	**50%**	**25%**	**43%**
thought that children should learn to do data analysis by collecting and analysing data themselves and 47% thought that they need to write problems based on their own experience	thought that children should do data analysis by collecting and analysing data themselves	thought they should be able to do data analysis by collecting and analysing data themselves, 20% thought they should learn to do textbook problems, 30% thought that children should learn to write problems based on their own experience, and 25% thought that they should learn to apply formulas correctly	believe children must do data analysis by collecting data and analyzing themselves, and 36% believe they should write problems based on their own experience

Continuous increase in usage of natural resources is leading to many problems like pollution and climate change. This means that new jobs will emerge that require

Telangana	Gujarat	Odisha	Overall
90%	**76.9%**	**90%**	**86%**
chose all options	chose all options	chose all options	chose all of the above (ecology understanding, interdisciplinary thinking, and ethics)

When it comes to doing well in Math

Telangana	Gujarat	Odisha	Overall
84%	**80%**	**100%**	**79%**
believe that all can do well in math	of teachers think all students can do well in math, 7.7% think boys can do better, and 11.5% think girls can do better	of teachers felt that all can do well in math	When it comes to doing well in Math, 87% think all can do well

In the case of the following subjects say whether girls or boys have more aptitude [Physics]

Telangana	Gujarat	Odisha	Overall
35%	**50%**	**42%**	**42%**
believe boys have more aptitude for physics	of teachers think boys do better than girls in Physics	think Boys do better in Physics	think that boys do better in Physics

In the case of the following subjects say whether girls or boys have more aptitude [Chemistry]

Telangana	Gujarat	Odisha	Overall
13%	**65%**	**80%**	**75%**
believe that girls have more aptitude than boys for chem	of teachers think girls do better than boys in Biology	think both can do well in Chemistry	think both can do well in Chemistry

In the case of the following subjects say whether girls or boys have more aptitude [Biology]

Telangana	Gujarat	Odisha	Overall
39%	**77%**	**26%**	**49%**
believe that girls have more aptitude for bio than boys	of teachers think all can do well in Chemistry	think girls do better in Biology	think girls do better in Bio

In the case of higher studies are some branches suited to a particular gender? If yes give examples

Telangana

NDA is for boys, said one teacher, Mechanical engineering is only for boys, said 2 teachers

Gujarat

Fashion designing, jewellery, Home science, Arts, B.Ed. for girls, Mechanical engineering for boys

Odisha

B.A. in Arts for girls by one, many ‘no’s and not answered

Overall

Teachers highlighted some areas as better for girls - ranging from B.Ed., fashion designing, jewellery making, home science, and a NO for mechanical engineering for girls. No such branches were found to be appropriate for boys

In science class how do you conduct experiments?

Telangana

90%

said they allow children to do experiments

Gujarat

53%

per cent say they allow children to do experiments, 34% say they do the experiments and show the children

Odisha

60%

thought children should be allowed to do experiments

Overall

70%

say they allow children to do experiments, while 21 % do experiments to show children

When it comes to technical skills

Telangana

84%

believe that all have equal technical skills

Gujarat

80%

of teachers think all students have technical skills, equally

Odisha

95%

thought both are equally able, while 5% thought men are better

Overall

10%

thought boys are better at technical skills

As a teacher,

Telangana

90%

said they are confident to do experiments

Gujarat

88%

are confident about doing experiments

Odisha

60%

As a teacher 60% are confident, but 30% want help to do experiments

Overall

82%

were confident about performing experiments

When it comes to handling people

Telangana

58%

believe that all have equal people skills

Gujarat

30%

believe women are better than men when it comes to handling people, and 50% say both are the same

Odisha

100%

thought both are equally able

Overall

26%

thought girls are better at handling people

The science syllabus

Telangana

45%

thought the science syllabus is vast and there is not enough time to explain everything well

Gujarat

46%

think the science syllabus is vast and there is not enough time to explain everything well

