QUEST ALLIANCE

STEM Mindsets, Careers and Women

An India Study

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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

पूर्व चलने के बटोही बाट की पहचान कर ले।
पंथ का अनुमान कर ले।

- Harivansh Rai Bachchan

The world of work is changing rapidly. Science, technology, engineering and mathematics are transforming the way we live, creating new jobs and enabling us to solve complex problems of the future. Young men and women have to upskill and re skill through their careers and educational institutions must focus on creating mindsets and transferable skills. What then is a STEM mindset which working professionals consider valuable? What is the nature of STEM careers, what are the STEM skills and trends across sectors, what are the barriers for women at the workplace and how may we overcome these challenges? The study is the first part of a two-part enquiry to bridge the gaps between the world of work and the world of education, so that youth are prepared for the Future of Work.

The stakes are high – get relevant or miss the 21-st century bus. In a scenario where technology has forced itself upon us in the pandemic, getting a grip on the right STEM mindset for the future — of work, society and of the planet — is key to moving ahead.

Schools and colleges work to prepare students as citizens and as participants in economic processes, but is the work aligned to industry needs, and more importantly, societal needs? What is the right STEM mindset that our children have to develop to get future-ready? As Bachchan says in his poem: principals, civil-society-heads, parents, and students need to map the path ahead.

This study arrived at a pragmatic definition of a “STEM mindset” by querying working professionals in various fields - both STEM and non - STEM - about the skills and attitudes that they considered important in their careers. An online survey covering 70 respondents was conducted and in addition, 28 professionals from mid and senior positions were purposively selected for in-depth interviews.

Career professionals 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.

Skills described 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 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. However, persons with a specifically 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.

Convergences between STEM and non- STEM careers show the boundaries between STEM and non STEM blurring. Participants who came from non-STEM careers acknowledged the all-pervasiveness of technology in their lives, while those in STEM careers spoke of the need for communication and empathy. Professionals in non-STEM fields like art, graphic design, media, marketing and finance all emphasized the importance of critical thinking and problem solving. A shift from perceiving the constituents of STEM as isolated disciplines to using knowledge to think and act rationally was emphasized. Being ready for continuous change through continuous learning was another recurring theme.

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)

Nearly all career pathways have aspects of STEM skills which are essential. Careers across many different fields - research, finance, agriculture and healthcare are all adapting rapidly to advances in STEM. We see professionals in sectors such as Finance and Health taking up courses in Big Data Analysis and Machine Learning thus complicating our understanding of STEM careers and bringing to sharp focus how a STEM capable workforce is a requirement across many fields.

Careers across many different fields - research, finance, agriculture and healthcare are all adapting rapidly to advances in STEM. Big data analysis, artificial intelligence, machine learning and deep learning are going to play ever greater roles in diverse fields. The future will also see more opportunities in green jobs as humanity struggles to find ways to mitigate climate change and move into more sustainable paths.

Present day occupations continue to be divided along gender lines with women far less likely to pursue careers in engineering and technology than men. In the age of automation, men and women need more than ever to have the right skills, to be mobile and adaptable, and to be tech-savvy. Due to the barriers they face, women lag behind men on all three. In order to benefit from the new economic opportunities women will need to develop the skills and mindset to leverage technology and participate in its creation. Governments, educational institutions and companies need to enable women through concerted and creative solutions to equip them for the change that lies ahead.

An exploration of the gaps in the current education system gave clear pointers for strengthening curriculum and pedagogy in order to develop STEM mindsets. The respondents noted that problem solving, critical thinking and statistical thinking could be taught better, and that systems thinking, entrepreneurship, coding and programming, social skills and ethics should be included in the school curriculum.. Improving pedagogy to build critical thinking, connecting the subjects to the real world, having hands-on practical work and developing conceptual understanding and problem solving approaches rather than jumping on a coding language bandwagon were highlighted. The critical importance of STEM mindsets as we move into the future has serious implications for education. The focus needs to shift from imparting content to inculcating the attitudes and skills that constitute the STEM mindset.

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Introduction

The notion of STEM (science, technology, engineering and math) mindset overlaps with the idea of scientific temper which continues to be one of the important aims of education in modern India.

The Constitution of India encourages the citizens of India to have a scientific temper. According to the Fundamental Duties under Article 51 A(h): [It shall be the duty of every citizen of India] To develop the scientific temper, humanism and the spirit of inquiry and reform. Having a scientific temper means that the individual/society is able to use the methods of science such as questioning, observing physical phenomena, hypothesizing, testing, analysing and communicating. “Scientific temper” describes an attitude which involves the application of logical reasoning and critical thinking within an ethical framework that values democracy and humanitarianism.

India’s National Education Policy, 2020 speaks of development of scientific temper as 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.

The idea of STEM mindset is related to the notions of STEM literacy and scientific temper. Zollman (2012) argues that STEM literacy should not be thought of as a content area but rather as a way in which students use certain skills, abilities, knowledge, concepts and metacognitive capacities to develop further understanding. This notion of STEM literacy overlaps with that of the STEM mindset, but does not coincide with it. Crucially, the notion of a STEM mindset seems to include attitudes which are not mentioned in the definition of STEM literacy. However, attitudes are a part of the notion of scientific temper. We could therefore say that the notion of STEM mindset is related to both the idea of scientific temper and STEM literacy, but is distinct from either of these.

The STEM mindset framework being developed by Quest Alliance includes subject knowledge, attitudes, values and skills (Quest Alliance, 2020) and has a relationship with the world of work, changing professions and skills required. Law (2002) has articulated how various STEM skills and attitudes might be required in different careers and also in everyday decision making.

As an emergent concept, a STEM mindset is somewhat fuzzy and one of the key objectives of this study is to arrive at an appropriate definition. It may be said that a STEM mindset includes certain general attributes that are independent of an individual’s academic and career pursuits while having STEM specific elements. The present study certainly indicates the importance of STEM mindsets in diverse areas ranging from space exploration and chip design to mental health and performing arts.

Abilities such as critical thinking and problem-solving find mention in literature dealing with 21st Century skills as well as those dealing with STEM mindsets and skills (NEP 2020, MHRD 2020, Murphy 2019). There is no consensus on the definition of 21st century skills. However, it is recognised that one of the key aims of STEM education is to develop 21st century skills and capabilities among individuals (Sen, Ay and Kiray, 2018).

Sethi (2020) writes about STEM mindset: “it is essential to articulate STEM as a mindset which needs to be inculcated, rather than as subjects which need to be taught.” Murphy (2019) argues that the STEM mindset is required by everybody because of the role played by science and technology in our world today.

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 discussed more fully in section 4 of this report.

This will bring opportunities to those who can find their way in the new age. However, innovations 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).

Many career fields across the world are dominated by men, and this is even more true in STEM areas. Women form only 28.8 percent of the world average of the 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. The low participation of women in the workforce in general and STEM careers in particular will also prove to be detrimental to the development of science and technology in India, since there is considerable evidence that shows that teams having greater diversity amongst members do better than homogenous groups on complex tasks, problem-solving, innovations and making more accurate predictions. (Page SE, Lewis E, Cantor N. 2017; Freeman RB, Huang W. 2014; AlShebli BK, Rahwan T, Woon WL 2018).

As our research shows, the world of work is changing rapidly and STEM skills and STEM mindsets are needed across careers. Therefore, ensuring that girls develop a STEM mindset becomes all the more important if we are to achieve the UN's Sustainable Development Goals of gender equality and women's empowerment. There is an urgent need to help all students, regardless of gender or socio-economic status, develop a STEM mindset so that they may participate and contribute to a more equitable and sustainable world. Having said this, it becomes necessary to arrive at a clearer notion of what might constitute a STEM mindset and further to understand the importance of it in various career fields.

Overview of the present study

A STEM mindset comprises of many aspects, and people differ in their conceptions of its understanding. One of the key objectives of the present study was to derive a pragmatic definition of a STEM mindset by querying working professionals in in various fields, both STEM and non-STEM, about the STEM mindsets that they considered important in their careers.

The second key objective was to arrive at an understanding of STEM careers based on STEM mindset as well as convergences of STEM careers in traditionally non-STEM career options. This the study has looked at present and emerging careers, and the convergence of STEM. It also looked at traditionally defined STEM careers, explored shifts and trends, and how the STEM mindset informs careers in diverse fields. The role of education in career preparation as well as factors that influence individual career choice have been included in the study in order to give a holistic picture about careers in relation to STEM mindset.

A qualitative approach was taken to arrive at the definition of STEM mindsets and explore the trends in careers. 70 respondents completed an online survey to capture perceptions on STEM mindsets and skills that inform work, role of technology, choice of careers, issues concerning gender, sustainability and work. A subset of 28 respondents was purposively selected for in-depth interviews. The interviews provided a deeper understanding of STEM careers. In a neat complementarity, the study also uncovered the importance of non-STEM skills such as empathy and collaboration in STEM careers.

The study allowed us to capture nuances concerning STEM skills and attitudes that constitute a STEM mindset among working professionals. Senior and mid-level professionals from different fields were chosen as participants to help build up a composite picture of the STEM mindset across careers, explore convergences between STEM and non-STEM careers, pinpoint gaps in skills and how professionals adapted and learnt some of the skills through experience. The insights from interviews were rich and helped to weave a narrative on STEM mindsets and capture the career trends which are described in the report.

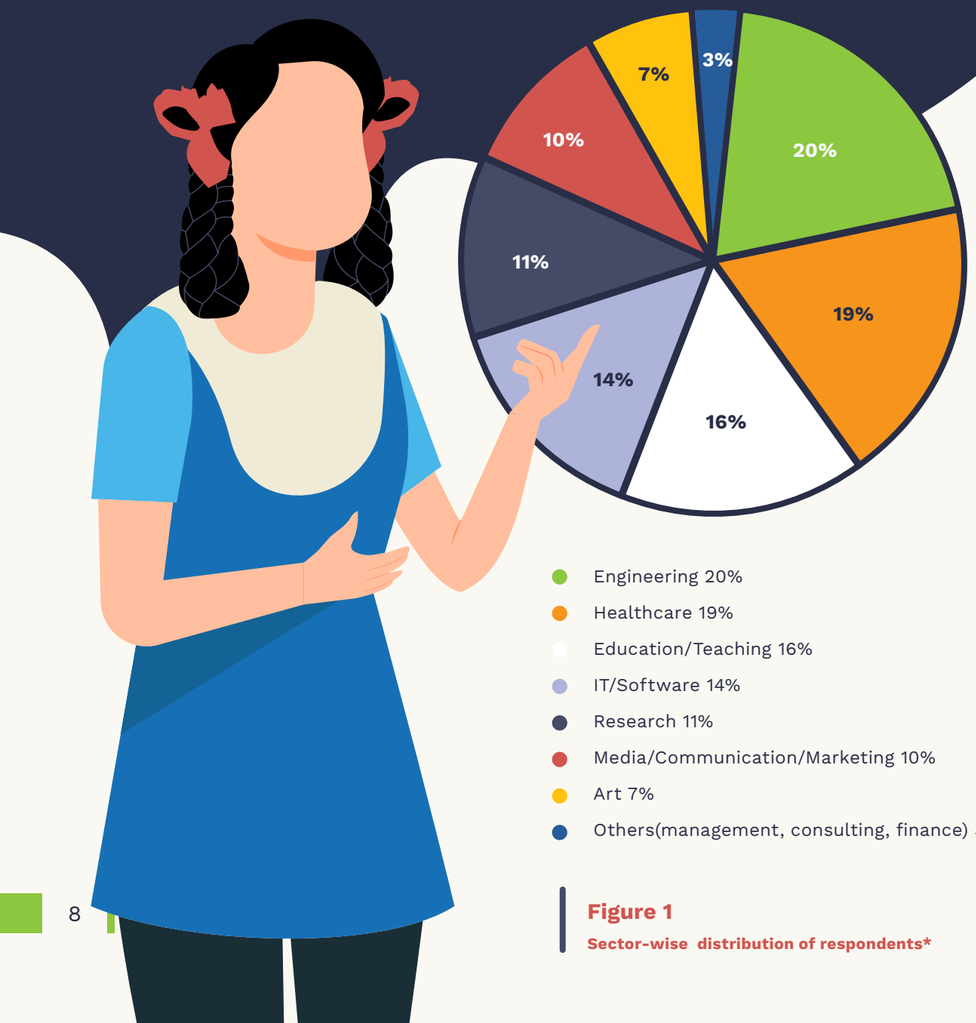
Based on the survey and interviews with working professionals, the study attemps to arrive at a definition of the STEM mindset. A range of skills and attitudes were articulated by the participants as constitutive of the STEM mindset. A section of the report presents these finds along with a nuanced description of the most significantly mentioned skills and attitudes, and their importance vis-a-vis careers. This section of the report thus attempts to define the STEM mindset.

The third section of the report looks at convergences between STEM and what are traditionally considered non-STEM careers. STEM mindsets (consisting of skills and attitudes) are valued across fields, and the line between STEM and non-STEM careers is blurring. What also emerged from the study, although it wasn't explicitly designed to check for this, was there are some general skills and attitudes that are important for STEM careers.

The penultimate section of the report discusses STEM and careers and elaborates three crucial aspects - STEM career paths and how advances in STEM are impacting the future of work, women in STEM careers and thirdly, the gaps in education with respect to STEM mindset formation as perceived by various professionals.

STEM Mindsets

The survey respondents spanned across various careers such as information technology, research, healthcare, media, arts, engineering and education.



- Engineering 20%
- Healthcare 19%
- Education/Teaching 16%
- IT/Software 14%
- Research 11%
- Media/Communication/Marketing 10%
- Art 7%
- Others(management, consulting, finance) 3%

Figure 1

Sector-wise distribution of respondents*

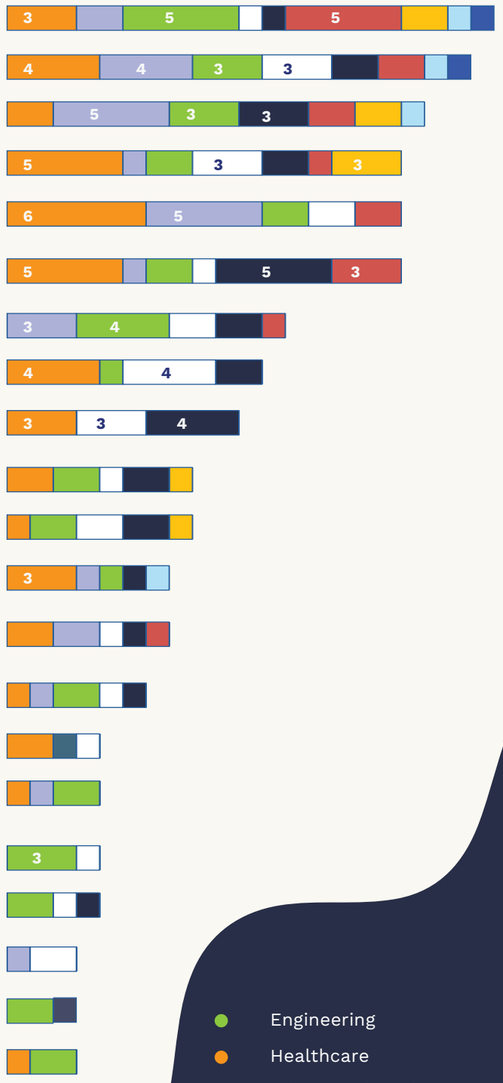
Some respondents have indicated two career fields. There are professionals who have mentioned engineering as a broad area, however they work in healthcare or energy or aviation.

The survey asked people to list the STEM mindsets and skills that were important in their area of work and generated a list of 104 attitudes and 88 skills, which were coalesced into broader categories and sorted on frequency of occurrence. Skills and attitudes that were mentioned thrice or more were identified as constituents of a STEM mindset

The skills and attitudes, listed, sector-wise, are shown in the table below. The rows indicate the counts for the skill for the sector, listed in the column.

Figure 2

Skills and attitudes that constitute STEM mindset in different sectors



KEY 1

- Skills
- Attitudes/habits of mind

- Engineering
- Healthcare
- Education/Teaching
- IT/Software
- Research
- Media/Communication /Marketing
- Art
- Finance
- Consulting

2.1 Skills constituting the STEM mindset

The image below captures the skills mentioned by the experts.

Figure - 3

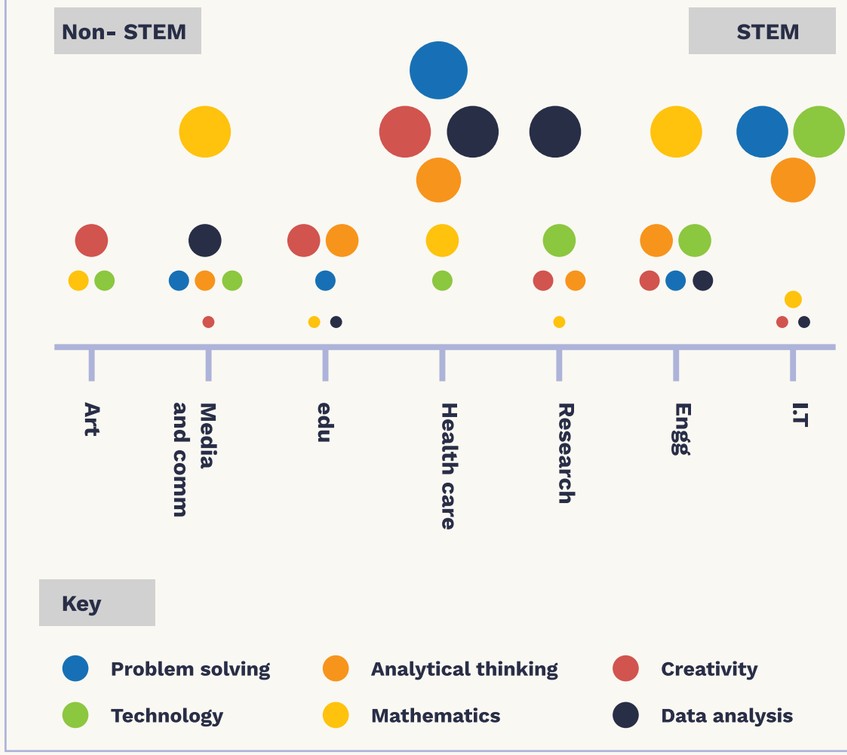
STEM skills

The most common skills mentioned are mathematics/ mathematical mindset, technological skills, analytical thinking, creativity, problem solving, logical thinking and critical thinking. The other skills that are mentioned are communication skills, design thinking, innovation and systems thinking. Some of the respondents highlighted knowledge and deeper understanding of concepts in their respective areas. This seems to corroborate with the literature on STEM skills. STEM skills include “numeracy and the ability to generate, understand and analyse empirical data including critical analysis; an understanding of scientific and mathematical principles; the ability to apply a systematic and critical assessment of complex problems with an emphasis on solving them and applying the theoretical knowledge of the subject to practical problems; the ability to communicate scientific issues to stakeholders and others; ingenuity, logical reasoning and practical intelligence” (EU Skills Panorama, 2014).

The image below captures and highlights key skills and their relative importance across different sectors as mentioned by the experts,

Figure - 4

Top STEM skills across STEM and non-STEM fields



From a global perspective, STEM skills such as Artificial Intelligence (AI), computing, data analysis, computer science and Information technology (IT) are emerging as skills of current and future importance. 21st century skills such as communication, entrepreneurship, leadership, global awareness, sociability, networking, self-management and interpersonal skills are of growing importance as well. Skills such as critical thinking, creativity, problem-solving and design thinking are pertinent across most professions.

From an Indian perspective, STEM skills such as the monitoring, control and design related to technology, system analysis and troubleshooting user experience are projected as STEM skills of growing importance. Along with the above, leadership abilities, social negotiation capabilities as well as the skills of persuasion and negotiation are emerging as vital non-STEM skills. Analytical thinking, problem solving and ideation, active learning, creative, service orientation are skills that are valuable across most fields and domains of work (WEF, 2020 a). The articulation of skills and attitudes by the experts in the survey as well highlights analytical thinking and problem solving, communication and creativity and ability to learn and unlearn.

