It is a truism that basic research leads to technological and economic progress. Governments and the public have come to see all of science through the lens of applications. This is short-sighted: in a democracy, science is a public good for a multitude of reasons.

The astronomer and author Carl Sagan spoke of science as a candle in the dark: a way to push back ignorance and uncertainty, a way to discover truths about our world and chart our way forward.

In the wake of the Bhopal gas leak of 1984, reacting to the horror of the deadliest industrial disaster in history, a collection of grassroots groups across India assembled to talk about the future. These groups, some of whom had existed for decades, were dedicated to spreading awareness of science and its fruits, in schools and town halls, through street theatre performances, and in vernacular media. Their members, mainly non-scientists, were driven by conscience and idealism. They saw a role for science in the literacy and anti-superstition efforts of the era, but also knew the limits of a science divorced from society. In 1988 they came together to form the All India People’s Science...
But these singular achievements are not universally celebrated. The genesis of the All India People's Science Network echoed the turbulent social upheavals of a previous generation, when the Hiroshima bomb triggered mass movements against the proliferation of nuclear weapons. The Green Revolution has all but petered out: growth in agricultural yields has slowed, India's farmland is increasingly too saline to be usable, and the total cultivated area is declining. The country now faces deleterious environmental degradation and loss of wildlife, a water crisis with no solution in sight, and massive displacements of people, all as a consequence of the post-independence push to industrialisation. This is the people's history of Indian science, and it stands in direct contrast to the great-man narrative.

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The key to revitalising Indian science is the careful choice of rich questions. These questions could be driven by new national missions that bring the excitement of a collective effort. Or they could be inspired by observing the complex interactions of the world immediately around us.

The study of India’s traditional knowledge systems, the country’s enormous biodiversity and human genetic diversity are an exciting and bottomless source of scientific puzzles and important secrets. Such questions would allow for a deeper two-way engagement with India’s people. This is not to say Indian scientists cannot work on internationally important problems, quite the opposite. The scientific community in India, working within their own unique contexts, could become the source of important problems that anyone in the world would be excited to work on.

A science that builds global connections. The internationalisation of science is an important goal in and of itself. While it stimulates cross-fertilisation of ideas and pushes up standards within science, it also creates opportunities for broader global discussions and engagements. The fortunate hurdles which curtail the ability of many young academics and students to travel abroad, and the enormous difficulty foreign academics face in obtaining necessary permissions to visit their colleagues in India, serve no purpose. In spite of all this there is a healthy trend toward stronger international links. Major global science funding agencies such as the Wellcome Trust and European Molecular Biology Organization directly fund research within India. And while India’s current capacity to train its young scientists is slowly improving, Indian students are exposed to excellent opportunities abroad. The US National Science Foundation estimates that nearly 9,000 Indian students enrolled in science and engineering PhD programs in the US alone, with thousands more spread across the world. This is a substantial fraction of the 77,000 students presently enrolled in such programs in India according to the Ministry of Human Resource Development’s 2017 Survey. Young Indian scholars abroad represent parts of the world, they build links to productive academic and research networks, are trained in cutting edge discipines and generate new scientific output, while maintaining close ties to home.

A science that renews itself and passes on its values. Academic scientists have long played a dual role as teachers and researchers. Within India science has a remarkably broad appeal. Public science talks are standing-room-only affairs, and famous scientists receive the kind of adulation typically reserved for movie stars. Movie stars across the world are excited about science, many aspire to become scientists themselves. Historically, engineering and medical colleges have attracted scientifically-minded students, but this is changing. The Indian Institutes of Science Education and Research (IISERs) have now been running undergraduate programs for over a decade in India. These institutions are to science what the IITs are to engineering, attracting some of the brightest students each year. Science programs within public universities have not fared as well, and must seize every opportunity to reinvent themselves. A science curriculum based not on dry facts and figures on the history and process of discovery can form the base of a broad education, in conjunction with the humanities and the arts.

These are just a few of the reasons I believe science in India deserves public support. Every so often the work of basic scientists has led to useful applications. But there are enough instances in which actual harm has been done in the name of science. We cannot be so naive as to claim innocence, we must take some responsibility for this and participate fully in correcting it. This does not mean overrating our lives and institutional structures. But for a start it means we must be open to ideas and criticism, sensitive to the consequences of our work, most importantly connected to the complex society around us. Words from the 1983 essay ‘A Toward a People’s Science Movement,’ by historian Mahesh Rangarajan and co-authors, remain relevant today: ‘Science and technology has been alienated from the people, their understanding and knowledge, life experiences and problems. It is time that every Indian, and people everywhere, are able to carry the candle of science in a way that brings meaning to each of their lives.

Mukund Thattai is a biologist and a faculty member at the Centre for Cellular and Molecular Biology, University of Hyderabad. This essay was originally written for a forthcoming publication for the National Centre for Cell Science, Pune, and the Indian National Science Academy’s 2017 Symposium on ‘Universalizability of Scientific Temper and the National Scientific Temper Day’. This essay was written in a public forum, addressing the basic problem facing India’s scientific community, and was published in STAR, an online science newspaper. The text is mirrored here and adapted from the original.

Richard Feynman is an illustrative case study. In his lecture titled “Cargo Cult Science,” Feynman gives an apt description of science as: a long history of learning how not to fool ourselves. Yet, in another of his essays titled ‘The Value of Science’, he argues, ‘From time to time people suggest to me that scientists ought to give more consideration to social problems – especially that they should be more responsible in considering the impact of science on society. It seems to be generally believed that if the scientists would only look at these very difficult social problems and not spend so much time finding with less vital scientific ones, great good would come of it.