Odisha

75%

thought the science syllabus is appropriate

Overall

48%

thought the science syllabus was appropriate, while nearly another 40% thought that the syllabus was vast and there was not enough time to explain everything

Regarding math

Telangana	Gujarat	Odisha	Overall
32%	**38%**	**10%**	**31%**
thought that math was difficult for children, 26% thought it should be made simple and 29% thought it was good	think the math syllabus should be made simpler	but only 10% thought the math syllabus was good (40% thought many children find math difficult, and 50% thought the syllabus should be made simple)	thought that many children find math difficult, 36% thought the syllabus should be made simple, and 25% thought it was good

While teaching math

Telangana	Gujarat	Odisha	Overall
23%	**69.2%**	**80%**	**70%**
thought it is difficult to relate math to real situations, while 65% thought that children should be allowed to find different ways to solve problems	think that children should be allowed to find different ways to solve problems.	thought that children should be allowed to find different ways of solving a problem	thought that in math children should be allowed to find different ways to solve problems, but 16% thought that it was difficult to relate math to real situations

What kind of training support would be useful to you?

Telangana	Gujarat	Odisha	Overall
79%	**76%**	**90%**	**81%**
want training on how to make science and math more interesting for students	want training in making science and math more interesting to children	want training on how to make science and math more interesting to students	wanted help in making math and science interesting

How often do you use computers/mobile phones in your teaching:

Telangana	Gujarat	Odisha	Overall
61%	**77%**	**55%**	**60%**
use computers or mobiles once or week or more.26% use it once a month or more. 13% do not use it at all	use computers/ mobile phones in teaching once a week or more, 23% use them once a month or more, 0% do not use it at all	does not use computers/ mobile phones in their teaching at all, 10% use it once a month or more, and 35% use it once a week or more	said they use mobiles and computers once a week or more, but 11 of 20 teachers in Orissa say they never use it at all

Regarding online classes, what is your opinion?

Telangana	Gujarat	Odisha	Overall
39%	**50%**	**55%**	**47%**
think it cannot reach children and 39% think it is one-way teaching	think it cannot reach all children, and 46% think it is one way of teaching	think that it cannot reach all children and 30% think it is one-way teaching	thought online classes do not reach all children, but data from Gujarat is compromised because the last option was misread

When a new syllabus is introduced, what are your expectations?

Telangana	Gujarat	Odisha	Overall
58%	**70%**	**65%**	**49%**
thought a change in syllabus will mean you have to study it yourself	want an orientation when a syllabus is changed, while 27 % think it will introduce new topics that you have to study yourself	think they have to study topics by themselves	believe that if a new syllabus is introduced, they will have to learn it themselves, while 40% believe that there must be an orientation

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References

1. TPCK - A framework originally conceptualized by Mishra and Koehler (2006) ; TPCK stands for Technological, Pedagogical, and Content Knowledge. Each element of TPCK represents foundational elements of a teacher's expertise. Working backwards, a teacher must first be an expert in a content area of the learning experience. Next, they must possess knowledge concerning how students might best connect with curriculum content, or pedagogy. Finally, a teacher must possess knowledge related to the use of the technological tools themselves.

2. CSIR - NISTADS: CSIR-National Institute of Science, Technology and Development Studies, New Delhi is devoted to a study of various aspects of interaction among science, society and state and exploring continuously the interface between Science, Technology and Society. NISTADS is one of the 38 institutes/ laboratories of the Government of India's Council of Scientific and Industrial Research (CSIR), New Delhi.

3. Growth Mindset: "In a growth mindset, people believe that their most basic abilities can be developed through dedication and hard work—brains and talent are just the starting point. This view creates a love of learning and a resilience that is essential for great accomplishment. (Dweck, 2015).