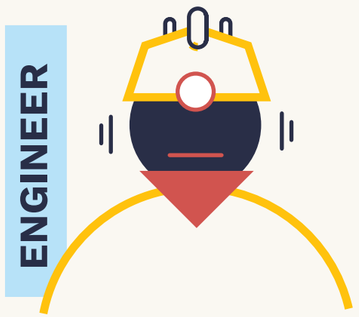
Description of skills

In the detailed discussion, the experts elaborated on a few skills and attitudes. Professionals shared the importance of some of the skills and attitudes that their work demands. Between the three researchers, a range of experts in various fields were interviewed. These included people working in academic research, healthcare, Artificial Intelligence, cloud computing, finance, theatre and performing arts, mental health professionals, agriculture, media and communications, design and digital marketing.

The following section discusses five skill areas that have been consistently identified across fields as part of the STEM mindset.

Problem-solving, analytical thinking, logical thinking

These have emerged as very important aspects of the STEM mindsets that are required in careers. Problem solving also involves the ability to think independently and analyse the situation afresh without relying on formulaic response. This also involves an adequate understanding of the field. A methodical, meticulous and systematic approach to problem solving is considered a highly valuable skill whether it be in scientific research or in applied fields of technology and engineering. Many respondents indicate that a step-by-step and logical approach is a quintessential part of problem solving. This implies that necessary complements to problem solving are attitudes of patience and perseverance. Attitudes constitutive of STEM mindset are described in the next section.



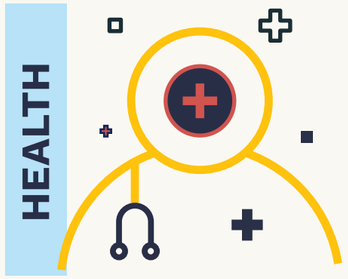
An engineer who provides electrical solutions said,

We were installing a transformer, Air Circuit Breaker (ACB) was tripping and we were not able to restore supply. To identify this, there are 10 steps, I asked one by one. In a breakdown such as this, we have to solve this methodically. If a breaker trips, we have to reason what would have caused a trip, it could be due to overcurrent, short circuit, earth fault, ground fault. So we have to try one by one and resolve.

The scientist, Kumar[2] from ISRO elaborated on how he approaches a problem systematically

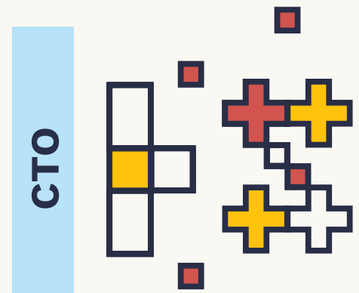
I use a step by step approach to solve a problem. Many people tend to panic if there is a problem. For e.g.- There was a flaw in the design of the satellite and we could not identify the flaw, the problem was considered as liveable. (However, in our work, when there is even a small problem, we would be worried, it might grow and there would always be a concern). Now, this is like finding the needle in the haystack.

We have to look at huge log data, so we need patience. We also need to know where the problem could be. We have to relate the problems, identify the interconnections and correlate. Once we relate then we could solve. Like a problem might happen during a particular test and it would happen on a particular day, we need to go back to the tests and correlate this. We got some clues when I looked at the log. Once we started establishing the correlations, then the problem became obvious and clear. I could then identify that problem and locate that nanosecond issue and simulate the same and recreate the situation/ test. I was able to analyse and give proof.



Anandi, mental health professional reiterated that problem solving consists in breaking the problem down into smaller chunks

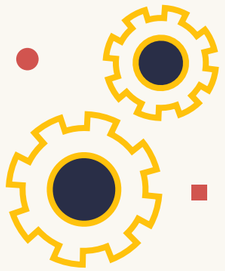
As a clinical psychologist, there are issues that clients would bring up, one important skill would be to break it down in smaller chunks and help people with problem solving.



Hari, who is also a CTO of a software company also spoke of a systematic approach

We are told- there is a business problem and we need to write a program for it, for e.g.- it could be payroll, it could be a complex thing. Our job is to understand the manual process completely and then translate into the software. Also, it has to be efficient. Manually for example- if you are filling a voucher- you may not fill or miss, say- an employee code, or accounting code, or date etc. In a simple voucher, there are 20-30 controls we need to put in place, there is a series of things to do, which only an analytical mind can do. We need to understand the entire business process, find out what needs to be done, this is what is problem-solving. Now, how do I ensure that a wrong employee code is not entered, or a wrong date/year is not entered, there are various such things that might come and need to be solved? You need to think through the whole process and then write a code. What we do is all problem-solving. We write a program to resolve it and we do it in a systematic manner.

2 All names are fictionalised to protect identities



Experts across domains elaborated how the systematic approach characterizes problem solving by professionals as opposed to everyday problem solving. The implication is that everyday problem solving can be improved by following the systematic approach of the STEM mindset.

In our work, it is little more complex and more practical, In real-life, problem-solving is based on gut feeling, it is not based on data, real experience and it is based on biases which are taught to us by elders, friends, whereas specifically to our work, the problem solving has to be precise, a person who doesn't know how to do that - will have a fairly average career. If you are able to excel as a programmer, or a coder, or a system strategist, and then you apply to real life, your quality of life will be high, because you will be able to analyse and solve problems quicker than others (Programmer - CTO).

Daman, a senior AI scientist emphasised the importance of learning to "ask the right question." when it comes to problem solving.

Raj, who retired as a guest house manager of a large government facility said that he did not think his work required STEM related mind-sets or skills. However, along the course of the interview he recalled a crucial incident where scientific problem solving helped his team uncover the cause of the unpleasant smell associated with the fries that were served at the guest house. His description clearly indicated that the solution emerged from logically examining the various possible causes of the problem and ruling them out systematically to identify the actual cause. This then paved the way for the solution.

Mathematical thinking

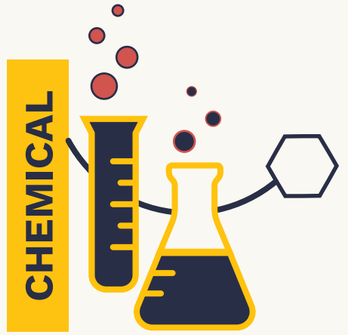
Math ability, computational thinking, data handling and analysis were emphasised by people from many different fields, ranging from engineering to media and humanities. Mathematical thinking involves thinking in terms of measurable quantities.

Computational thinking helps us to take a complex problem, analyse it and then present solutions in ways that can be understood by a computer or a human.
Before using computers to help us solve problems, the problem itself and the ways in which it could be solved need to be understood.

Vanita, a female physicist said

One of the biggest things is having a mathematical way of doing things- quantitative abilities. Everyday problem solving has qualitative aspects – 'this is better or is this better'. It does not encourage you to think about how much something matters and that is why quantitative skills are important.

The experts also spoke of the need to understand these topics conceptually and holistically, rather than as topics in school.



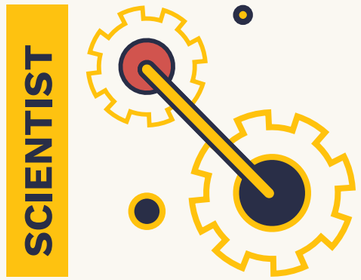
Giri, chemical engineer, scientist and associate dean:

You should think of your discipline as a foundation, and not as a wall.

If you are a mathematician, you should not be averse to looking at the biology... You have to do a lot of hard work in trying to understand different disciplines, but it pays dividends.

I am of that generation- I did not have bio in 11th and 12th. You could be an engineer, or doctor growing up without doing biology. That was completely wrong... It is critical that doctors do math – they are doing dosing, and non-linear dosing (your weight doubles and you double the dose – it works for adults – but not for children and adults, for example).

Krishna, machine learning scientist, Rishi, IOT expert and Giri, scientist and dean, all spoke of the importance of statistics and statistical inference in various fields, including psychology.



Krishna, machine learning scientist:

People do need to understand stats and maths for a successful career in any scientific endeavour. Some math and statistics is needed. Even my daughter's psychology course – the way they are teaching – control variables, independent variables, dependent variables – it is like statistics.

Rishi, IOT expert:

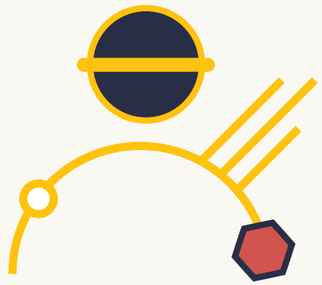
Statistical inferencing: For STEM courses, we might start teaching coding, but we are not teaching statistical inferencing. We learn to draw a histogram and learning mean, median and mode, and that is where statistical learning stops.

Giri, scientist and associate dean:

Subject itself – we completely miss out on statistics. ...What we don't appreciate is that statistics consists of distribution and that things have a spread. Even in schools, we can start thinking – mass has a spread, physical ability has a spread. It is not about intellect – height, weight everything has a spread. Even if you observe 2 students out of 60 students, you cannot say it is true of all students. Even simple things like how many do you test to get a reasonable idea of the graph. The non-mathematical concept – when someone says this magic pill works- then you have to ask how many have you tested this pill on?

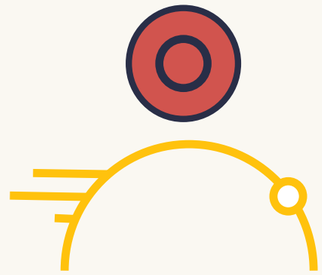
One STEM mindset that is important – is the distinction between the anecdotal versus systematic. One thing I want to emphasize is – there could be lots of anecdotal evidence, and when there is lots of anecdotal, it can eventually become a big data set, and becomes 'systematic'. As long as you are relying on 'no correlation, no control' – it is still anecdotal. You can use it as a starting point, but you cannot use it as a basis for decision making.

Experts also pointed out the need to remove math phobia:



Krishna, machine learning expert said:

...Some people seem to have a math phobia. That is one reason they go to non-STEM. As a society, we should get rid of that phobia.



Siva, An educator for many years, who is currently teaching literature also emphasized the importance of math, specially in everyday life and also talked about how math phobia is created

Maths is posited as a difficult/specialist etc thing, we are made to feel that we should leave it to those who know better. This attitude was acquired way back in high school. It was always all the other subjects and then Maths on a pedestal accessible to only a few.

The lead strategist, Sasi, mentioned how big data analysis is emerging as an important area where mathematical thinking will be required, even if much of the grunt work is done by machines

It is going to be automated, now, it is programmatic. Algorithms will work, but people will be there to analyse it, there is big data, data science, visualising the data... data science is emerging. More the data- so you need a data scientist.... Imagine digitising the business- like the counter, shop floor...restaurant- for eg- how much yeast, how much flour and then even multiply by 100x, scaling is possible. If decisions are data driven then all business can improve, can be scaled.

Rishi, IOT expert also spoke of computational thinking

Computational thinking: My understanding of programming is – it's a language just like any other language that you learn, and language – is just the final frontier to communicate to someone else. You have to learn computational thinking or algorithmically before you start languages. You cannot start C++[3] - constructor and overloading before you understand computational thinking.

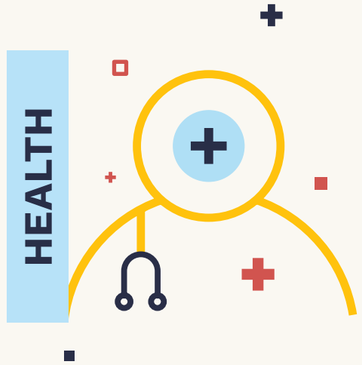
[3] A programming language

Technology skills

The survey and interview data provided us with an unequivocal picture of the importance of technology in almost all careers. The survey asked professionals the role of technology in their work and the overwhelming importance of technology skills came across clearly in their responses. "Technology is everything" was one of the responses! Not just professionals working in scientific research, IT and engineering, but even professionals in performing art, film-making and mental health spoke about the influence and importance of technology in their work.

Some respondents have pointed out that technology cannot be seen as a panacea while accepting the obvious benefits of using technology. It is also clear that the level and kind of technology use differs in different sectors. In many professions such as performing arts, medicine, psychotherapy and education technology is seen as an enabler and as a tool to support the main work. Professionals in these fields typically make use of available technology, especially ICT. Since tech interfaces have become much more intuitive and user friendly these professionals quickly become proficient in using such enabling technologies. Professionals in education and mental health are also adapting to doing work virtually through on-line platforms.

Professionals also recognized that technology has the power to democratize access and participation in fields like education, health care and arts.



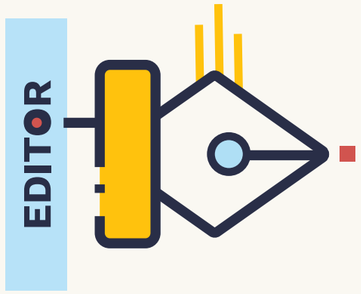
Binita, mental health professional said,

I think technology is a tool to democratise education/ healthcare/ basic living amenities etc. It isn't the end all, it isn't also the only solution to everything. But it can be very useful to improve the quality of and access to a more resourced living. Finding a balance between all of it is really key.

The potential of technology to democratise was also mentioned by dancer and choreographer, Vaijayanthi

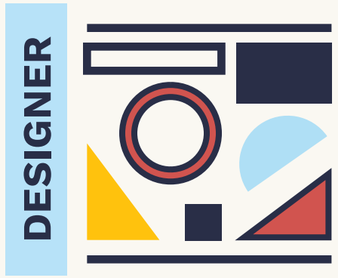
See there will be a shift of some kind. I feel the digital platform has made it a little more democratic - the performance. Which was not there. Today anybody can record and anybody can put on the different platforms. Whether you want to watch or not is your choice. But everybody has the right now . So there is no - what do you call - when people are curating for festivals and all there is a lot of pull and push and all those things involved. So for all dancers it is not easy to make it out there without the right resources in some ways - either it is your money talking, or your PR(Public Relations) or your contacts or something. I think that is being challenged on this platform. But at the same time both the dancer and the artist and the audience are kind of missing a live experience.

Being aware of available software tools and becoming proficient in using them in their work is considered important in many careers.



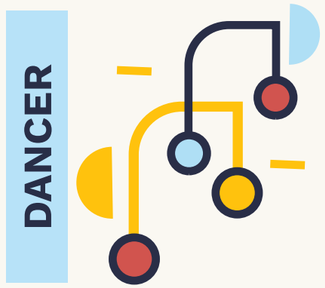
Sudha, Copy editor,

Radio Jockeys use radio computing software- now there is a software... the software is also updated now. It will make everyone's life easy. We never thought RJs could work from home. This pandemic taught us and every show went on AIR.



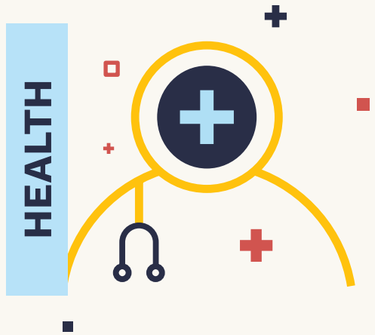
Graphic Designer, Tanu, mentioned

My profession...it is digital design now. 10-15 years this change is visible.Digital space would become more and more important and may be less work for people like me- who is in print. Even now, I see that the projects I do, there is always never only a print project, there is something in the digital space that will become more and more important. The process of doing design, that space will become easier and easier to work and the software that I use now is intuitive and it is flexible, that will make the process different, I would say (easier ofcourse).



Professional dancer Vaijayanthi, speaks of technology as something that adds an extra dimension to her productions:

Definitely, I feel the use of technology is contributing because technology is playing its own role in terms of choreography. We are able to kind of bring about a lot of things that we visualize Dance being of a certain dimension. It's a two dimensional thing you have music and you have beats But if you want to add other dimensions to your narrative or something then i am sure, i feel technology has helped in terms of how we are using the light, how we are thinking about sound. What all we can do at the recording studio...



Mental health expert, Anandi, elaborated on how virtual consultations are possible,

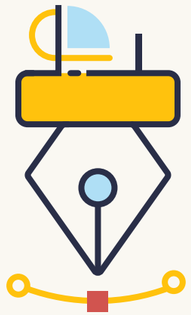
I am able to do virtual counselling now, since people can't travel this is the best solution. Now that mental health is a serious concern, I meet a lot of clients online. One can access people across the world now.

Professionals working directly in technology careers spoke about the vastly enhanced computational power now available and how they have to keep learning on the job. They also spoke about how increased automation would affect their work.

Hari, CTO said

Hardware power has grown, the processing power of the hardware is inconceivable, memory has increased- data can be processed quickly, programming has become simpler and quicker. Programming has also become complex at the same time, coz memory has increased, hardware power has gone up, complex things we used to do to manipulate data have become simple now. But the cloud components which have come in and the security requirements were not there before, so it has become complex, there has been massive change. The resources were limited. I have worked with 16k memory, now 8GB memory. The technology was few, now you have 150 odd tech, now things are at your disposal, but at the same time, that means you need to learn more now, understand and you need to know how to amalgamate and put together a good system.

Communication skills



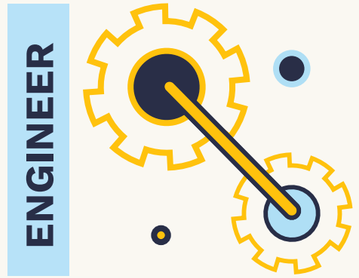
A majority of the experts interviewed spoke about the need for effective communication both written and oral. As, Naresh, an experienced VLSI engineer explained,

My work involves to some extent communication skills. We have to document our work and written communication is very important. We also have status update meetings and oral communication is also very important.

Although one may question whether communication is a STEM specific skill, it is de rigueur for people in STEM fields to communicate their work and this implies developing clarity of thought and understanding about the technical vocabulary used across disciplines. The nature of science itself demands that observations, findings and reasoned argument be used to communicate openly and transparently to both peers and payment. Unless scientific work is published, it has no validity. STEM careers in both pure research and technical fields involve work in teams, where once again communication becomes very important.

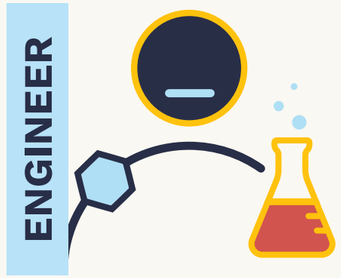
Giri, scientist and associate dean spoke about the importance of good written skills

You need a very good ability to communicate. If you study literature that is good. If you find other ways to do it, that is also good. Depending on how I write, I can get it published in a premier journal versus a normal journal – it is important to communicate both to the public and to your own group. Communication is critical.



Rahim, an engineering director in a chip design company spoke about the importance of saying the right thing at the right time

If you are in a corporation, apart from being knowledgeable, creative and knowing your stuff, you should be able to articulate what you are thinking, in a critical negotiation, at the right moment.

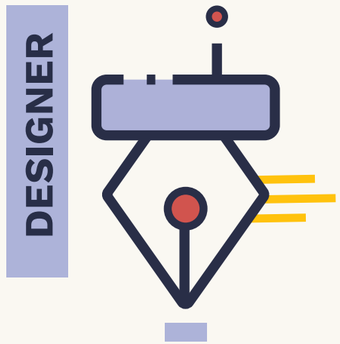


Good communication in a professional setting involves understanding the other person's mental frameworks. Saini, data security engineer gave an example of this:

Engineers may not have a full understanding of what they need to build. If you want me to build disaster recovery, tell me what disaster recovery means to you. If you say, there is an earthquake, and I can lose my data people might come back with other questions– you have to define the problem differently – I have to have 2 different places where data exists, if one went down, then still the other one should still be up. What might be obvious to a salesperson or a product manager – the engineer must hear it in his language. It is easier if you think about it the way the engineer thinks about it.

Creativity and Lateral thinking

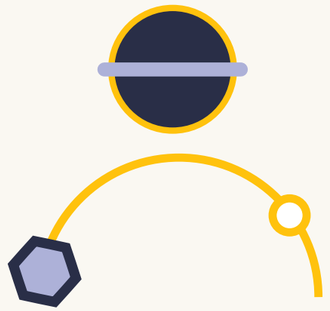
Creativity and lateral thinking as an important skill was reiterated by professionals in art, media and communications during the detailed discussions. These skills are also mentioned by software and hardware professionals as important. Given the prediction that automation and AI is taking over 50% of human work in the next 15 years, creativity and creative jobs are predicted to stay as creativity is a unique human trait (Belsky, 2020).



Creativity involves exploring and researching widely and also thinking out of the box.

Graphic designer, Tanu, elaborated on how and where she finds her inspirations,

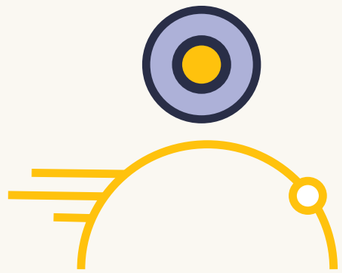
I spend some of my day- on a specific design task, developing the design, part of it or a layout. Usually at the beginning of the project- it is more explorative, more playful. For eg- Today I was designing for social media, so I was exploring, looking at references. and experimenting. I read a lot- depending on the project, understand and do background work. Others are more explorative and visual, I look at lots and lots of references, and also refer to other people's work, work designed in different time periods, to be inspired.



Rahim, the engineering director described creativity as arising out of an exploration outside of your comfort zone, and said that exploration allows you to blend ideas:

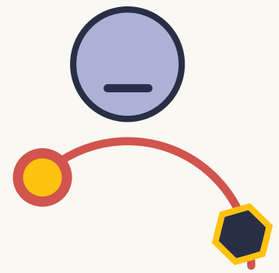
I would rate myself as a very good engineer. But I wouldn't call myself a creative engineer. What creativity means – given a problem, whether you can come with a solution outside the box, and those things allow you to really build things or companies that have not been thought of before, or a solution that simplifies something. I have realized that with our education we were never allowed or encouraged to bring out our creativity. Creativity could be in art or thinking or going outside of your comfort zone. I grew up in a very traditional family where you do your stuff, and you operate within boundaries.

Creativity is also about blending things. I used to love geography a lot – I used to look at the Atlas that an uncle bought me- and I can actually visualize any place in the world. But, we tend never to use anything apart from what we studied to build a solution. If a system is there that allows them to become creative, they become better at anything.



Mani, A cloud computing engineer noted how lateral thinking brings in different perspective,

There may be multiple solutions to the same problem and approaching a problem from a different perspective is lateral thinking according to me. The solutions also have to be feasible with respective time and money.



On the similar lines, a copy editor, Sudha from Radio Mirchi elaborated on lateral thinking as follows,

putting yourself in other's person shoes, think from multiple perspectives... you have to take in so many factors into consideration.

2.2 Attitudes constituting a STEM mindset

The image below captures the attitudes mentioned by the experts.

Figure - 5
STEM attitudes

While describing STEM mindsets professionals frequently referred to attitudes such as patience, perseverance, attention to details, ability to learn and unlearn, curiosity, passion, hard work, and open mindedness. In essence these attitudes characterize a growth mindset.

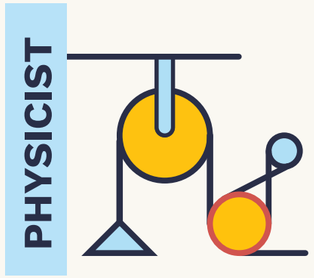
"Those with a growth mindset possess grit, perseverance, and embrace learning from failure—no doubt a beneficial outlook for STEM students and practitioners as they question and investigate to understand phenomena, or design and evaluate solutions to new problems."

(Murphy, 2019)

Naresh, a senior engineer working in VLSI said that "I always solved problems - I could do it in any subject (referring to school subjects) and also in work." This seems to exemplify an attitude towards problems and also indicates a confidence in one's personal capacity to solve problems. SN went on to say that he was motivated enough to continuously learn and pick up knowledge and information through his extensive reading habits.

Patience, perseverance and ability to withstand failure

In the section describing problem solving as a skill that constitutes a STEM mindset, we noted the importance of a set of attitudes that complement problem solving. Professionals spoke of the careful and methodical approach required for problem solving. This approach requires patience, perseverance and hardwork. Not surprisingly, a significant number of respondents mentioned patience, perseverance, hard work, meticulousness and attention to detail as STEM related attitudes that they considered to be highly important. In many cases these qualities were rated above others like creativity, curiosity or problem solving.



Vanita, physicist said:

In terms of mindset, patience is important in STEM, and in science – when you are doing research you don't get results immediately, you have to do 100s of tests before you get results.

These responses and other similar statements of respondents from interviews indicate that while mindsets like creativity, open mindedness, curiosity and flexibility are valued, people consider it equally if not more important to be able to stay with a problem and steadily and methodically work towards a solution. The following response clearly indicates that it is important to be resilient and not give up at the first signs of failure. "Ability to take failures and rejections, ability to deal with uncertainty and unpredictability of the research environment, ability to work in rouch field conditions, persistence".

In essence, what mid-level and senior career professionals are saying is that it is hugely important to have the ability to persist despite initial lack of success and to develop a way of working that is careful, methodical and systematic. Some responses indicate that in order to be able to cultivate this attitude there has to be an underlying sense of self-esteem and confidence. This is something that needs to be kept in mind while considering how young people can be helped to acquire STEM attitudes that are highly valued in the workplace.

Taking risks

While persistence, patience and a certain methodical way of working are considered important, professionals have also mentioned the ability to step out of the box or take risks as important mindsets. Several respondents have explicitly mentioned risk taking as an important mindset, for example "willingness to experiment and take risks". Other respondents have mentioned mindsets like "divergent thinking"; "innovative and thinking beyond the norm"; and "being crazy"! Other expressions like "creativity", "flexibility", "willingness to be open" etc also have been used and indicate the importance of thinking unconventionally. At first it might seem to contradict the mindset associated with a methodical and patient working style. However people have mentioned both kinds of mindsets as being valuable. What this would indicate is that there is a value to trying out new or innovative things, but that this must be accompanied by a willingness to persist and patiently work through the details.

Open minded and willing to learn

The interest to keep learning is of obvious importance in most STEM fields which are experiencing a rapid rate of change.

Speaking of self- motivated learning, Lead AI(Artificial Intelligence) scientist Anu, who made a switch from neuroscience research to developing better diagnostic tools in health care with the help of machine learning, speaks about her own efforts to learn beyond what was required in her formal studies

I learnt programming when I was at Rishi Valley at high school and then I built on that during my masters and I did a lot more programming during my Ph.D and also continued to learn during my postdoc.

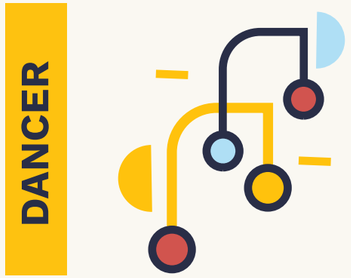
Rishi, IOT expert:

I've done 43 courses (online!) and counting...keeping myself up to date on the developments that are happening. These are things we don't teach people.

Saini, data security expert:

The biggest technical skill is the ability to learn. Depending on the company, product managers act at different levels. Some are sales focused, some are engg. focused, and some are across the board. Engg. ones are most common...

Change is the way of tech. Three years from now, it is going to be different. The interest and curiosity to learn is a really big skill.



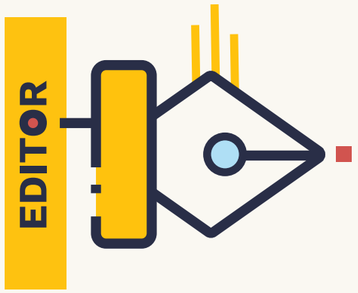
Vaijayanthi, dancer and choreographer has taught herself many 'small skills' as she calls them

Yeah, for example I learnt how to edit videos myself. Not something very grand but I know how to edit a small piece from my performance if I need to put it up in social media. If i need to create some effect - something very basic but I am able to do. I am able to edit music myself. Very small things but they are helpful to me especially in this time (Referring to the pandemic and resulting lockdowns where live performances are not possible). Those skills I have picked up. Or poster designing, you know on the .. using some software. They are very small skills but I am picking them up and they are helpful to me in what I am doing.

Rihan, artist – who does visual, performance, installation, earth and VR art:

I kept on improving my skills and evolving. But there are others who don't. They are artists and stop learning.

Some of the professionals highlighted how being open to feedback and being open minded help them unlearn and learn.



Copy editor, Sudha, shared,

Being open and willing to take feedback is an important attitude. Creative work is very subjective, we should be open to feedback and one's ego can't come into play. (Copy editor, Radio Mirchi)

2.3 Definition of STEM mindset

The study provided us rich narratives and insights into how professionals thought about a STEM mindset. They articulated it in terms of skills and attitudes as described in the sections above. Based on the present study and with some degree of trepidation, we attempt to arrive at a working definition of the STEM mindset. It could be said that the STEM mindset includes both skills and attitudes. Some of the skills described by STEM professionals such as creativity, communication and critical thinking are also considered to be 21st century skills. The attitudes described constitute a growth mindset. Although necessary for STEM careers, neither the growth mindset nor the 21st century skills are specific to STEM. How then might a specifically STEM mindset be defined? Perhaps it maybe articulated as follows:

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, engi neering and technology used responsibly and ethically, to solve local and global problems.

BACK TO INDEX

Convergence - STEM and Non - STEM

It is also worth noting that there is a good deal of convergence between the STEM mindsets considered important by people working in STEM as well as non-STEM fields.

Many of the same skills and attitudes are mentioned by people in both STEM and non-STEM fields. At the same time, there are specific skills and attitudes that experts have highlighted which are specific to their work such as empathy and listening skills in the case of a psychologist and a medical doctor. Similarly, experimentation, handling instruments and observations are mentioned by people in STEM fields. People in creative fields such as content writing or graphic design seem to have mentioned creativity and lateral thinking as an important mindset.

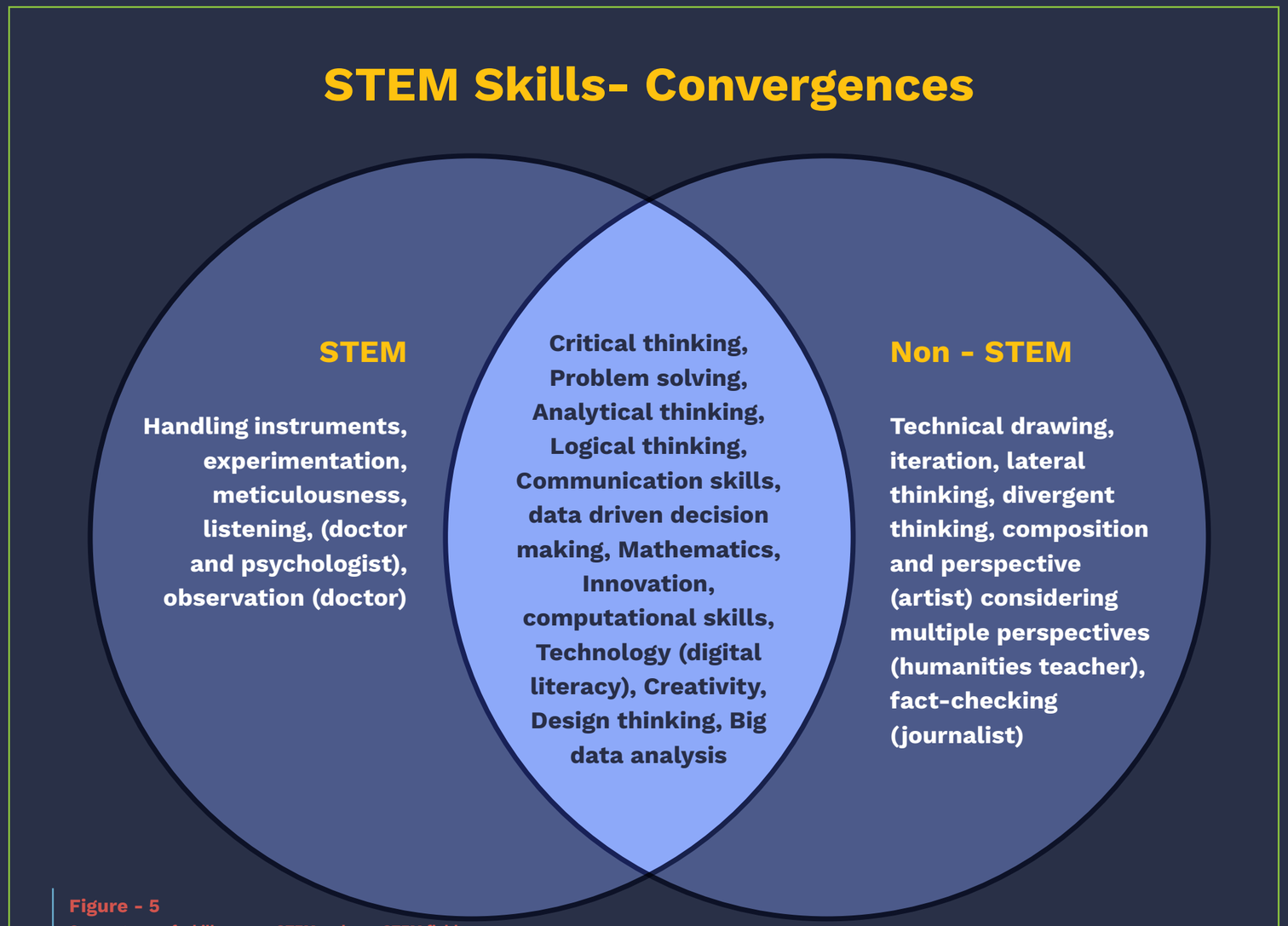
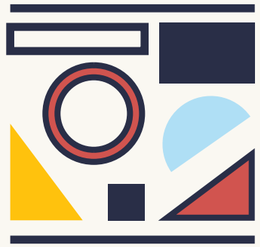


Figure - 5
Convergence of skills across STEM and non-STEM fields

3.1 Elements of STEM in non-STEM careers

The convergence mapping makes it apparent that the boundaries between STEM and non STEM skills and careers are blurring. Technology is one of the key aspects or skills that cuts across all careers. The role of technology across different fields was highlighted in one of the earlier sections. Similarly some of the professionals in the field of arts- such as personnel in communications, an author and a designer highlighted how critical thinking and problem solving is important in their work.

DESIGNER



Graphic designer, Tanu, highlighted on problem solving,

My work in designing and designing involves problem solving or analytical thinking. For example, the idea of design is to communicate, but I need to think through what might be the ideal design. If I have some ideas, which of them will communicate the idea better and effectively, I need to analyse... try different things and see what works, this in a way is analytical thinking to me.

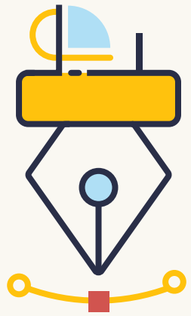
THEATRE

Theatre worker, Binita, spoke about STEM skills in her work

There's also other things – my work as a designer for the stage (sets, costumes, lighting and sometimes in make-up) involved STEM mindsets. It required me to be unafraid of technology, to befriend it. Sometimes, it involved a simple understanding of mechanics, at other times of light to create the right illusion/effect. Sometimes, knowing what fabric/material works for the stage involved an understanding of how light plays off of them and at what distance this could be seen, how colours contribute to the visual experience, the semiotics of it all... Add to this the management of the cost of production...

It didn't mean I was efficient all the time, but it certainly pushed me to think harder about the choices I was making. It helped me push my creativity to newer levels.

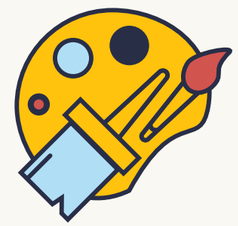
AUTHOR



The author as well as a professor in communications, Rita, spoke about critical thinking as follows,

Writing is creative, however critical thinking is very important. I write to reach my audience right...so I need to know what might be useful to communicate and how do I communicate. I need to break down some of those aspects in my head, that is what I call critical thinking. I ought to have readership, so I analyse what might people be interested in, how do I present it and how do I write. I am not doing creative work for the sake of it...

ARTIST



Artist, Rihan, spoke about how science is needed in art:

We did installation art – and had to make a bird in iron. First, I had to study the anatomy of the bird, and its flight. How its wings open. The calculation is there, for the grid I need to make. When it goes on to cutting iron, and which angle you will bend it to – again math comes in.

People think art is about painting, but if I am using 2.5 tons of iron and other material to make a bird, I need to even have material science – the angle of the unipole – a huge pipe where the bird's centre of gravity will sit. How is this bird standing – on a unipole – 8 inch pipe, with another 6 inch pipe, a male-female joint....and if I have not been taught physics, where will I go?

3.2 General attitudes and skills for STEM careers

The convergence mapping makes it apparent that the boundaries between STEM and non STEM skills and careers are blurring. Technology is one of the key aspects or skills that cuts across all careers. The role of technology across different fields was highlighted in one of the earlier sections. Similarly some of the professionals in the field of arts- such as personnel in communications, an author and a designer highlighted how critical thinking and problem solving is important in their work.

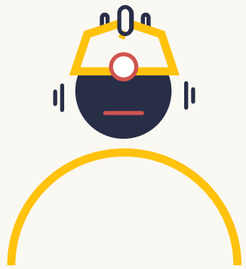
Empathy

Empathy and the ability to connect are certainly important in STEM careers. The psychologist, Anandi, explained how the ability to empathise is important,

> Empathy and listening skills are the key for a clinical psychologist. Empathy is needed, if you are in this profession for money or other purposes, it might be exhausting. Psychology can be seen as scientific, involving problem solving or critical thinking but you need to consider the human side of it and empathy is key to this profession.

Other professionals referred to the need to connect by using the terms like emotional quotient (EQ) or emotional intelligence

ENGINEER



Mani, cloud computing engineer noted,

EQ(Emotional Quotient), a lot of young professionals seem to lack this, what I mean by EQ is...ability to connect with people, one could be a good programmer, but listening, being open to feedback, considering other views is important.

ECONOMIST

Krishi, an economist, computer science and machine learning expert said,

Both non-STEM and STEM need emotional intelligence. How do I get the label of the data? I need to talk to people. How can I make them talk to you? They are not willing to talk to you...

Emotional intelligence may be more prevalent in non-STEM. STEM guys come across as socially inept.

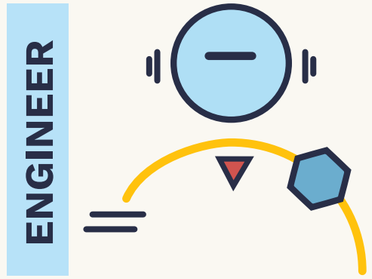
Emotional intelligence is absolutely essential to survive. Nothing is given to you on a platter. You build it with the help of another human. Even the most stubborn person will see it if you put it in a certain way. You provide the insight to them. If I see this guy is not a numbers guy, let me draw a graph with the basic data set, and most likely that will click.

From a STEM perspective, creativity, initiative and empathy by company leaders to ensure efficient workforce strategies and effective learning in employees are recognised as key skills among the workforce (WEF, 2020 b).

Ethical and moral responsibility

This general attitude needs to be reiterated in the context of STEM careers, particularly since narrow technical and financial considerations can prevent people from seeing the consequences of their work with respect to its impact on the well being of others and of the planet as a whole. Only an ethical stance can alert professionals to the human and environmental impact of their work. This is vitally important if humankind is to find ways to work sustainably and reverse climate change. Professionals that we spoke to, have a sense of individual responsibility towards the environment, but by and large seem to have missed the bigger picture. A mere 7% of the respondents recognized the adverse impacts of their work, whereas, almost all industries have an adverse impact on the environment in terms of resources used, waste generated, altering land use patterns and drastically altering natural environments.