4. HDI: Human Development Index is a composite index measure to measure key dimensions in human development.

5. Names of participants have been changed to protect their identity.

- Agarwaal, Kapur, & Tognatta. (2012). The Skills They Want: Aspirations of Students in Emerging India. CASI working paper series [serial online] 2012; Available from https://casi.sas.upenn.edu/casiworkingpaper/aggarwalkapurtognatta
- Aggarwal, A. (2020). How COVID-19 fuels digital gender divide, IT for Change https://itforchange.net/covid-19-fuels-digital-gender-divide-FES-in-asia
- Aravamuthu, K. & Vijaysimha, I. (2018). Impact of teacher classroom strategies on student motivation towards science. (Unpublished)
- Bardapurkar, A. (2020), Teaching Scientific Temper, Resonance, Volume 25, Issue 10, October 2020, pp 1399-1405.
- Barton, A., & Brickhouse, N. W. (2006). Engaging Girls in Science, in C. Skelton, B. Francis & L.Smulyan (eds.): Handbook of Gender and Education, Thousand Oaks, CA: Sage. pp. 221-235.
- Brussevich, Mariya & Dabla-Norris, Era & Kamunge, Christine & Karnane, Pooja & Khalid, Salma & Kochhar, Kalpana. (2018). Gender, Technology, and the Future of Work. Staff Discussion Notes. 18. 1. 10.5089/9781484379769.006.
- Clarke, P (2003) Culture and Classroom Reform: The case of the District Primary Education Project, India, Comparative Education, 39:1, 27-44, DOI: 10.1080/03050060302562
- Construction of the Subnational human Development index and SUBNATIONAL Gender Development Index. (2018). Retrieved from https://globaldatalab.org/shdi/about/
- Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. Journal of Research in Science Teaching, 28(3), 235-250
- Department, P. (2020, October 16). India - gross enrolment ratio in Gujarat by Gender 2018. Retrieved from https://www.statista.com/statistics/939210/india-gross-enrolment-ratio-of-students-from-first-to-eight-grade-in-gujarat-by-gender/#:~:text=The%20total%20gross%20enrolment%20ratio,almost%2097%20percent%20that%20year.
- Department of school and mass Education government of Odisha. (n.d.). Retrieved from https://sme.odisha.gov.in/
- Executive Summary. (n.d.). Retrieved from https://censusindia.gov.in/2011census/PCA/PCA_Highlights/pca_highlights_file/Odisha/Executive_Summary.pdf
- Haney, J. J., & McArthur, J. (2002). Four case studies of prospective science teachers' beliefs concerning constructivist teaching practices. Science Education, 86, 783-802.
- Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching.Journal of Research in Science Teaching, 33(1), 47-63.
- Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. Journal of Research in Science Teaching, 36(8), 916-929.
- Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. Science Education, 86(1), 1-22.
- Gautam, M. (2015). Gender, Subject Choice and Higher Education in India: Exploring 'Choices' and 'Constraints' of Women Students. Contemporary Education Dialogue. 12(1), pp.31–58.
- Gilbertson, A. (2014). 'Mugging up' versus 'Exposure': International schools and social mobility in Hyderabad, India. Ethnography and Education, 9(2), pp.210–223.
- Godbole, R., & Ramaswamy, R. (2008). Lilavati's Daughters. The Women Scientists of India. Indian Academy of Sciences.
- Gujarat population 2011 - 2021. (n.d.). Retrieved from https://www.census2011.co.in/census/state/gujarat.html
- Halim, L., Rahman, N., Zamri, R., & Mohtar, L. (2017, June 10). The roles of parents in cultivating children's interest towards science learning and careers. Retrieved from https://www.sciencedirect.com/science/article/pii/S2452315116301825
- Jain, S. (2020, September 11). STEM and the digital economy for women. Retrieved from https://www.orfonline.org/expert-speak/stem-and-the-digital-economy-for-women/
- Kamat, S. (2011). Neoliberalism, Urbanism and the Education Economy: Producing Hyderabad as a Global City. Discourse Studies in the Cultural Politics of Education, 32(2), pp.187–202.
- K, G. (2020, August 4). Education in Gujarat – Check Primary, Secondary & Higher Education | Schools, Colleges & Universities. Retrieved from https://www.embibe.com/exams/education-in-gujarat/
- Lederman, N. G. (1992). Students' and Teachers' Conceptions about the Nature of Science: A Review of the Research. Journal of Research in Science Teaching, 29, pp.331–359.
- Lederman, N.G., Lederman, J.S (2019).. Teaching and learning the nature of scientific knowledge: Is it Déjà vu all over again?. Disciplinary and Interdisciplinary Science Education Research, 1:6 https://doi.org/10.1186/s43031-019-0002-0
- MacLeod, J. (2009). Ain't no Makin' it: Aspirations and Attainment in a Low-Income Neighborhood. Boulder, Colo: Westview.
- M. (2019). All India Survey on Higher Education (AISHE). Retrieved from http://aishe.nic.in/aishe/viewDocument.action?documentId=262
- Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A new framework for teacher knowledge. Teachers College Record 108 (6), 1017-1054.
- Mukhopadhyay, C., & Seymour, S. (1994). Family Structure and Indian Women's Participation in Science and Engineering, in C. Mukhopadhyay and S. Seymour (eds.): Women, Education, and Family Structure in India, Colorado: Westview Press, pp. 1-33.
- Mukhopadhyay, C., & Seymour, S. (1994). Family Structure and Indian Women's Participation in Science and Engineering, in C. Mukhopadhyay and S. Seymour (eds.): Women, Education, and Family Structure in India, Colorado: Westview Press, pp. 1-33.
- Muralidharan, K (2019) "Reforming the Indian School Education System" in What the Economy Needs Now, edited by Abhijit Banerjee, Gita Gopinath, Raghuram Rajan, and Mihir Sharma, Juggernaut.