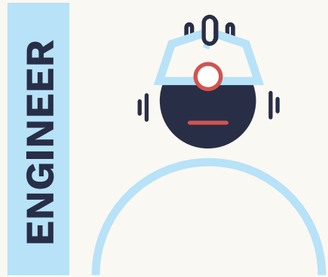
An ISRO engineer who was interviewed, did not speak of the adverse impact of space programs and rocket launches and instead spoke about green practices in the office like saving paper by printing less. Other professionals are more aware.



An IT professional, Naresh, reflected,

E Waste is a hazard- we haven't thought about and managed it. The more hardware we use then there is more carbon emission, the power consumed, the server for the data storage, cloud computing... servers/ data- more users, there is damage, E-waste is a big problem. Consumption of data is also a damage. Sustainability is a serious issue. In tech and IT there is no emission like in automobiles. For e.g- Amazon online ordering- there is a big server which is maintained somewhere, which generates unbelievable amounts of heat, carbon emission, etc, etc.

IT companies are not bothered so much about green energy or green buildings. Corporates are bothered only about reducing cost.



Naresh seemed to have a much deeper understanding about industrial impact although he continues to work in industry. Naresh seemed to hold the view that all the technology industries ultimately lead to environmental problems. Reflecting on his own work and sustainability, he said

I feel I am the wrong person for this question. These kinds of career paths will damage the earth in the long term... is what my personal feeling is. They will damage the earth and also damage the society in the sense that these industries lead to more urbanization. We have to find out career paths and career options that can be more earth friendly and which can decentralize our society. Which can encourage people to go back to their villages and roots. Whether it is possible with science and technology I am not sure.

Apart from the ethics of sustainability there is also a concern about misinformation and several professionals in various fields spoke about the need for fact checking and being morally responsible for the information they shared.

Krishna, IOT expert said that what was needed was:

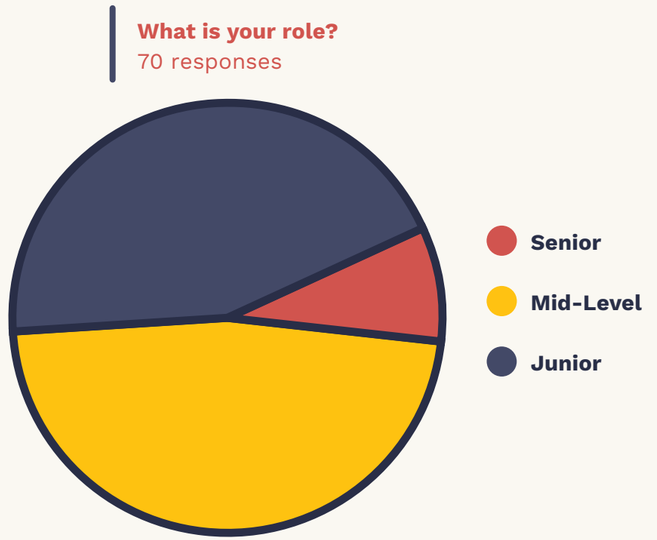
Ethics and morality. In the world of deep fakes, it is important that the students are educated on what is considered ethical and what is not.

STEM and Careers

Through the survey and interviews, the study mapped the narratives of people to understand how they built their careers. This gave us insights into different careers and the influences that shaped careers and mindsets.

Background of people surveyed/interviewed:

Survey questionnaires were mailed out to people that were directly or indirectly known to the researchers and keeping in mind the need to cover a wide range of careers - both STEM and non-STEM. Out of the 70 respondents who responded to the questionnaires, most were in senior or mid-level positions. The spread in terms of seniority of positions is indicated in the chart below.

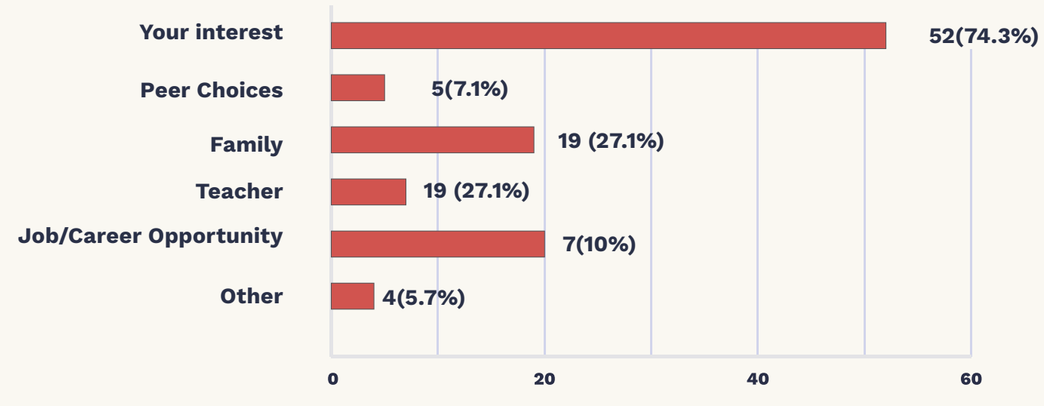


This distribution is important to keep in mind while analysing the data. The fact that the data is drawn majorly from people who are in mid-level or senior level positions, indicates that their views will be of those who have experienced relative success in their careers. The data would have filtered out those who had moved out of their initial specializations due to various factors like job dissatisfaction or career failures. This is one of the limitations of the present study. On the other hand, this data from people who have experienced success in their careers will be better able to provide clear pointers about the constituents of a rewarding career path.

Factors that influence career choice

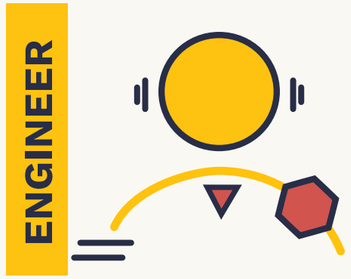
Typically, young people select a stream or specialization at the tertiary level keeping future work options in mind. A number of factors can influence the choice of careers. These include personal interest, peer influence, advice from family, teachers, and job opportunities. Factors other than these may also influence an individual's choice for higher studies and career. Through the questionnaire survey, we sought to find out the influences that shaped an individual's choice of specialization. When it comes to factors influencing choice of specialization, three fourth of the respondents indicated that it was their personal interest that was the reason. This was also the main reason mentioned during the interviews. However, as the figure here indicates, other factors also had an influence on people's choices.

What motivated you to choose your major or specialization in college?
70 responses



Interviews provide us with deeper insights into the way careers are chosen. There were outliers in the response to the survey question about factors influencing career specializations. Career counselling and internship with a research scientist at Indian Institute of science were two of the responses that are worth noting.

Some of those interviewed, mentioned the role of a parent, special teacher or mentor, who shaped their attitude to their work.



Several of the professionals interviewed spoke about changes that have been brought in due to automation and machine learning. Dinesh working as AI scientist said how she chose her profession considering how data science and AI were emerging,

I think I was basically at the beginning of the wave where you know the NIH changed policy and they really started forcing people to consider a wide range of careers. Having said that, I think that I also got lucky - at that time data science was becoming - like there was a lot of hype around data science -massive sort of job market in which there were not a lot of people.

Through the interviews it became clear that careers in diverse fields are changing under the influence of technological advances.

4.1 Advances in STEM and the future of work

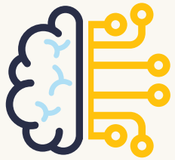
This part of the report focuses on the following questions: what are trends in jobs due to advances in STEM and what are the mindsets needed for those jobs, and what are our respondents doing in response (last 6 months, now, next year) to stay relevant to the world of work?

With regards to careers that are emerging in the future, STEM careers such as Artificial intelligence (AI), machine learning, big data specialists, internet of things specialists, and software application developers are projected as important careers of the future globally as well as in the Indian context by multiple reports. From the Indian context, there is a continuing shift of resources in businesses towards big data and digital products (LinkedIn Emerging Jobs Report, 2018). In India, almost half of the above professionals are qualified upto the undergraduate level only and receive most of their training on-the-job, making it a highly remunerative career choice (LinkedIn Emerging Jobs Report, 2018).

Keeping emerging careers in mind, the career profile of those interviewed fell broadly in the following categories - STEM research, finance, digital marketing/content development and communication, cyber security, healthcare, and agriculture. The educational spread was: bachelor's/undergrad (7), masters/grad (12), and doctorates/postdocs (9). This section gives an overview of the trends in these careers as gleaned from interviews, as well as skills needed for the future.

Professionals from various fields, both STEM and non-STEM mentioned Mathematics, statistics, data handling and computing - as required skills across careers.

Artificial intelligence, machine learning and deep learning are going to make their presence felt in several areas, from health care to finance. Krishi, whose work straddles electronics, IOT and healthcare, unpacked these terms as follows:



Artificial Intelligence has been a field around at least since the 1940s or maybe even before. Today, it has come to be associated with AGI or Artificial General intelligence, where machines would be capable of human-like thinking. This year (2020) Nobel laureate in Physics, Sir Roger Penrose, believes unless machines are capable of exhibiting "consciousness", true AGI will remain a dream. By some estimates, we are about 50-100 years away from achieving that despite the advances in the area such as reinforcement learning.

Machine learning is that branch of AI that uses data to predict the past. It primarily learns from the past and uses a trained model to predict or draw inference on data hitherto unseen by the program so far. It is largely what is called supervised learning where data and correct labels are both required for training and inferencing. Today, due to the technological advances in hardware such as extensive use of powerful and cheaper GPUs, it is possible to solve a certain set of problems. The interest in STEM fields across the board is to deploy machine learning to various subfields of science and engineering.

Deep learning is simply a subfield of machine learning where a specific architecture of the system is driven by our current understanding of how biological neural networks work in our brains. Hence, these are also sometimes referred to as artificial neural networks.

What follows next, indicates how careers in various fields are responding to the latest STEM advances.

Careers in:

Research

Career in STEM research in the future will continue to ask for deep specialists and good generalists. Competency in the domain of science, data and computing is also expected. So, being able to handle big quantities of data and running high-performance computing jobs become desirable skills even if they can draw on the relevant expertise of others. Interdisciplinarity and a systems approach to problems were also mentioned by two researchers.

Giri, chemical engineer pointed to three trends: interdisciplinary nature of science (a biologist knowing math); imaging and technology allowing us to do better investigations, and niche companies supplying you with a wider range of technologies. He also spoke of biology as the new frontier.

Research

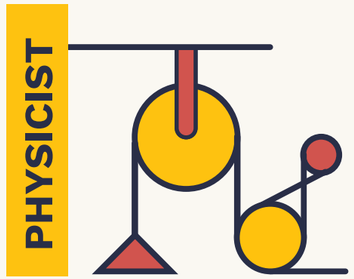
There are concepts of engineering and mathematics that are applied to design of motorcycles, cars or planes, and that is a well-established concept. These concepts are increasingly applied to studying biology. A chemical engineer applies the principles of a chemical factory to the human body, and it is now called systems pharmacology....

The objective is to understand biology. The state of knowledge in biology is not like that of physics. We are still in empirical observations and forming a framework. One thing that is changing is that a lot more technology is being applied to the study of biology. The capacity to analyse the 3-D images – imaging power and technology was not there. The capacity to look at individual cells and individual molecules has changed dramatically in the last 15 years. Everything I did in my Ph.D. is now obsolete. Things are different every day.

The capacity to do measurements is much better – in the 80s – for instance, people had to construct a gel and it was routine, but you had to do it yourself. Now you have kits, and specialized companies will do it – they will measure the RNA in the cell – they will do the genomics. Niche companies have helped individual investigators to access a wider range of technologies.

The biologist has changed. Earlier, in the year 2000, there were hardly any biologists who understood any mathematics, whereas the current generation of biologists are very familiar with mathematics. Biologists are much more interdisciplinary than they were earlier and the technology has changed. These are the dramatic changes.

The other things are common to others too – ability to handle data has changed. My fellow Ph.D. students had to write code to analyse images – now it is routine.



Vanita, the physicist says:

Technology has a very high influence – I need a lot of computing power, do parallel computing, do high-performance computing jobs. Writing code in local computers is one thing, scaling it to a different level is a whole new challenge. I am looking at the statistical significance of the data.

Careers in:

Finance

Krishna, a machine learning expert, who works in financial services, talked of how data sizes have exploded, and that you have to use algorithms to work with huge data sets, and that the skills from a statistics perspective is to be able to group and label things. Even the machine learning models will be automated - he referred to auto-machine-learning. He is a trained economist who taught himself computer science and is now wholly focused on statistics and coding.

Finance

Now, we are using huge data sets. We have to come to using algorithms like gradient-descent.
The main skills from a statistics perspective – is how to group things. How do you cluster them? One of the major techniques is grouping. Once you group- can you find a label?

After all the data is collected, and the data is cleaned up, what we do finally takes 10-20% of the time. As years go by, that particular work will disappear– lots of articles are written about auto-ML. The machine learning models can be automatically done, and the computer can fine-tune and deploy it automatically. You don't need human intervention- where you need a human being is – understand and define the problem, and say where the data sets are, and to tell – that is the datasets the guy says is useful, but there are others which are more useful.

Careers in:

Marketing & Communication

Even non-STEM careers like marketing have been totally transformed by data and numeracy. Rishi, a vice-president in digital marketing, unpacked how all aspects of marketing (strategy and brand management, traditional media and digital media) are now quantifiable, and that people with old-style-offline-marketing skills are now bad hires, because they bring the wrong thinking to the table. Numeracy and data skills are key.

Marketing & Communication

Marketing can be divided into three aspects – the strategy and brand management, and what channels are you using to market to your target audience – traditional media, and digital media.

As far as marketing strategy, branding, positioning and persona development – it has largely remained the same but because of technology – development of data and tools – it has become much easier to quantify what was earlier not so quantifiable. You are able to use tools to develop audiences, you can capture people's reactions to television ads in a much better manner using technology.

Traditional media – media planning and buying – that aspect has always been numbers oriented. Numbers drove your decisions on what you want to spend and how much. This has become more accurate in reporting people's reality – earlier this was self-reported, and there were inaccuracies. Human errors would creep in, but now, it is built into the TV system - there are heat maps and other ways to capture the data – – how many people have been reached, are they really engaging with your ads, how many times have they seen it. ... There are automated models that make decisions on the fly about where you should be spending.

The third area is digital or performance marketing – acquire leads – search marketing, display marketing, video, youtube – this is entirely quantitative – measured – and driven by numbers.
Tools are increasingly sophisticated, and what used to be collected in spreadsheets is now automated. Numeracy and being data driven has been the revolution.

...People have to upskill. It is now better to not hire traditional marketing people – they don't have skill sets, and they bring the wrong thinking to the table. The consumer behaves differently now, and they don't understand it.

Content development or creation and communication are also fields that are emerging as important with the requirement for content writers and developers across media, public relations (PR), digital marketing and even the IT industry. With the growing importance of STEM careers and education, content creation for STEM education itself is considered as an important current and emerging career. STEM learning content combined pedagogical techniques is in rising demand ("High quality content", 2020). Similarly, careers in communication are of growing importance owing to practically every field which requires individuals who are efficient communicators in various forms. STEM skills such as data analysis and interpretation are very useful generally in a communication position and particularly useful in fields such as science communication and journalism.

Related to the above two sectors are careers in design.There has been a growing demand for design professionals such as graphic designers in the past few years owing to the rising need and importance of visual and digital content. Graphic designers are also in demand owing to the importance of aesthetically producing products and information which help businesses communicate effectively with their clientele. Basic drawing skills, creativity, detail-orientation, knowledge of graphic design software as well as good listening and communication skills are considered important in this field ("Showcase your..",n.d). Career opportunities for graphic designers can be found both in the public and private sectors in roles involving design for print media, mobile device applications, websites, electronic publications and videos. Design plays an important role in marketing, media, advertising, publicity, promotions and communications ("Graphic designing..", 2019).

Careers in:

Cybersecurity

Saini, Cybersecurity expert talked about how cybersecurity is changing and what skills are needed. She said that cybersecurity has a range of tools, but the hacking methods are getting more sophisticated and more system-driven. Corporates and countries are now hacking each other. Attacks in an IOT environment can come from different spaces. In such a scenario, a hacking way of thinking as opposed to a structured way of thinking, and a shaky computer science background as opposed to a deep dive into computer science will not work for the cybersecurity specialist.

Cybersecurity

Most companies have a lot of cybersecurity tools -firewalls, secure web gateways which protect users when they go to the internet, anti-virus software on your laptop. The focus on the past was on preventive tools.

Over time the focus is now shifting to detection and remediation. You can detect something called a vulnerability or a defect. A vulnerability is about something that has not happened. A threat is something that has happened and you are responding to it.

In spite of all of these tools – for prevention, detection and response, the level of threats has gone up – what is an attack against a person or corporation, to what is an attack by a nation. Country A might use cybersecurity to attack Country B's nuclear services. Company N was attacked by Country K. Corporations are having to protect themselves against nations. They had data centers that were like a fortress – now you have a cloud, and shared data. So, they are getting slammed in both ways.

What are other technologies that are changing, that is changing the cybersecurity option?

Cloud and Internet Of Things (IOT) are changing the way data-security is being done. Operational Technology(OT) is about attacking infrastructure... for example, the electric lines that are coming into a city. A lot of the focus is on cloud. The next area – nascent area – is IOT. If someone can hack Nest[4] devices, they can almost get into any company. All network devices – the problem with IOT is that they are identical. It takes a hacker one way to hack something, you can hack something else in the same way.

If someone hacks production, I am going to have financial loss. I have multiple power lines, I have multiple internet connections etc. There is this idea of risk measurement and risk assessment.

The biggest technical skill is the ability to learn. Change is the way of tech. Three years from now, it is going to be different. The interest and curiosity to learn is a really big skill...

Even if you are an engineer, or a product manager – there is a structured way of thinking, and there is the hacking way of thinking. The code has to be robust enough to know when to say – it is like a stabilizer – when the TV is not getting the right input, it should be shut off rather than get burnt. To write code that has an inbuilt stabilizer – a code that is written to trap errors, rather than code that keels over. Many undergrad kids don't touch an operating systems course. They think...why do I have to worry about a file system? There are a lot of jobs where you don't need to know the whole system. In cybersecurity, you need to understand what happens in every layer.

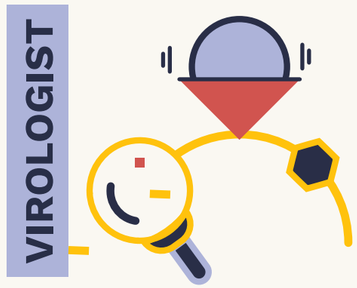
4 Nest devices are electronic, programmable and self learning Wi- Fi enabled devices

Careers in:

Healthcare

This area has been revolutionized by the development of automated tools and instruments. Data and statistical thinking is also playing big roles in healthcare. Labeling and machine learning is automating tasks.

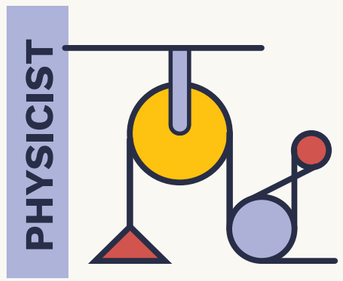
Healthcare



Vani, virologist - a key player in the Covid-19 testing labs in the east (Jharkhand) said:

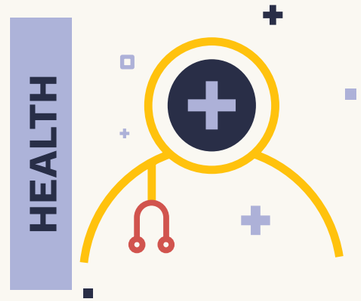
We now have point-of-care instruments. Discovery of new instruments, and discovery of new organisms – both are impacting the field.

The PCR test – this was unheard of – we were only 2 labs partly doing it – now many labs have come with it. It's the development of the instruments and manpower. Lots of scope for development, and rapidly changing. We are reporting faster and accurately – automated tools have come. We can eliminate human error with those tools.I started with 25 tests a day (Coronavirus) – today, 1000 – 1200 tests a day



Nisha, the Immuno oncologist indicated that she is training herself to learn data analysis and update on the use of the latest equipment in the lab. Vihan said:

There is huge data now and that is useful for cancer research. We can now do big trials, going forward I think I need to learn to analyse data better...wrt to lab equipment , they are really advanced, as we receive them, there is a demo and each of us are responsible for an equipment initially and we train ourselves to use them. I think there will be more and more advanced equipment and lab materials coming ahead....



Rishi – electronics engineer, IOT and healthcare entrepreneur listed the following technical skills: mathematics, statistical inferencing with focus on causal inference, computational thinking, and programming. He explained the idea of data science in more detail - using the example of healthcare:

Data science was a term coined in the late 2000s – but it was not that we were not doing data science before. We were, 100 years ago. It is in appreciation of a particular field, and we have data to look at.

People take chest X-rays to detect pneumonia. You had a radiologist who would look at the X-Rays to say whether it was bacterial or viral pneumonia. Now as a matter of standard of care, all hospitals and polyclinics take this data. You are asking a question, instead of a radiologist, can I train some algorithm to look at the data and make a prediction or inference if the person has viral pneumonia or not. Primarily we need data, and we need labelled data. It does not suffice for me to say that I have 10000 X-rays – I need some radiologists to have annotated the X-rays to say this person has viral/ bacterial/....Once I have the labels , I have the data then I can train the neural network. You ask the right questions. Data science is a broader framework and sometimes, the data will change the way you ask questions.

I have 10,000 X-rays, I have labels and I train a network (traditionally called machine learning). After the training, I am saying look for the specific features that have labelled as having pneumonia and tell me whether I have pneumonia or not. The machine will start abstracting things across chest X-rays – if I give the machine – an X Ray which has not got a label it can predict with certain probability that the person has viral pneumonia or not. This idea has been extended into almost every field in science – even in ecology. It can be about prediction of floods, afforestation and deforestation- you can take images and predict the most likely next event.

Through secondary research, we find that within the health sector, telemedicine is emerging as an important career owing to the need for universal access to healthcare services. It calls for the intermeshing of skills and knowledge in the field of medicine with technology, primarily by means of telecommunications and AI, through treatment models such as remote patient monitoring (RPM). Particularly with the Covid-19 pandemic, the demand for telemedicine has increased and is expected to grow globally at an even more rapid rate by 2024 than projected before (India Today, 2020). On the similar lines a mental health expert, Bharath highlighted the increased use of virtual counselling and how it has made the counseling and counsellors accessible.

With the global rise in cases of mental illness along with the lack of qualified mental health professionals and resources to cater to, careers in mental health related fields are emerging in importance globally. Psychology, mental health counselling, psychiatry, social work, nursing and so on are mental health professions which are rising in demand. In terms of educational requirements, a bachelor's degree in a mental health field is suitable to enter the workforce, but a masters degree is desirable. Experts in the field report that empathy is the most important trait required to excel in the field, followed by compassion, curiosity, critical thinking and so on ("Making a Difference....", 2020). Empathy, compassion and creativity as future skills and attitudes were discussed in depth in the section on STEM mindsets.

In the Indian case, the future of mental health professions in the country is prospective given that the opportunity to deliver services through the usage of technology, especially with the use of mobile wireless technologies is available owing to the largely young and technologically sophisticated population (Yellowlees & Chan, 2015). This also comes with the adequate experience that India already has in telemedicine, tele-education provided to medical colleges and mobile telemedicine units set up in disaster relief camps.

Mobile mental health care is progressing fast globally and India which often has the highest number of suicide deaths and a young population has the need for more qualified mental health professionals who are equipped to handle technology to increase mental health treatment penetration.

Referring to technology in the mental health space, Binita said:

In the mental health space it (technology) has been a boon to me in this year of lockdowns and social distancing, where I have really just got on the internet and done my work. I have been there, kind of ... been there with people and supporting them. Receiving support as well. And been economically sort of stable because of technology and it's really been a blessing.

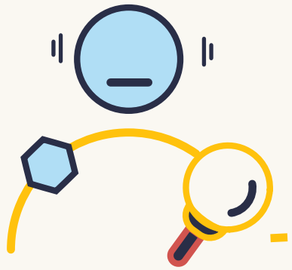
Careers in:

Agriculture

This area is getting transformed by new advances in biology- transgenics, gene editing, genomic selection, and bioinformatics are bringing in revolutions in the area of food production, a field that is growing and attracting more people into its fold.

Agriculture

BIOTECH



Manish, plant breeder and biotech expert (agriculture) talked of trends in his field,

It is plant breeding, management, production, processing crops into foods...so we are now in the food industry. Five years back, the food industry was not even 7 billion dollars – today it is 30 billion dollars. Production, processing and marketing – the middle class is bigger than the US population. Then imagine, the first place where they spend – added income – is proteins.

Increased middle income group will bring a lot of demand for food. It is a 90-100 billion dollar industry - It is like the electrical battery industry – the ceiling is not there.

What do you see shifting in your field in the next 5 years?

GMO – genetically modified organisms. Crops are getting infected by diseases and pests. Every crop is being sprayed to protect crops. We pollute the land when we spray the pests. If I transfer a gene to a crop, and if the gene is toxic to the insect only, the toxin is specific to that insect variety, then transgenics is providing a solution specific to a problem.

There are methods of risk assessment of transgenic experiments. There will be 14 to 15 studies on whether there is an impact on poultry, fishes, rabbits, goats, buffaloes, when you extract oil, seed cake – all these are done before we allow this to happen. The scientific panel then comes to a conclusion that the risk assessment studies are over, and the transgenic event is safe. This is very safe.

The growth in this industry is going to be great. Every organism has a DNA. Every crop species has a genetic map – grain type is connected to a particular DNA, or genetic map place. Huge work is going on crop genome mapping. These maps are going to drive which character I'm going to focus on – should I overexpress it or under express it - these molecular markers are going to drive the industry.

Gene editing is also a big space. Amino acids join together to become a protein. People are isolating genes for different characteristics. If they edit the frame of code and reintroduce it in the plant, we are making the plant express better. No toxicity involved in it. It is a bio-safe phenomenon and safe. If I create a high-tillering rice, will it become a weak stem, then that is a problem. Gene editing coupled with fool proof framing is an exciting phase.

These are very specialized skill sets – in biotechnology. These are called tools to improve plant breeding. How the edited gene will behave across the environment, the lab guy cannot predict.The performance in the field, that has to still be observed. A person will edit a gene in the US, but this will not do well in India. Again, one working in Karnataka will not work in Faizabad. You license the gene edited thread into different varieties. This innovation has to be transferred to different farmers. These technologies improve the precision, efficiency and speed of plant breeding. This is how science is emerging.

Genomic selection is another trend. A plant breeder will create variability and select the best variability for human use. Gene combinations will be millions in the species. The DNA profiles can be pointed out and filtered. You can create millions of combinations and then filter it out to the desired level, and then when they bring the selected genes to us.

Bioinformatics is also another field. Genetic codes have to be read and superimposed and analyzed. Mathematics is also important. Bioinformatics is not mycore skill. I outsource it to someone.

...There are ethics in plant breeding. There is a framework for a plant breeder – wherever domesticated species are needed for human survival and development, we have to do it. We now have cauliflower, wheat in hotter climes. Wheat is now grown in several parts of Karnataka. We have developed heat-tolerant cold crops to enable a diverse variety of food to be available to people in all places. We are manipulating cultivated species.

However this techno-centric view of agriculture is not shared by others in the field. SP, agriculture economist and researcher, pointed out that agriculture practices are not monolithic and there is a great deal of diversity to be found in the farming sector. She said that there is no one description that can be given for the term “Indian farmer”. Elaborating further she briefed about the characteristics of different kinds of farming- city farming is very demand driven, whereas in the peri-urban areas greenhouse cultivation may be practised and even precision farming. These may be what the plant geneticist may have been referring to in his interview.

However, Apoorva estimated that there may be over 120 million small family farms which practice more or less subsistence agriculture under resource constraints. These are facing distress due to de-skilling, ecological degradation and climate change. She felt that these farms have to be helped to stay on a firm footing or there will be large scale ecological damage as well as huge human costs due to outmigration. In this sector, she felt the key skills to be promoted were the skill of understanding deeply the local ecosystems and the interrelationships between the flora and fauna through careful observations. Current economic policies are leading to a loss of traditional knowledge and some of the sustainable farming practices are in danger of being lost. On the other hand a revival of such practices holds out the hope for building climate resilient food security for a very large number of people.

Careers in:

Sustainability

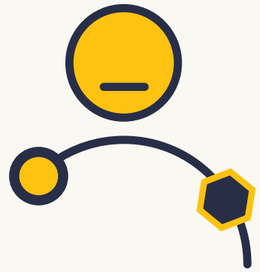
Over the last five decades humans have been using up more resources than can be regenerated and generating more waste than can be absorbed (ILO, 2017). This form of development has resulted in deadly pollution of air, water and air, destroyed fisheries, damaged soils and led to irreparable loss of biodiversity. Probably the biggest threat is the rapid onset of climate change brought about as a direct result of our present patterns of production and consumption. Climate change will result in many predictable and several unforeseen catastrophic changes to ecological systems and will ultimately threaten human existence.

“The future of work and society must therefore entail an environmentally sustainable development path. The promotion of economic growth and decent work can be achieved in parallel – not at the expense of –the environment and the natural resource base that supports economic activity and livelihoods. The Sustainable Development Goals articulate this challenge, highlighting how in the medium- and long-term decent work is only possible in the context of environmental sustainability” (ILO, 2017).

What kind of careers may open up in the future given the prospect of climate crisis and widespread ecological damage that is threatening to undermine the very basis of human existence?

As society becomes more concerned about climate change and other ecological crises technological solutions are beginning to emerge as a new area of enterprise. A sector that is rising in demand are green jobs, owing to the growing concern for the environment and sustainability. According to the ILO, green jobs refer to jobs that help to protect ecosystems and biodiversity, reduce energy, materials, and water consumption, decarbonise the economy and minimise or altogether avoid generation of all forms of waste and pollution (ILO, n.d). There are career opportunities for revamping existing practises in traditional occupations such as agriculture, manufacturing and construction. Forest and environment agents, Prevention of labour and environment risks agents, Waste classification workers, Environmental and forest technicians and Electricity technicians are some globally emerging careers in the sustainability and green occupations sector (Cedfop, 2019). Green architecture and sustainable housing is also projected to be an important future career, although mostly from a mature economy perspective (Pearson, n.d). It is projected that STEM skills in the fields of microgeneration and skills related to renewable energy need to be integrated with the existing skills and expertise in the engineering of buildings (Pye &Aggett, 2010).

A combination of knowledge about sustainability, occupation specific STEM skills and skills of leadership and management are important to take part in the green economy through green occupations (SpringerOpen’, 2017). The focus on sustainability and efforts to slow down climate change is also adding to jobs to the emerging green sectors such as in renewable energy, energy efficiency or recycling. Careers in the realm of the emerging green economy are also seen as secure and having equal opportunities for men and women along with adequate labour protection (Mohamed, 2020).



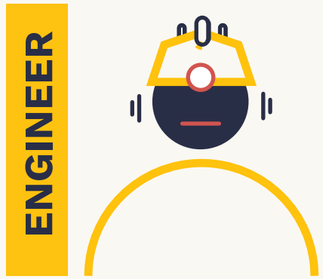
One of the respondents in the study spoke of this emerging sector,

My startup focuses largely on energy efficiency issues in the commercial sector and develops products and solutions for them to be sustainable.

To conclude, jobs in sustainability or the Green sector, are likely to see a significant uptick and along with the general STEM mindsets like problem solving, and creativity these jobs would require people with interdisciplinary and systems thinking skills. People in green jobs would also require the ethical values associated with sustainability thinking. It is also likely that green entrepreneurship will become a growing trend - we are already seeing the beginnings of this.

How are people preparing themselves for the future?

Technology advances like automation and AI are entering almost every field as discussed above. This will bring opportunities to those who can find their way in the new age. Professionals need to continuously learn and update their skills. Upskilling and reskilling are two changes that are considered important from a future of work perspective.



Speaking of changing requirements for skills, Naresh, a software engineer said:

My field is very dynamic. Job roles are constantly changing even within the VLSI industry. And within VLSI, there is more and more automation coming. As I told earlier previous generations used to design by hand at a very micro level, now it's all at a very macro level and a lot of re use is happening, one has to constantly be aware of what is happening in the industry and change oneself accordingly. It is quite possible that in the future, in the next generation, not in this generation I would say may be my grandchildren's generation, all this VLSI chips are done by computers themselves. It is quite possible Then different types of skills will emerge Ultimately someone will have to be there to guide the computers or harness the power of the computation to achieve what is required. That's where new skills keep emerging.

Through the survey, we asked people the kinds of training/learning/coaching they were doing - past 6 months, and 1 year in the future, and what skills were they trying to build right now?

Answers to this broadly looked at management issues and domain knowledge. Most were looking at skill development purely in terms of organizational needs.

Management

Framework thinking

Lean management, change management, Agile technologies, quality, design thinking, planning, data driven decision making, long range planning, strategic thinking, statutory and compliance

People skills

communication across organizations, not judging, team leadership, executive coaching

Writing

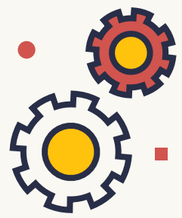
Domain knowledge

Specific domain courses

Royal Society of Chemistry teacher developer and K-12 certified educator, search marketing, digital marketing, doing Polymerase Chain Reaction (PCR) of various types (Virology), a six-monthly proficiency training and check on simulation devices to enhance and ensure safe handling of an aircraft, behavioural event interviews, compensation analysis, recruitment, finance, accounting, intensive seminar on moral psychology, lactation skills, movement based therapies and techniques, mental health trainings were mentioned. Each of these are very domain specific - for example - PCR training makes sense for a virologist, while a behavioural event interview training makes sense for a HR specialist.

Technical skills

AI, machine learning, Deep learning, programming tutorials in R, development of mobile apps,web security, cyber security, Kafka, Azure basics, Swagger, Enterprise JavaBeans, Java Message Service, chatbots, online metrics, our backend/frontend software, tech to identify fake news, fintech are current technologies and trends that people are catching up with.



Statistical skills

Data analysis workshops (in frequentist and Bayesian statistics), training in hypothesis driven thinking, analytical hierarchy process.

Increasingly, employers are providing additional training and development opportunities to their existing workforce in order to fill skills gaps, about 54% in 2018 as compared with only 20% in 2014. (Madgavkar, Krishna & Ellingrud, 2019) As mentioned by the professionals interviewed in the study, in the age of automation, big data analysis and machine learning, men and women need more than ever to have the right skills, to be mobile and adaptable, and to be tech-savvy. However, women may also be at a disadvantage compared to men in the new types of jobs emerging out of the new wave of technologies. Jobs such as social media managers, data scientists, and drivers on ride sharing apps that did not exist 20 years ago but have emerged as the result of the digital revolution. Evidence from the United States shows that in recent years more than 60% of newly created occupations have been in male-dominated fields.(Madgavkar, Krishna & Ellingrud, 2019)

Barriers faced by women in STEM careers are discussed in the next section.

4.2 Women and STEM

Women and girls continue to be underrepresented in STEM careers. There is wide variation among countries and across STEM fields when it comes to women's participation. The gender gap in STEM is a missed opportunity for economies and an inefficient allocation of labor and talent (Alicia et.al, 2020).

Gender gap in STEM studies from the US state that the gap may arise from several factors: difference in abilities, gendered role, socialization and peer groups, and gender stereotypes (Reinking & Martin, 2018). The 'Glass ceiling effect' and 'leaky pipe' representing gender discrimination due to perceived cognitive ability differences in the Western context may not be the case in India where familism and domesticity are important factors (Sujatha, 2017).

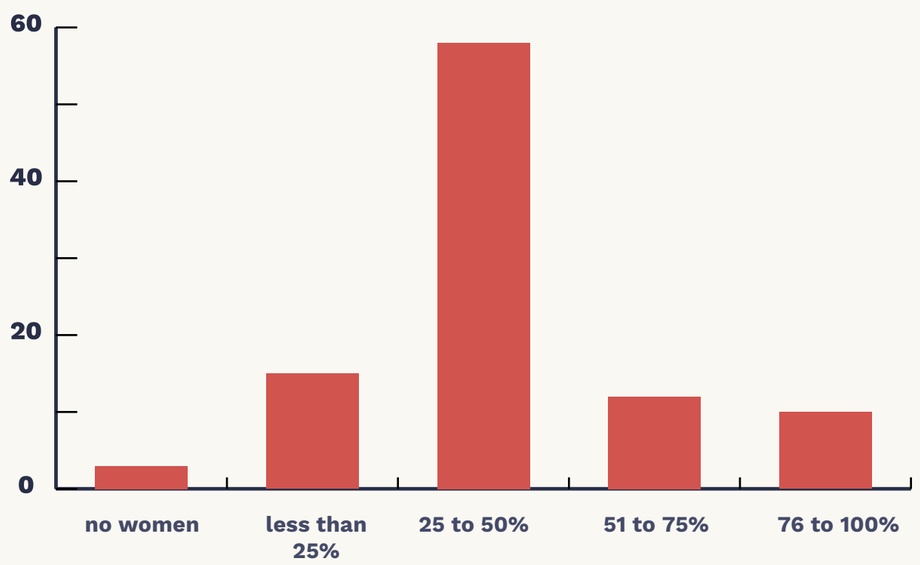
Technology can be an enabler for women by opening up new economic opportunities. Many women are now self-employed in what is popularly known as the gig economy, by leveraging technology that enables new and more flexible ways of working. However, women lag behind in access to tech, the skills to use it, and participating in its creation. Globally, men are 33% more likely than women to have access to the internet. Fewer than 20% of tech workers are female in many mature economies. Only 1.4% of female workers have jobs developing, maintaining, or operating information and computer technology (ICT) systems, compared with 5.5% of male workers, according to the OECD

(Madgavkar, Krishna & Ellingrud, 2019)

This study explored the gender gap in STEM careers through the survey completed by 70 respondents and through detailed interviews with 28 professionals in different fields. Professionals were asked the percentage of women in their organisation and the reasons for gender gap if present.

The graph below shows the percentage of women in different organisations as reported by the survey respondents

Percentage of women in organisation

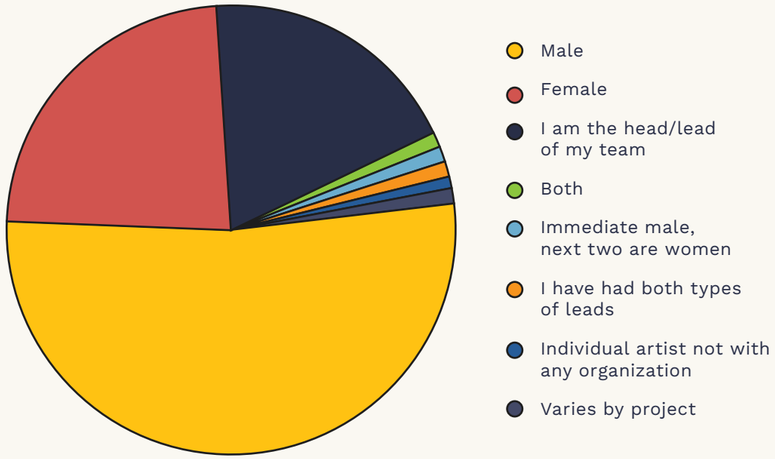


Professionals who reported more than 70% women in their organization were all in the education sector. Professionals in other sectors reported 50% or less women. People who reported the least women (less than 20%) in their organisation were in engineering(automobile, construction), technology and pure science.

The reasons for poor participation of women in different fields were stated as societal stereotypes (27 %), family pressures (23%), lack of organisational support (19%) and difference in abilities (10%). Various other reasons were mentioned by individual respondents.

The professionals were asked whether they reported to male or female leaders to find out if the gaps widened at the leadership level. The graph below represents the same.