- Muralidharan, K., & Sundararaman, V. (2011).Teacher performance pay: Experimental evidence from India. Journal of political Economy, 119(1), 39-77.
- Muralidharan, podcast (https://seenunseen.in/episodes/2020/8/9/episode-185-fixing-indian-education/)
- Murphy (2019). What STEM mindset is... and why everyone should have it. Connected Science Learning https://www.nsta.org/connected-science-learning/connected-science-learning-october-december-2019/what-stem-mindset-and
- Nargund-Joshi, Vanashri & Park Rogers, Meredith & Akerson, Valarie. (2011). Exploring Indian Secondary Teachers' Orientations and Practice for Teaching Science in an Era of Reform. Journal of Research in Science Teaching. 48. 624 - 647. 10.1002/tea.20429.
- Nargund-Joshi, Vanashri & Park Rogers, Meredith & Bhagwate, Deepali. (2019). A Comparative Case Study of Primary Science Teachers' Beliefs and Orientations. 10.1007/978-981-13-9593-2_5.
- National Council of Educational Research & Training (NCERT), 2006. "Position Paper: National Focus Group on Teaching Science, NCERT: New Delhi
- Nehru, Jawaharlal (1989). The Discovery of India (Centenary ed.). Oxford: University Press. p. 513.
- Pednekar, P. (2015, May 04). Survey finds 75% students in India want humanities in college. Retrieved from https://www.hindustantimes.com/education/survey-finds-75-students-in-india-want-humanities-in-college/story-YZ8ykeiZdBEhl7hgN1jiVO.html
- Prasad (2017). Closed City 'Spaces': Differential Access to Education in Vijayawada, South India, in Pink and Noblit (eds.): Second International Handbook on Urban Education, (Vol 1). Switzerland: Springer International Publishing, pp.397-418.
- Prasad, R. (1982). The Debate on Scientific Temper. Social Scientist, 10(1), 56-60. doi:10.2307/3517123)
- Quest Alliance (2020) Engaging Girls In STEM; Barriers And Enablers In India : https://www.questalliance.net/wp-content/uploads/2020/09/Engaging-Girls-In-STEM-Enablers-and-Barriers-By-Quest-Alliance.pdf
- Ramachandran, N, (2020) , "The Scientific Temper that India Needs for Inclusive Growth", Opinion, Mint
- Ramanujam, N. M. (2020), Why developing a scientific temper is essential for Indian democracy to flourish, https://scroll.in/article/891052/why-developing-a-scientific-temper-is-essential-for-indian-democracy-to-flourish
- Rampal, A, Sahapedia.org (2020), Scientific temper and humanism: Rereading Nehru during the Covid-19pandemic,Scroll.in, https://scroll.in/article/978477/scientific-temper-and-humanism-rereading-nehru-during-the-covid-19-pandemic
- Raza, Gauhar & Singh, Surjit & Khan, Hasan. (2013). Quest for Scientific Temper. Publisher: National Institute of Science Communication And Information Resources (NISCAIR) Council of Scientific & Industrial Research (CSIR)