Whom do you report to?
70 responses



51.4% mentioned that they report to men and 18.6% mentioned that they report to a woman lead. The gap seems to widen as the professionals move up the ladder. Of the 22.9% respondents who said they were leaders, half were women.

A scientist at ISRO mentioned that there are 30-40% women at ISRO. He noted that,

> “Women are project directors, however there is no lady chairman, so far. The reason may be, promotions might be delayed for women, they tend to avail maternity leave or parental leave for child care, so their career growth might be delayed”.

This trend is well recognised across sectors. India ranked second in the world’s top 20 countries with the highest number of female CEOs. However, the share of female CEOs in tech companies in India is only a miniscule 5.01%. Women also constitute only 14% of the 280,000 scientists, engineers in research and development institutes in India (Sanchita, 2020).

A study conducted by Kelly Global Workforce Insights (KGWI) found that 81% of Indian women in STEM jobs perceived gender bias in performance evaluation and that women tend to drop out of the STEM workforce around the years of childbearing or at mid-management levels which leads to fewer roles in top management in STEM which they occupy. The study also found that 42% of women leave technology companies post 10 years of experience compared to only 17% men (Business standard, 2016). Thirty percent of women in science reported that their career adversely affected their family commitments and responsibilities and forty-seven percent cited the same as the reason for refusing to accept challenging opportunities in their careers (Niti Aayog, 2017).

How women navigate careers

Detailed interviews explored the reasons for low participation of women in different careers and reasons for women dropping out. The interviews shed insights on how women could navigate high-tech careers. What emerged was the need for changed mindsets at four levels: societal, organizational, professional teams within organizations and individual.

At the societal level, the general mindset that women need to give up their career for the sake of child rearing or caregiving needs to be challenged.

Families could pitch in by having both men and women share the responsibility of childcare, and be supportive at home of women who are working or wanting to get back after a break.
Organizations could create systems to support women who want to return to work after childbirth, rather than viewing the temporary break as a setback. Workspaces should provide childcare facilities. The National Center for Biological Sciences, Bangalore has managed to retain its pool of women scientists by providing excellent childcare facilities within the campus. Secondly, organizations could insist on hiring women to offset the statement that ‘ suitable women candidates do not exist’. This would force managers to look for women employees rather than stay with their biases.

Within the organization, professional teams need to create spaces for women to be part of the office network - if it is not possible for them to be part of the male watering holes, then there could be alternate ways of networking. Male managers could be made aware that women are left out of the groups, and try to include them in safe spaces for discussions on work. Women could create their own networks.

As individuals, women need to challenge stereotypes and be comfortable with their own femininity, as mentioned by a woman data security engineer. According to her, women should focus on contributing to the company’s goals (making money) and carve a niche for themselves. The director of engineering in chip design also spoke 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. Lastly, women ought to view their career as a marathon, rather than a sprint, and pace themselves.

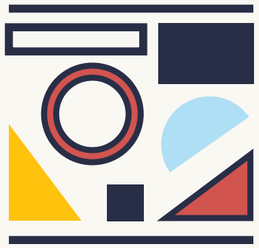
Some women professionals mentioned the role of a teacher in their career - for aspirational STEM careerists, it is important to actively and purposefully build such teacher/mentor networks to help them grow.

Perspectives of professionals

During interviews professionals provided several insights into how women navigate their working life and the issues they encounter.

Women in art, design, communications and digital marketing

DESIGNER



Graphic designer, Tanu, spoke about lack of visibility and male domination in the work space:

There are a lot of women in design- but how many are visible? In the UK, there were much more women in college, but in the workplace in India- there are more men,the professional workplace- it is quite male dominated in India. It's male led. If women have children and come back to work- there is no environment that supports them. It's like- you have made a choice- you left the profession- its like your responsibility to keep up and comeback, I see a lot of women starting their own design studios. There is designentra- conference- it's young, if you are 35 and have a child- I don't think you can stay till night and network. Male centric idea of community... balance between family and work- if childcare is women's responsibility, and if there is no help, it becomes hard, maybe that is the reason for women dropping out.

Women in manufacturing

ENTREPRENEUR

Bala, entrepreneur said,

Many women are capable, some women are supported by family/ husband. My friend's wife runs a paper mill. Women need freedom, they have skills, but some may find difficulty in traveling. If women after work, have to cook and clean – then they can't manage a factory.

Women in Science

CHEMIACL

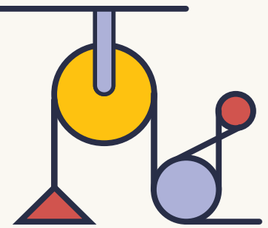
Giri, chemical engineer, spoke of the paucity of women in top leadership positions and identified the existence of subconscious biases as the cause:

There are – in my univ- director, 2 assistant Directors, 5 deans, associate deans, and there is only one woman – the dean that I report to. In a <national level> lab – there is one woman director out of 30, if you take HODs, there is a one out of ten. The ratio is somewhat consistent, and in biology related work – there would be more PIs, but not in the director level...

There is this problem – it is related to how much you like somebody, rather than how much you respect their technical skills. In companies, it is written down and couched in different terms - you have to be a team player, you have to have interpersonal skills. That is different from likeability... It is very much subconsciously associated with something within yourself. There are experiments – even women pick men – it is like an old boys' network. Likeability manifests itself in do you get along at tea, fewer women come to the watering holes than men. It is not that they are barred from the canteen, but they cannot join the group.

I am avoiding any mention of plain harassment. That is of course, unethical. This is more dangerous.

PHYSICIST

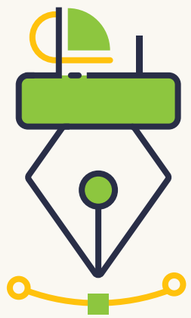


Vanita, physicist,

In my physics department, there are 95 to 100 people. I would say about 21-22 people. 21 to 22%. women. Having women in physics is difficult. We were discouraged since early times.

Women in technology

DESIGNER



Saini, data security expert spoke of the “bro culture” that excludes women:

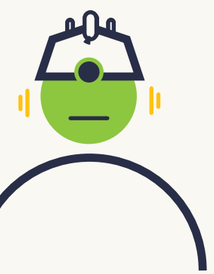
We are looking at women now in serious tech careers. One of the things that women might do is women might get turned off by the bro culture. You might have to type away at the screen, wear a hoodie, and drink cups of coffee. The media represents tech culture in a wrong way.

She elaborated how she has been able to navigate,

I have been treated with respect. As the only woman, I was not part of the network initially. Now the way I personally handle it is – you have to find what works for you in your personality. I am not a shy person. I also realized that when I go into a meeting room, with all the bigwigs and more junior people, I do get noticed as the woman in the room. Life is what it is. There are certain times when it is a disadvantage, and certain times when it is an advantage.

In the end, Silicon Valley is about making money. If you make money for the company, you are making it grow. It should be seen that you are the person fuelling money into the company. Are you being noticed for the work you are doing?

ENGINEERING



Rahim, engineering director, spoke of women being risk averse as a reason for their lower participation:

In my organization, there are 25% women. I am blessed that my key designer – the key architect is a woman. She has done a Ph.D. – technical director in my group. She influences design and writes code. And women in my group – they are all in good positions.

The question is why not 50 percent? My personal thinking is that it starts very early in childhood – in the society where I come from – it is ok for boys to take risks –for girls, it is not ok to take risks – we prod them to be perfect. Any time they are doing something – we want them to be perfect - if you are writing it must be good, if you are doing this – you must be good. We do not allow them to do things where they can fail.

They get this concept that I must be perfect, or I am not successful. But engineering is about failure – most of the time things fail. You are not on your deadline, things rarely go in the right direction.

That kind of uncertainty we don’t let our girls learn early on. World is a certain way, you have to handle it, and you’ve got to produce things. That is why women in tech are less.

Hopefully, in our new generation – we allow our girls to take more risks, it is ok to get less marks, and go do other things except study. Then they will participate in business and engineering.

SCIENTIST

Daman, AI scientist spoke of bias in hiring

The hiring process is biased against women, the way job applications are written they discourage women from hiring. People that are hiring do not make enough efforts to make sure that amongst the applicants they see is balanced, more diverse.

Some companies are trying to change this. Krishna, machine learning expert, economist spoke of hiring policies that insisted on having equal women hired as a way to correct the male bias within his organization:

It has become important in the last 3 or 4 years. Teams are full of men. In tech infra – all of them are men. My boss was a man. After I moved to the next group, we managed to hire a few women. They force – we are not finding enough candidates – people were complaining. In the team of 18 people, 4 were women. That would be 2015 to 2017. In the last 3 years, if you have a requirement, you better hire 50% women. If you have 2 recs, you hire one man, you hire one woman. If you cannot find a woman, don't even hire.

At least the new hires, close to 50% are women. Whoever is working already, it may be 70-30.

MARKETING

Sam, digital marketing expert said,

What I have observed is that women have taken a break or closed down when they have children or need to raise young children. Childcare, support – companies and individuals - have to take this as a marathon rather than a sprint – that mindset and structured thinking around a woman's career is not in place. If you say run at full speed or not at all – then women make the choice to do it not at all or move out, volunteer rather than saying is that a solution- that mindset has to change - women have to look at it - how it is so difficult to work when maternity leave continues to be 6 weeks. The large tech companies in the Bay Area are providing day care and other facilities – it is just – can you work those hours – you need to run at a certain pace – and it is difficult with children. A lot of career growth is about what you do outside of work – are you networking – this additional time in your work –are you upskilling, getting a degree – then women tend to do the minimum and then they fall off – because they are no longer competitive – they are like – one big company – where I can do 10 hours of work and pade rahenge – that means that you are not in a certain path.

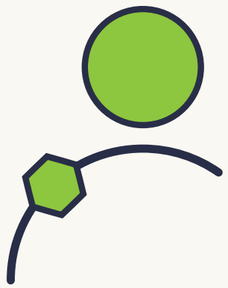
That's the biggest issue – it's not that men are naturally skilled. Girls may have a STEM perception issue, but no innate difference. It is fear at the schooling level, and in the career they are not able to run at that pace. It requires singular focus in the upper echelons – you are not running the same race – you are running an obstacle race, and not a regular race. Women who have succeeded are better – if anything, if they have a personal life and have managed it. A normal support from the husband – someone has to enable you to compete at the same level.

SCIENTIST

According to AI scientist, Anu, women need to be taught to advocate for themselves

I think confidence is a learnt skill. Someone needs to teach you to be confident. Like some people are just born confident and some are not. But the one thing that you could do is to definitely advocate for yourself. Once you get the job, ask for promotions, ask for more money. I have come across studies that show that women often don't negotiate. Always negotiate jobs, always negotiate a promotion. A lot of these things men do and men teach each other to do.we should just be doing the same.

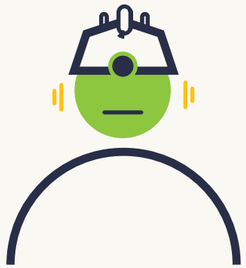
CTO



Hari, CTO suggested,

Organisations need to create a bias in favour of women. Everything that has been done against women over these 100 years, now for the next 20 years it has to be in favour of women. They should be given positive bias, they need to be encouraged more and more.

ENGINEER



Echoing the role of organizations in increasing women's participation, Naresh, VLSI engineer said

Nowadays many companies are adopting wfh, or even flexible hours of work, some companies are slow to adopt these things there you can see a skewed gender ratio. But in companies like IBM where the working culture is very flexible, the gender ratio is much better, I would say it is external factors which are preventing more women from succeeding. The reason is not technical or lack of knowledge at all; it is either compulsions at home or because the company is not supporting them.

This section has discussed concerns about unequal participation of women in STEM careers. The next section discussed the role of education in supporting or hindering the development of STEM mindset

4.3 Gaps in STEM education as seen by professionals

STEM education should increase students' understanding of how things work and improve their use of technologies (Bybee, 2010). In providing quality education, a globally competitive environment, classes and schools must be structured towards 21st century skills and knowledge and skills must be integrated and implemented by educators (Cookson, 2009). With the demand for 21st century skills, it is important that students are able to acquire these skills from the school system and the curriculum, evaluations and content of school education must be accordingly aligned. One of the goals of educational institutions is to prepare their graduates to be workplace-ready. How well are schools and colleges preparing students for careers in terms of STEM mindsets? Towards answering this question,

This section we will look three broad areas:

- **What are the mindset gaps perceived by employers?**
- **What are educational institutions missing?**
- **Pointers for education**

Mindset gaps perceived by employers

In the survey conducted by us, several respondents wrote explicitly about the various attitudes that they found lacking in fresh hires. It is important for us to keep in mind that these gaps may be referring to specific employees, rather than to general trends. However, the identified lacunae do provide us with insights into attitudes that are valued by employers and that they think need to be inculcated in job-seekers.

Fresh hires were found to be lacking in creativity, curiosity, initiative, and independent thinking. "They also lack the ability to think out of the box and innovate." said a respondent, while another mentioned that, the problem with recent recruits is "tunnel vision within a field and not having bold ideas". NS, senior VLSI engineer said "the majority of people whom I see in my industry are not innovating. They are either learning from others or maintaining the status quo".

INNOVATION

He went to comment on the lack of innovation in the Indian industries as follows:

But whatever little experience I have in visiting the US - I have visited the US a couple of times - even there I see many employees happy with what they are doing. But there will be some 20% of the people - of the population of employees - who would be really into their jobs. Very much into their jobs. They'll be like , they will not have a job outside their line of work... fully immersed into the job which they are doing. Those 20% will be totally a class apart. I have seen that in US. And all the innovation comes from them. It is not like 100% of the population in western countries are innovative. They are exactly like us. But there will be a minority who will be a class apart and they are the ones who do the innovation. That is my observation...

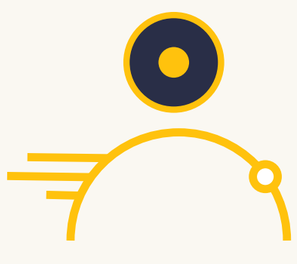
Here, I don't see - I would say it is close to zero in my company or may be 5 % even less than 5% who are innovative. 5% may be a good number.

CRITICAL

A sharply critical comment on new recruits was

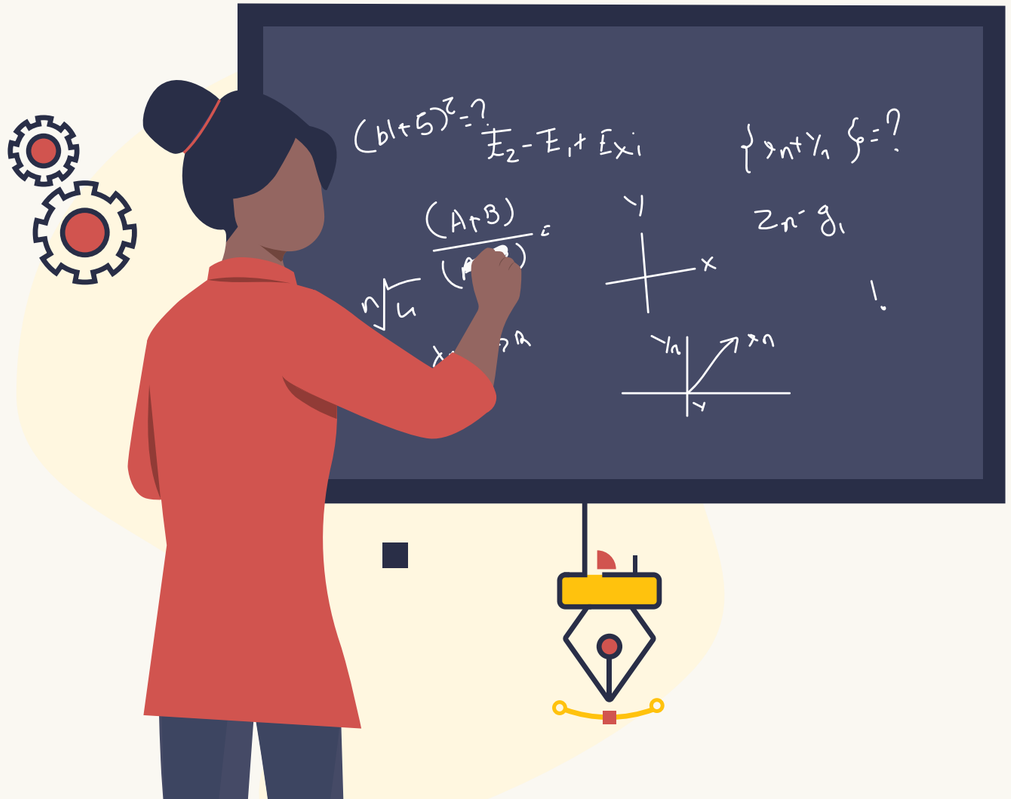
The new generation doesn't want to spend time sharpening their skills of hands and brain, they don't want to actually labour, they only want to acquire managerial skills.

HR



HR executive, Usha, corroborated this by saying that the newer pool does not do a deep dive:

In the pool of candidates specially the freshers, so far, I would say the gap that I find is they don't deep dive into any of the things that they do. They learn a lot of things but they are not ready to invest time into something that they are actually doing currently. In which case everything goes half-baked and it's like ah they know everything, but they don't know anything in depth. In that case it becomes you know a little extra effort to put them for work.



Perceived knowledge Gaps

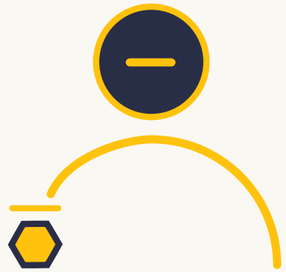
Although in the study we did not explicitly ask respondents to identify knowledge gaps these were mentioned several times and it is worrying to note that schools and higher educational institutions sometimes fail even in this first level function.

The knowledge gaps mentioned were

- Poor basics
- Poor conceptual knowledge
- Lack of deep knowledge

What are educational institutions missing?

Educational experiences were uneven, and varied across respondents with many of them appreciative of the skills learned during school/college such as problem solving, logical thinking, analytical thinking, research skills and creativity. Almost equal number of respondents pointed to these same skills as missing from their education. In the case of critical thinking, while no one mentioned it as a skill learnt during formal education, it was mentioned a few times as a skill that people wished they had learnt. While several respondents were appreciative of the computing and programming skills that they learnt as part of their education, an equal number wished that these skills had been taught to them in school or taught better at later stages of education.



Some of the interviewees referred to the mathematics taught in schools. Mani, noted,

It was rote based and a lot of mathematics is not relevant...We were not taught to think, we were told to copy and reproduce in exams and in fact we were asked not to be creative. Or for example thinking of different solutions or solving a maths problem in different ways was not taught, now my kids are taught.

Some new areas were mentioned that have not found their way strongly into education.

These are:

- Systems thinking
- Interdisciplinary skills
- Self-understanding
- Social skills
- Ethics

At this point it is worth mentioning that all of the above areas have found mention to a greater or lesser extent in the NEP 2020. It remains to be seen if the curriculum framework that will come out in the light of the NEP, will truly meet the emerging needs of learners and society or will it be another Saber Toothed curriculum. The parable of the sabre-toothed curriculum is briefly discussed below.

Pointers for Education

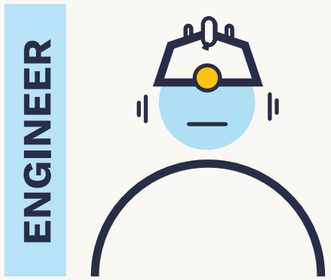
The Saber-Tooth Curriculum, (Peddiwell, 1939) first published in 1939 is a satirical commentary on the education system that is resistant to change. The book consists of a series of humorous essays by Professor Peddiwell about stone-age education. Almost a century later, these remain relevant today.

A chapter in the book describes a society of cave-dwellers. The skills valued in this society and thus taught to its children consisted of grabbing fish, clubbing woolly horses, and scaring saber-toothed tigers with fire. These skills were needed for the society to sustain itself and survive dangerous predators. The saber-toothed curriculum worked fine until the climate changed and brought about the onset of an ice-age. With the coming of the ice-age, the tigers gave way to bears who could not be scared with fire. The rivers became full of silt, so fish could not be caught with bare hands. The people in the society adapted to these changes by inventing bear traps and fishing nets. However, schools continued teaching children the “classical arts” of tiger-scaring and bare hand fishing. The fable of the Saber-Toothed curriculum is a cautionary tale for our educational institutions. Schools and colleges need to be responsive to the changing needs of society. We need to question why students are made to learn outdated skills that neither help them in their future, nor help society face emerging issues and problems.

In the course of interviews, we explicitly asked experts to speak about schooling and education and sought their suggestions on how these could be improved. Broadly speaking, we may categorize suggestions into those pertaining to curriculum and those pertaining to pedagogy.

Curriculum

As noted above, some of the content taught in school is still valued, especially mathematics and basic science. A few people mentioned that all the subjects in school, if taught well can really contribute to satisfying career paths.

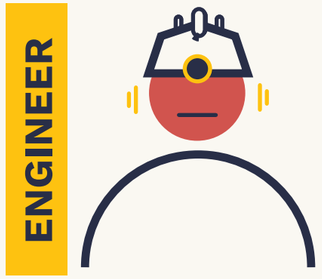


Naresh, VLSI engineer

Languages and reading has helped me to make better presentations, for example, if I were to take a specific example. Or communicating with my team. Humanities has helped me in understanding what kind of background people come from and it has taught me to be patient with people, with my team members - give them space and time. And respecting diversity at work. All those things have come from my teachers, my social studies teachers who were .. So from my school teachers I have learnt these things apart from whatever was written in textbooks. And of course math and science is very important for a career in engineering. But many neglect languages. That I feel will impact them later in their career. Like for example there was a fresh engineer who I used to mentor. He would forget all the punctuation marks while compiling emails. It was very difficult to read his emails, even the full stops were absent.

What should a future oriented curriculum include in terms of STEM mindsets? There were several suggestions made in this regard. Of course, the tired old refrain of moving away from rote-learning was articulated by quite a few people. Alas, the saber-toothed curriculum and associated forms of assessment still seem to hold sway. On a more constructive note, expert professionals made a number of valuable suggestions for the school curriculum:

1. Entrepreneurship needs to be built into the curriculum, connecting hands on learning with entrepreneurship is also important.



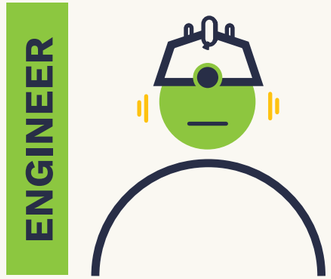
Manufacturing engineer, Bala suggested

They have to teach entrepreneurship. There have to be courses for such. There can be industry exposure and earn while you learn. I don't remember why we learnt trigonometry. But in diploma, I used to think why I need to work in a foundry or do blacksmithing. But now I find it useful because now students do not know where to start. Needs hands-on experience.

2. Programming and coding are becoming important in almost all areas and should find a place in the curriculum.

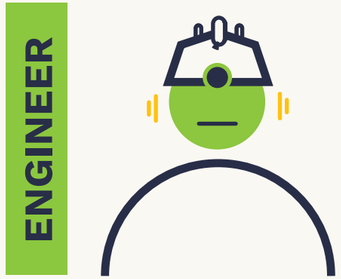
Teaching computers has to be mandatory noted, Heena, CTO,

Programming and coding is a systematic approach to solving a problem, developing a solution for a problem, looking at various options, coming up with the right option, implementing it, continuously improving it, this process is going to be useful - wherever one is going to work. So I would suggest, start at a young age and continue this, because in the future, there will be a quantum jump in the use of software, which will affect our lives in a positive manner.



Naresh,
VLSI engineer

So actually programming coding is becoming important everywhere , in every field of work. See, when you talk about computers there are two things - one is you need to be good with computers, in the sense you should know how to operate a computer and use all the programs which are available in the computer. That is one type of skill, another type of skill is to harness the power , computing power and make it do a particular job. So instead of knowing how to let us operate a zoom call, if there is a person who can create a zoom like application, then that skill is more valuable. So our education system, they teach children, increasingly our children are learning how to use computers effectively. But they are not learning coding or programming. So for example my daughter, if you give her any new software program now, within half an hour she can learn everything about that. But if I ask her to create a similar kind software program then she does not know how to do it and that skill will become increasingly important - whichever field it is.



Naresh felt that along with programming or software skills, children should also learn about hardware and electronics

So two things - if we talk about computers there are two things - one is the coding slash programming aspect, other is the actual hardware behind it - the actual electronics behind it, Both things if children learn. then their ability to innovate will improve a lot. Instead of teaching them software packages, we should teach these two things.

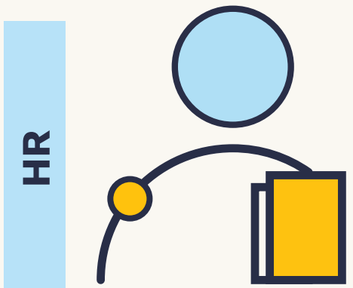
We see that at one end of the spectrum there are professionals who are developing and creating very advanced technologies for a range of applications and professionals listed above mention coding as an essential skill. But, there is sufficient evidence (Tewathia, Kamath and Illavarasan, 2020; Myths of Online Education, APU, 2020) to indicate that access to technology is not equitable and a very large set of people are excluded from being able to make use of technology in their work due to lack of access.

What kind of computer literacy and coding skills should be included in schools is a question that needs to be considered. Certainly access to computers must be more widespread. Along with access, training for basic skills to handle computers has to be put in place, and along with it the tools and skills to maintain the infrastructure well. It is important to think about how to build higher levels of computer skills including the ability to code in a resource constrained sector.

3. Mental health and well-being are emerging as an area that curricula need to provide space for.

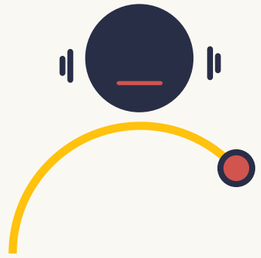
Mental health expert and Psychologist, Anandi, noted that well being is an important area that schools need to focus on,

Mental health and well being has to be integrated with subjects... the problem is it is done as extracurricular activity or it is outsourced to NGOs, then it does not help. Well being and mental health has to be done by the subject teachers. It can go in language lessons.



Usha, working as an HR executive felt that psychology should be included as a school subject as it would help students understand themselves and develop new perspectives

I feel that as a kid, everybody in every school this subject (psychology) has to be incorporated. It should be part of the syllabus because right in the beginning if you teach a child psychology, it will you know make them into beautiful individuals, beautiful whatever it is in the future.



In a somewhat similar vein Sai, felt that finding out about oneself is very important

Firstly, we don't pursue our passion, we don't find out what we are really interested in. During our schooling days and college days when we get into high school there is pressure to score good marks in our SSLC. After SSLC we don't get time to decide for ourselves.

4. Arts should be included and seen as complementary to science was another important suggestion,

TEACHER

Rihan,
Art teacher,
artist

Engineers lacking design perspective - software skills are there, but drawing skills are bad, so visualization skills are bad...

Even principals in colleges don't understand why art is in the curriculum. I went into education because nobody, or a very small fraction – less than 1 percent see it for what it is. People will start bargaining, or say they don't understand. In all other countries, people are inclined to art.

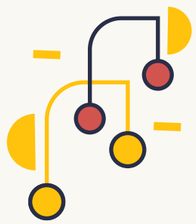
In India, we are asked to copy what the teacher does, so how can we produce out of the box thinking when we are teaching children to copy.

If you are an engineer, you go to an artist and then ask him to tweak it. The tweaking takes several hours – balance in color – and he won't get paid, but he will use it. There is a process in creating a color combination and the understanding will not come, if that is not introduced at school level. Even textbooks are so pale – there should be color, quality of paper should be good, the cover should be good.

If you are not adding art to science, you are negating that aspect of society.
And if you are not trying to do art, you won't realize the effort that is needed to do art. Good artists from abroad are always journaling about art. We don't have those practices here.

Children take art, and parents who are clueless about art, think they are wasting so much time in art. They don't understand that this is an experience that helps the child release stress from other aspects of life. This understanding is not there.

THERAPIST



Binita, therapist and theatre worker says

Music and classical dance gave me the ability for mental and physical rigour, an ability to decode for myself how I learn, how to break down a sequence into teachable bits. These are life skills I use today in my personal and professional life. (Oh! It's given me so much, I don't think I can put down all of it!)...

Pedagogy

It is widely It is widely observed in the Indian system that there is a resistance to shifting from lecture methods, over emphasis in passing exams. Additionally, teachers' subject knowledge with respect to science and mathematics has particularly been found to be weak, there is a lack of teaching resources, a strong pedagogical weakness in bridging theory and practicals and a lack of coordination between technocratic culture and cultural heritage.(Mohanty & Dash, 2016)

During interviews it was clear that some respondents were appreciative about the way their teachers taught. At the same time there were many suggestions about how teachers could teach better/differently

1. Connect learning to the real world: Teachers should help students see the connection between what is being taught and the real world, and that abstractions should follow from more contextualized understanding.

Krishna, machine learning expert, economist,

In terms of math, instead of theorems, you give them hands-on skills. How to utilize certain things – it has to be application oriented. The person will be quick to understand. In math also, people say, I don't like word problems. It is the most important skill. Why you don't like word problems – translate math to English. You should never say 2 + 2. R has 2 chocolates and N has 2 chocolates, how many chocolates that we need to have. Everything should be on the application oriented kind of teaching – both math and stats.

Rahim, Engineering director

What I missed in school is a lot of theory – remembering laws of physics or chemistry. We never got a chance to apply the laws. In the US, school children are learning by doing applications. There is more hands-on-work. When my children go to school, the teacher will show how static electricity is generated.

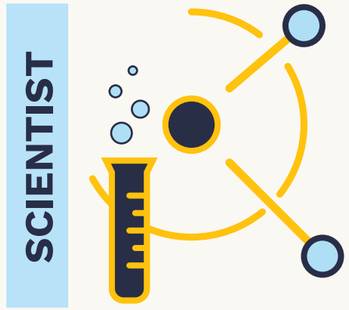
Experts opined that STEM teaching was not very effective in schools and that students are not being encouraged to think for themselves.

Saini, data security expert

But the way STEM is taught today, it is easy to compartmentalize the learning – STEM is not taught as a fundamental skill, it is not taught as a problem solving, it is an application skill – if I give you a quadratic equation – I can plug in values and do stuff, it is a repetitive skill – like going to do cooking, you know there are certain variables – you ask me to follow the recipe – I need to know what fry means, the hotness of the dosakal – now I can repeat that. I am not learning to think for myself.

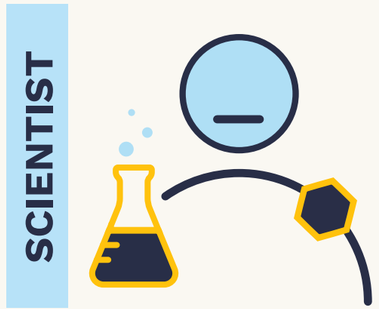
I don't think STEM per se, or much of the education is helping us to think for ourselves.

2. Include hands on an practical work: The importance of hands on practical work was mentioned by many interviewees



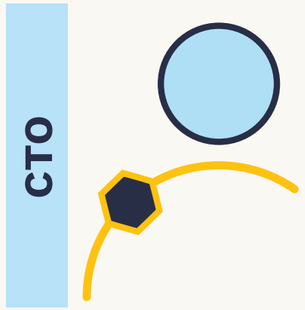
Nisha, Scientist, immuno-oncology felt that the science she learned in school could have been more

Project-based, instead of teaching the definitions and laws alone. Theoretical knowledge is important. For e.g.- In class 11/ 12- there could be a project on medicines and drugs, students could do secondary research and have an informed view about the drug, they cannot run an experiment, but such kind of research can be encouraged.



Students with a diploma have hands-on work experience, they are skilled, whereas engineering students lack a lot of practical skills noted Kumar, scientist at ISRO. He mentioned,

People who have done a diploma + B.Tech. – practically they have learnt a lot, and then the B.Tech. is useful. The hands-on experience from a diploma – IC, pin no. 1 – they will know. Some people from engineering. would not know how to use a meter, would have never been in a lab. School – In KV, in SUPW – we learnt soldering, identifying a capacitor – those initial foundations were useful. In science class, there would be a basic introduction to components.



Hari, CTO said

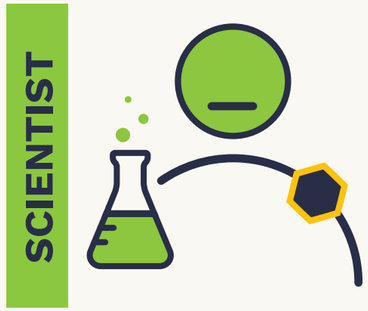
It is a little disappointing- because the exposure to application in real life is limited...Lets draw a parallel with hotel management course, these guys spend 50% of their time in the hotel. They will be in the kitchen, room services, front desk, in accounts dept. It is 80% practical. But courses on accounts, selling, manufacturing, systems development- there are no practical aspects that are taught. Medical degree for instance- you are in the operation theatre. For e.g., you can say this is how you dress a salad and actually ask them to do it, the two things are pretty much different. This is what happens in computer science classrooms. The computer sciences students I am not sure how much they spend time in practical learning.

3. Use strategies to develop critical thinking

Anu, AI scientist, while appreciating her teachers at one of the top-notch schools in India, felt they could have done more to develop critical skills.

So things like skepticism and definitely critical thinking- that is a learnt thing. So while I do think the basics of it were taught in Rishi Valley, I think a lot of it was stuff that I learnt over my like you know graduate and postgraduate education. I think that's something that not enough of it is taught at schools. ...

I think it is interesting that content wise they were ahead, but in terms of teaching tools at the highschool level, they didn't have that much variety. They had the standard.. You know like a teacher up at the board. It was more that they were open to discussion and questions. I think if I look back, I think you could make STEM - you could use a lot of different teaching techniques to teach a lot of these skills. You could think of.. I mean think about it - there is no reason why we can't have journal club at school.

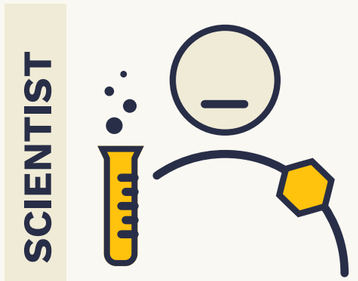


We can see that Anu is appreciative of the fact that her teachers allowed them to ask questions. Another expert was critical of the schooling that discouraged questioning

The problem is deep rooted in our system, where you are discouraged from asking a question. If you ask too many questions, you are branded a show-off. We don't allow inquisitiveness, and exploration to happen.

4. Develop conceptual understanding and problem solving rather not just computing skills.

Given that statistical analysis has been cited by many respondents as an important part of the STEM mindset, it is worth quoting this expert on how statistical skills should be built in before teaching coding the way it is currently done,



Rishi,
IOT expert:

Pretty much I see people are paying money for certification programs. The biggest misconception is these are about coding. This is not about coding; it is about hardcore statistics and statistical inference, which as a subject we don't teach. People will churn out code. We will give garbage in and get garbage out. We don't have a domain expert saying this is right or this is wrong. Once you deploy these in real life situations, we have a bigger problem.

For STEM courses, we might start teaching coding, but we are not teaching statistical inferencing. We learn to draw a histogram and learning mean, median and mode, and that is where statistical learning stops.
And before statistical analysis and inferencing, we don't teach problem solving. Problem solving is an approach, and it is not taught.

Is the curriculum saber-toothed?

This study doesn't provide us with an unequivocal answer to that question. However, unless significant changes are made to curriculum, pedagogy and assessment, the education system will not serve us well as we go forward.

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

In terms of pedagogy teachers have to make significant shifts towards providing more hands on and project-based learning with real world connect. Teaching strategies should shift from a narrow focus on examination success and instead make efforts to build deep, conceptual understanding. Schools also need to set aside time, space and resources for socio-emotional learning and also ensure mental health and well-being of students.

Discussion

STEM is seen as the driving force of economic production, innovation and research. STEM skills such as problem solving, critical thinking, logical thinking, creativity, computation, systems thinking and practical understanding of subjects have been pointed out as critical by professionals across careers. Math with a focus on statistics, data management, and technology have been noted as important.

The lines between traditional STEM careers and non-STEM careers are blurring. An integrated approach to individual STEM subjects, a focus on meta-understanding rather than acquiring disjointed bits of knowledge, and the ability to make connections, see the bigger picture, adapt and learn for a changing world is a 21st century mindset that students need to develop. Education in managing mental health, visual arts and performing arts, and in ethics has been listed as essential to cope with this world.

Green jobs of the future is one area that literature has pointed out, but has not been explored in detail, in this study. Environmental degradation of soil, water and air, climate change and the enormous footprint that humans are leaving on the world are new challenges for future citizens. Given the changing world scenario and adversities such as climate change and the pandemic, it is important that innovation, critical thinking, problem-solving, creativity, and sustainable solutions are given greater emphasis. STEM mindset is equally important from the perspective of well-being - both personal and societal well-being (Law, 2002). In her study, Law (2002) describes how scientific literacy can help people in everyday coping as well as in social decision making. Remarkably, the study points out the importance of habits of mind and attitudes in four areas of personal well being - home and workplace safety, health, nutrition and dietary habits and appropriate use of consumer products. Further the study indicated that scientific attitudes, habits of mind and values were accorded more importance than content knowledge by societal experts. This has serious implications for science education.

Data shows that while women are entering school and college and doing well in greater numbers, they are not staying on at work, especially in STEM. This means that more schooling does not mean better jobs or better lives. Academic success alone is not sufficient to make a smooth transition into employment or to help women stay at work. Focusing on delivering value, developing confidence and marathon mindset, using breaks from the world of work to network and upskill, and building long-lasting support systems have been mentioned as key to doing well in the world of work. Interventions have to be made at critical junctures, in organizations and at home, to prevent girls (and other children at risk) from participating equally in STEM careers.

While highlighting gaps in education, the words ‘analytical thinking’ and ‘critical thinking’ have been used often in the context of industry. For educators, the meaning of these words may be quite different and encompass broader areas. The focus on coding and technological prowess translates into questions of when and in what sequence should such teaching be introduced. Access to technology, tools and skills itself is a big challenge to many parts of India.

Digital literacy has been mentioned in passing, but this promises to become an in-depth topic on its own, and children have to be guided to handle the impact and consequences of what they hear, see, say and do on the net. A deeper understanding of the visual arts can help children to become designers and product makers, rather than copiers and service providers and can help them develop big-picture thinking, but it means that educators have to map this into a timetable that includes the changes that are being brought about by technology and climate change.

Keeping these questions in mind, now that we have looked at industry, we step into the school and the school ecosystem. The next part of the study will explore how and whether schools prepare students for the STEM mindsets, what is the students’ understanding of STEM? What are their mindsets towards tinkering, making, risk-taking, dealing with failure, and their own assumptions about gender and STEM? We interview teachers and teachers educators, headteachers and curriculum specialists to understand their own areas of growth, pedagogies and awareness of future skills and mindsets. This study will try to glean insights on preparing students in secondary school, to become critical thinkers who can evaluate the labour market and how it relates to their learning, to develop mindsets and skills that map to the world of work that has moved on from industrial-era repetitive work, and to become better humans who are aware of the consequences of their work on the planet.

Annexures

Annexure 1: List of skills and attitudes mentioned by respondents

Skills

- Analytical skills
- Logical reasoning
- Problem-solving
- Lateral thinking
- Experimentation and iteration
- Planning and organisation
- Digital competency
- Mathematics and technical drawing
- Design
- Meticulousness
- Innovative
- Big data analysis
- Hypothesis-driven
- Experimental planning
- Understanding complex logic
- A systematic approach to work
- Ability to visualise holistically
- Programming and design skills
- Data-driven
- Rational thinking
- Creativity
- Analyse data,
- Number crunching
- Use excel
- Communication
- Critical thinking

Attitude/Habits of mind

- Ability to learn and unlearn
- Adapt to change
- Positive attitude
- No single-mindedness
- Team player
- Determined
- Thinking beyond the norm
- Empathy
- Perseverance
- Curiosity
- Being non-judgemental
- Acceptance
- Listening skills
- Patience
- Open-mindedness

Annexure 2

The following table highlights few skills and attitudes across selected sectors.