- Report on • Status of Secondary Education in Telangana •Technology Readiness for CLIx Intervention in Telangana • CLIx in Telangana. (2017, November). Retrieved from https://clix.tiss.edu/wp-content/uploads/2017/11/Telangana-State-November-2017-Draft-Unformatted.pdf
- Sarangapani, P. (n.d.). Three Challenges facing Indian School Science Education. State profiles. (n.d.). Retrieved from http://mmistech.com/atlas/state_profile.html
- Sharma, Sashi (2015) "Promoting Risk Taking in Mathematics Classrooms: The importance of Creating a Safe Learning Environment," The Mathematics Enthusiast: Vol. 12 : No. 1 , Article 24. Available at: https://scholarworks.umt.edu/tme/vol12/iss1/24
- Sujatha, V. (2015). Forms of Asymmetry and Cultural Bias: Of Gender and Science in India and the
- World. Transcience, 1(1), pp. 1-19
- Sujatha, V. (2017). Scientism, familism and women scientists, Kafila. https://kafila.online/2017/04/10/scientism-familism-and-women-scientists-v-sujatha/"
- Sundararaman, I. (2019). Gender Matters in Science Learning: An analysis of Experiences and Aspirations in an Urban Context. (Unpublished doctoral thesis). Tata Institute of Social Sciences, Mumbai,India
- STATUS OF ELEMENTARY AND SECONDARY EDUCATION IN ODISHA 2018-19. (2019). Retrieved from http://osepa.odisha.gov.in/webadmin/pdf_link/UDISE%202018-201_07_04_37pm9d4773d0dfc121c936df3252a79808e0.pdf
- Telangana state portal State Profile. (n.d.). Retrieved March, from https://www.telangana.gov.in/About
- Varma.A (Host). (2020, August 9). The Seen and the Unseen:Fixing Indian Education (Audio podcast) Retrieved from https://seenunseen.in/episodes/2020/8/9/episode-185-fixing-indian-education/
- Vijaysimha, I. (2013). 'We are Textbook Badnekais!': A Bernsteinian Analysis of Textbook Culture in Science. Contemporary Education, 10(1), 67-97
- Vijaysimha.I, Sundararaman.I & Aravamuthu.K (2021), STEM Mindsets, Careers and Women - An India Study, Quest Alliance.
- Vincent.C & Menon.R(2011). The Educational Strategies of the Middle Classes in England and India in Lall, M. and Nambissan, G. (eds.): Education and Social Justice in the Era of Globalisation, New Delhi: Routledge, pp. 56 – 80.
- Weiselmann, J.R (2019). STEM mindset: Supporting girls ongoing engagement and success in STEM. Connected Science Learning https://www.nsta.org/connected-science-learning/connected-science-learning-october-december-2019/stem-mindset
- Wong, B. (2016). Science Education, Career Aspirations and Minority Ethnic Students. Basingstoke:Palgrave Macmillan. Doi.10.1057/9781137533982

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