STEM MINDSET												
SECTOR	Problem solving	Critical thinking	Analytical thinking/	Creativity	Logical thinking	Mathe-matics	Persever-ance	Patience	Hard Work	Curiosity	Open Mindedness	Communications (interpersonal, HR, listening)
Healthcare (13)	6	4	6	5	1	3	1	2	0	2	1	2
IT (10)	5	0	4	1	3	2	0	0	0	0	0	0
Engineering (14)	2	1	6	2	4	6	2	2	2	1	1	1
Research (8)	0	2	3	2	2	1	1	1	1	0	1	3
Education (11)	2	4	3	3	3	0	2	2	1	2	1	5
Media/ Communica-tions/Marketing (7)	2	1	4	1	2	2	0	0	0	1	1	0
Art (5)	0	0	0	3	0	2	0	1	0	0	0	0

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Appendix

Career Choices

‘Who are YOU?’ said the Caterpillar. This was not an encouraging opening for a conversation. Alice replied, rather shyly, ‘I hardly know, sir, just at present at least I know who I WAS when I got up this morning, but I think I must have been changed several times since then’. Lewis Carroll

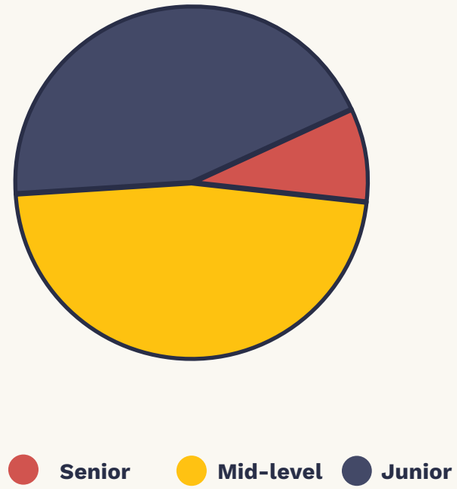
Lewis Carroll (1865) wrote these lines in his widely read book Alice’s Adventures in Wonderland. This scene from the book is evocative of what young people experience as they try to find their way to a satisfying and rewarding career in a complex and rapidly changing world. Career counsellors are trying to find out new ways of responding to the varied needs of job-seekers. Narrative career counselling has been gaining prominence in this scenario (McMahon & Watson, 2013).

In this section of the research report we have tried to give a glimpse of the rich narratives that we heard while interviewing people in various fields at various stages in their careers. It is hoped that this section, along with subsequent sections on the future of work and on the role of education in preparing students for careers will give insights on how young people can be better prepared and positioned for rewarding careers.

Career trajectories

Survey questionnaires were mailed out to people that were directly or indirectly known to the researchers and keeping in mind the need to cover a wide range of careers - both STEM and non-STEM. Out of the 70 respondents who responded to the questionnaires most were in senior or mid-level positions. The spread in terms of seniority of positions is indicated in the chart below.

What is your role?
70 responses

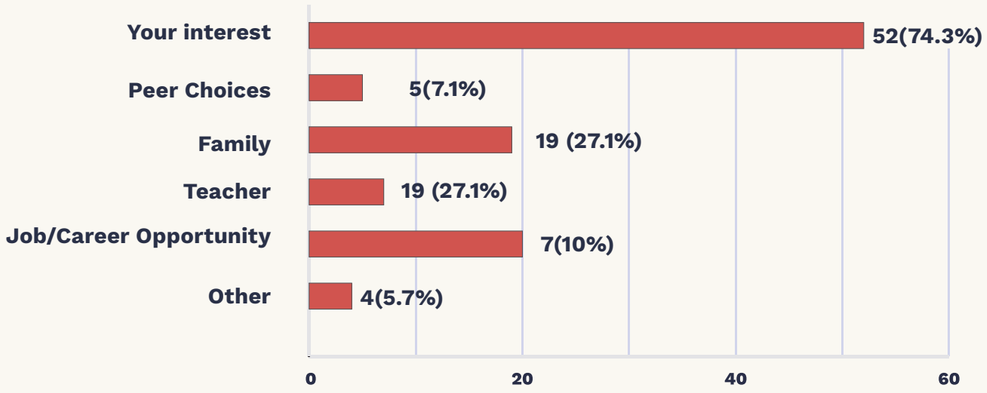


This distribution is important to keep in mind while analysing the data. The fact that the data is drawn majorly from people who are in mid-level or senior level positions, indicates that their views will be of those who have experienced relative success in their careers. The data would have filtered out those who had moved out of their initial specializations due to various factors like job dissatisfaction or career failures. This is one of the limitations of the present study. On the other hand, this data from people who have experienced success in their careers will be better able to provide clear pointers about the constituents of a rewarding career path.

Factors that influence career choice

Typically, young people select a stream or specialization at the tertiary level keeping future work options in mind. A number of factors can influence the choice of careers. These include personal interest, peer influence, advice from family, teachers, and job opportunities. Factors other than these may also influence an individual's choice for higher studies and career. Through the questionnaire survey, we sought to find out the influences that shaped an individual's choice of specialization. When it comes to factors influencing choice of specialization, three fourth of the respondents indicated that it was their personal interest that was the reason. This was also the main reason mentioned during the interviews. However, as the figure below indicates, other factors also had an influence on people's choices.

What motivated you to choose your major or specialization in college?
70 responses



Interviews provide us with deeper insights into the way careers are chosen. SN, a highly specialized engineer working in the field of chip design said that this was not a deeply thought out choice, nor was it one based on deep personal interest to begin with. This is how he put it,

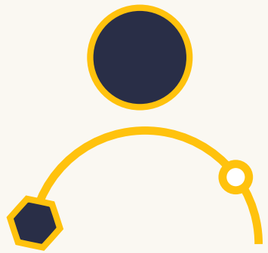
I did not make any conscious choice or effort. Overall, I was decent in my studies, not good, not bad and I was able to compete in the engineering exam and get a college seat in a decent college - Malnad college of engineering Hasan. And my field... branch which I picked up was electronics which is in line with this VLSI. During my final year interviews companies come to engineering colleges to the campus. During that time WIPRO came to my college and I opted for VLSI. There were various options, and I opted for VLSI, probably because it was closer to what I had studied.Then once I got into the job, then I consciously tried to stay within VLSI - in Wipro there were many opportunities. Once you specialize in a field it is difficult to move.

On the other hand, MS, a theatre worker and mental health professional started out with a very strong interest in dance.

Since the time I can remember, I have dreamt of being a performer. When I was young it was to become a dancer and I was mesmerised by Bharathanatyam. I couldn't wait to get started with classes. I had a cousin that was learning the form and my family couldn't afford classes. So I had to wait till she started teaching. I was 9/10 when I began learning Bharathanatyam formally. I started classical Carnatic vocal music classes before that around 5/6, my aunt said it would help me as a dancer. It was basically to keep me from jumping on their heads about dance classes. I was enrolled with a music teacher who taught for the love of teaching and didn't charge a fee. I went through music lessons impatiently almost. Dance was really all I wanted to do.

There were individual outliers in the response to the survey question about factors influencing career specializations. Career counselling and internship with a research scientist at Indian Institute of science were two of the responses that are worth noting.

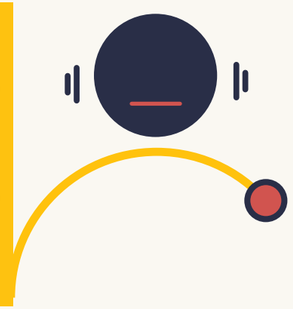
HR



In the case of Usha, who is an HR executive, career counselling at school helped her to take up psychology, unlike most of her peers who were preparing for engineering or medical entrance examinations.

My career, I would definitely say.. It is a pretty long story. If I share that then you will get a little more insights into how I ended up doing what I am doing today. So, like, I was into.. I am from a science background., I did Physics Chemistry Mathematics and biological sciences in my 11th and 12th. I did my schooling in Kendriya Vidyalaya, and I would say that I was an all rounder at school. I would participate in all activities..be it music, be it any activity,.. I would explore and give my name for it. But, I would stay that when it came to studies - Physics Chemistry, I was good at it, Biology I was really good at it, but mathematics scared me out. Initially I did have plans of doing engineering and you know going with the same crowd... predominantly people choose engineering or doctor, MBBS you know as their career option. But then 11 th and 12 th was actually a turning point, where I decided that this was not my cup of tea and I really need to move out and explore other options, like which would really suit my set of competencies . So then I had gone for career counselling. Luckily my parents were also open for it and they said go ahead and you can choose whatever you wish to pursue. Although they were also a little apprehensive as well as skeptical - because choosing something out of the box and especially coming from a very small town where people usually go with whatever the crowd does. All three of us were very a little apprehensive about it but then the career counselling - like I had taken it in two places - one which my own school had organized and another one in Chennai - which was under a psychologist's supervision. Then in both the cases the result was that psychology was one of the options that would really suit the personality that I had. So, actually it was merely out of blindly trusting those results that I stepped into the field. But then after that I never regretted the decision.

RESEARCH



Role of research internship in the career decision has been elaborated by AD, who consciously chose to move out of academia and into data science gave a very detailed reason for her decision,

Talking about my transition from academia into data science. So, I did my masters in neuroscience in India, I was already interested in academic research. I did my Ph.D in the University of Rochester. And I was fortunate that I did a mix of applied and more basic form of research. So, umm so we were actually working with stroke patients, we were helping them to recover vision and you know we were really helping people while at the same time figuring out how their brain changes. You would think that something like that would get funding easily. No!

So I saw my advisor go through something like eight rounds of grant writing in the hope that - I worked with her through two rounds where you submit a proposal, get comments, then address the comments and then send it again and then get a reject. It basically like destroyed her...

So I think , watching her go through that, I was like, you know what, this is not for me. And also the impact that you can have just by doing that kind of academic research is very limited. It is limited by the funding you receive. By the sort of rather nepotistic ..It is rather nepotistic you know. Like when there is limited funding, people fund the people they know. Then I did a post doc for one year at NYU. At Rochester we mostly got no exposure with what you can do with a STEM Ph.D, fewer exposure to alternative careers.

Whereas at NYU they had a very - and this I found out obviously after I started out with them - NYU was at New York city which is such a competitive place, with a vast job market. You know they had a very strong program where you, as a Ph.D you get a broad understanding of all the different careers that were there for you. So it was everything from - industry research, medical vending, data science, policy and what else - and like science foundational jobs - like there is the Autism Foundation. Basically there are lots of Foundations that do, you know, like work in specific areas. So basically there are a lot of jobs that are more rewarding and that basically have a bigger impact than academica. And the way the pipeline works, it is truly a luxury to stay in academia. At that time it was just a well kept secret. You know something like less than 10% of the Ph.Ds end up getting academic tenure track jobs.

I think I was basically at the beginning of the wave where you know the NIH changed policy and they really started forcing people to consider a wide range of careers. Having said that, I think that I also got lucky - at that time data science was becoming - like there was a lot of hype around data science -massive sort of job market in which there were not a lot of people.

Some of those interviewed mentioned the role of a parent, special teacher or mentor, who shaped their attitude to their work,

IOT EXPERT

Rishi, IOT expert, spoke about his parents and their attitude to learning, as well as a mentor who supported him in his Ph.D. and later,

I joined a Ph.D. program in IIT-Bombay. My guide was eventually Deputy Director, IIT-Bombay. He was my M.Tech. guide in IIT-Bombay. I was working as a RA in remote sensing in his lab. My guide asked me to do a Ph.D. and my background encouraged me to do it. Parents – Father was a professor of math – there were 4 colleges in Maharashtra. My mother was a litterateur.... As we were growing up, our upbringing was all from both of our parents. My brother and I had a balanced view because father was from science, mother was in arts. We used to have long chats. Father wished me to have a Ph.D.

In my six years of stay in IIT-Bombay, I learnt all the skills they don't teach you in colleges. My guide was very liberal in terms of his approach. My first 2 years were very exploratory. For example, there was no pc or computer. We had a centralized computer center and there was no connectivity to the department. My friends and I dug a space, put the cable and connected the department to the center. My guide was fine with it. I learnt a lot of stuff in terms of how you work with people, towards solving a problem which helps people immediately. We got a problem solved immediately. I joined in 1991,and the internet happened in that year.

ENGINEER

And Giri, a chemical engineer talked about two or three great teachers, who sustained him, and encouraged him to try new things:

I wasn't sure I wanted to do a Ph.D. My M.Tech. was a temporary move – I was lucky to get a very good mentor...my mentor had just joined, and he was in biochemical engg. It was not a popular topic in 1994. I had a reasonable rank, and many people questioned why I was working with an unknown professor and not a mainstream area. I thought it was an M.Tech., and at least in masters, people should follow what they like. I worked with him and I was ready to do a Ph.D. from him, but he said you will benefit from being exposed to a much wider canvas. And he strongly encouraged me to apply for a Ph.D. to the U.S. and to a top school, and at stage I was not very confident. Now,I realize that it was selfless of him. He pushed me to apply. So, I did go to Minnesota to do my Ph.D..

Again, in the same area – and again I was fortunate to get good mentors...I started doing plant tissue culture. I found I was not good at it – I didn't have the technical skills to do them well, my hand skills were not good, and I discovered that I really liked math and was good at math. My mentor was nice enough, kind enough ...when I said I want to do theoretical analysis of genomics, and he said yes, I can help you with the genomics and the other guy can help you with the math.
They held me to high standards.

Different career trajectories

Broadly people seem to have followed one of the following three trajectories when it comes to their careers :

- Specialists who having selected their field/ area of specialization early on stayed the course and developed deep expertise in their chosen area
- Those who branched out into related fields and developed a multi-disciplinary approach
- People who made significant shifts and developed new areas of interest

The table below gives examples of each of the above culled from the detailed interviews.

Chose to specialize in an area	Developed multi-disciplinary interests and Knowledge	Made complete shifts in their line of work and developed skills in a new area
SN- VLSI design - mentioned in an interview that he stayed in one area right from the start and was able to go deep into it. SS - Psychology- discovered interest in this field and intends to continue working SR - VP, digital marketing - IIM-A grad in marketing, stayed with this area - and watched it move into online space. Virologist - stayed in career and trained in microbiology and clinical pathology. HB- a chief technology officer stayed and continued to program for more than 40 years now, he runs his own software company.	US - moved from journalism to education and developed skills related to communication and literature. SR - branched out from theatre to mental health and feels that there is a strong link between the two in terms of understanding the body and emotions AK - most passionate about all kinds of learning. Ph.D. in electronics engg., brother in medicine, and later chose to study biology, AI, machine learning - 43 courses online. Now in 2 spaces - IOT - rational buildings and diabetes. RK - economist, who chose to learn CS, and became a machine learning expert in a financial services company. CG - chemical engineer now working in research straddling both biology and math. This person fits both the previous category and this one. MA - physicist who is working in biology. This story can be told about both - because it tells of how bio is the new frontier. SR did his physics and realised that he is creative and joined a course in advertising. He started his career in an advertising firm and now he is into digital marketing. He is able to bring together his skills in communication and marketing. His physics and maths in the college helps him to be analytical. He also blogs and is a wannabe author.	AD - Shifted from neurobiology to Artificial Intelligence and data science in medical diagnostics.. Programming skills developed from school onwards stood her in good stead. As a postdoc, she applied for a fellowship that she describes as a boot camp for building data science skills. AV - Shifted from Biochemistry to classical dance. Started learning dance early, but was keen on pursuing Biochemistry in college. The first year of college was enough to kill her interest in science. LV worked as a secretary in EDParry, moved to different companies for about 10 years. She was always interested in theatre and acting. She decided to make this shift and moved to Radiomirchi. She applied to be a Radiojockey, however became a copy editor. She continues to act now in the Amazon series and has appeared in an advertisement. RR did a course in biology, however realised that she has a creative edge and is able to write well. She did a course in creative writing and communications. She teaches communications now in a college and has published a few books. She is trying and continuing to publish slowly.

What follows are narratives that exemplify to some extent each of the three career trajectories shown in the table.

Specialization

In many instances people have developed a deep expertise in one area and become specialists.

CTO

HB, CTO, discussed how programming became his passion,

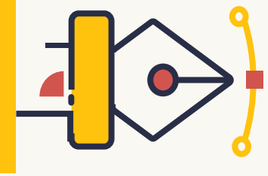
I did my Bachelors in Physics. I was lucky I used to stay in IIT Chennai campus, so I started doing a part time job in the evening and helped a researcher and worked in the computer centre there. I am talking about 1976, it was a punched card system at that time, it could hold 80 characters, it would read card by card and keep the information in the memory. That is how I started and slowly started learning programming.

I joined Zenith and directly reported to MD, we sold hardware ... Then I went to Xerox- I became the Executive.Director in a few years and then I became CEO of Usha Martin and then I started my own company. I was in a senior management position for a long time, but unlike other senior people- I stuck to programming. I never gave up the technology part, others by 40- move to project management, budgeting, paper pushing etc. Now, I am 60+- but still I do programming for 8 hours. I write programs- 7 to 8 hours of programming work everyday, 3 hours of management work. It is my interest and my passion. I will code and program till my last breath of life.

Multidisciplinarity

Ability to be a generalist, drawing from multiple disciplines and learn new skills as required has helped a few professionals navigate their career.

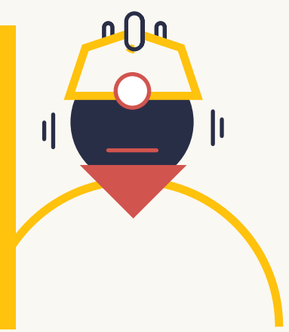
SR



SR, Lead strategist, Digital marketing, elaborated how he is able to bring together multiple disciplines,

I studied physics, I realised that I am creative and so I thought I will explore a course in advertising. After the course I started my career in an advertising agency and continued for 10 years.I was blogging at the time. Slowly I realised that digital marketing is emerging. I moved to work as a strategist and use my communication and marketing skills. Maths and physics in my college helps me to be analytical. I am trying to pick up blogging again and hopefully would be an author soon.

ENGINEER

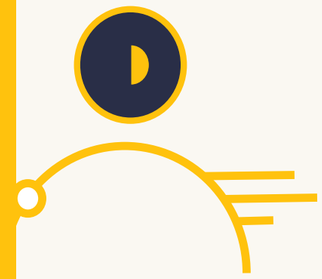


The cloud computing engineer, Mani, highlighted how he needs to be a generalist,

There is big time automation, instead of specialised narrow skills. One needs to know networking, storing and servers, all of them in cloud computing... they have merged now. Earlier it worked if I just new networking...now things are changing.

Moving to a different area

CHOREGRAPHER



This excerpt from the interview with a choreographer, AV provides us with an insight into what made her shift focus from an initial interest in science.

So when I passed out of my 12th I was very interested in Biochemistry as a subject to whatever level I was introduced to it in the 12 th standard. So I was very interested in joining and that was the only thing I was interested in and I was very clear on that. But when I joined the first year of Biochemistry we were told that we would be going through all the subjects sciences - physics, inorganic chemistry, organic chemistry, math stats you know everything That was our first year thing and that kind of completely turned me off because - I didn't want to pursue it again in the same way and it was completely uninteresting taught to us and never were we made to understand why was it important for your biochemistry research or anything else - or some specific topics that we could do. It was just another 12 class extended which was how it happened. Though in my 2nd and 3rd year there were some subjects which I really found interesting but I kind of lost interest. And performance itself - being on stage and performing gave me a sort of high which I don't think biochemistry was giving me in any way.

Career trajectories described above traced the trends and how professionals navigated their career journeys.

Researchers

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Co-researchers

Dr. Indumathi

Kalpana Aravamuthu

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