It seems to me that we do not think about these problems from time to time, but we don’t put a full-time effort into them – the reasons being that we know we don’t have any magic formula for solving social problems, that social problems are very much harder than scientific ones, and that we usually don’t get anywhere when we do think about them.

I believe that a scientist looking at nonscientific problems is just as dumb as the next guy – and when he talks about a nonscientific matter, he sounds as naive as anyone untrained in the matter.”

Evidently, Feynman’s view social problems are not ‘scientific ones’. They are in the category of ‘non-scientific problems’, ‘non-scientific matters’. In his view, quite common among natural scientists, there are two kinds of problems - scientific problems, about which one can think rigorously, and ‘non-
Scientific temper encourages questioning and thus is basically opposed to fundamentalism, which is based on unquestioning belief. Science is based on questioning, needs democracy. Questioning is also essential for democracy. Ask ‘why’ will encourage critical thinking in the common citizens and therefore help to strengthen democracy.

The scientists have played an important and commendable role in the initiation of NSTD with an appeal to all educational institutions to take up the work of promoting scientific temper. This year a large number of educational institutions observed the NSTD, with lectures, presentations, experiments, cultural events, films and videos. By next year, we can surely increase the participation several fold, and with a power of ten upsurging each year it should be possible to reach the UST target of every school and college in the country within a span of four years.

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We often speak about the sorry state of STE (Science, Technology, Engineering, and Mathematics) and STEM education in India. We recognize the problem, but do not appear to have a strategy to improve the situation. That is not to say there are no honest attempts at improvement, but they have, at best, worked in minimal conditions.

In this short note, I present a model-driven picture with the hope that this may help us understand the problem and, hopefully, find a road toward good STEM policy and practice.

As a Model
A game is a rule-following activity, where both the players and spectators are immersed. Such a game, in the absence of spectators (or audience), is not sustainable. It is dependent upon spectators, and that too, many more spectators than players.

Although spectators may not have sufficient proficiency at playing the game, their participation, from the sidelines, is crucial as the rule and the actions taken by the players of the game are also understood by the spectators, and their feedback during the period of play, and in their review, is instrumental.

Some of the senior players, who are well-versed and have a comprehensive understanding of the rules of the game, become umpires. There is one other subclass of players, the coaches, who are typically active or retired players themselves.

Spectators need not take players themselves, at any level, but understanding the rules of the game at some level of proficiency is necessary. Most games share similar patterns, and if we ever played at least one game, it is not difficult to play or appreciate other games.

Let us take STEM as a set of games scientists, engineers and mathematicians play. All those who have played a couple of STEM games at least once, and understood some rules of the game, will constitute the STEM spectators. The editors of the journals, senior STEM players, are equivalent to umpires, who understand the rules of STEM games very well.

A Pyramid Representation
A representation of a game-system as a pyramid may provide some light on the need and relationship between the spectators, the players, and the umpires in a game. A pyramid model also offers a good clue about where each of the agents of the game-system emerges.

In the representation, borrowed from an ecological pyramid, the base of the pyramid includes people, who form the primary support system, followed by spectators, players, and umpires. It is essential to keep in mind that the spectators also know the game, though they may not be as proficient as the players. The umpires are not only proficient in the game, but they are also skilled in judging, indeed, often framing the rules of the game.

The pyramid representation also suggests the population of the game system, in the decreasing order of people, spectators, players, and umpires. About the proficiency of the game, the order is inverse.

A Lesson from Cricket
Let us take the cricket game-system. India is one of the top-ranking countries in the world, producing several world-class cricketers. Cricket game is arguably one of the instances where India has achieved excellence. There are vast numbers of people who understand the game as well as those who play the game. The base of the pyramid for cricket, therefore, in this model, is strong and bulky.

If the national team is kept captive in a remote island with the intention to destroy the game, another team will take their place in no time with similar proficiency. There is sufficient buffer in a resilient system, and cricket in India is one such. This is an example of how equity generates excellence.

However, if the national champions of the STEM game of India are kept captive in a remote island, with the intention to destroy STEM in India, another leading team will take a few generations to reach the proficiency level of the leading players. Whichever team finds itself immediately as a replacement will be far less proficient.

We do not have a resilient STEM game system. If a similar situation were to arise in another leading STEM country hypothetically, it would not take generations to create new STEM champions. There are many potential team members of comparable proficiency available.

Why?
Using the game model, the reasons for not being able to play the STEM game proficiently emerge in quick order.

Where do people learn to play cricket in India? Anywhere that looks like a ground. Not in a classroom. Where do students learn to play the STEM game? They do not play STEM game at all, they read about STEM game in a school, and do not play it, either in a lab or in a ‘garage.’ We in India do not cover the ‘I’ and ‘E’ of STEM in our school education. In this scenario, a ‘garage’ is an informal one.

Consider the coaching system in place for games: the coach is necessarily a player, either active or retired. In India, for the STEM game, this is not true. The majority of STEM teachers are neither players nor spectators of STEM game.

Spectators of a game are possible only if they understand the rules of the game and play some game at any level of proficiency. We do not expose our students to any of the rules of the STEM game, nor do we allow them to play. Our system, therefore, does not make sufficient use of STEM. Their ability to consume and appreciate STEM is negligible.

We do not play STEM game with competitive proficiency because we do not have sufficient spectators. In their absence, our STEM players are, so to speak, scratching each other back, becoming spectators for themselves. When we want to share our work, we often have to participate in a conference abroad in search of a peer group. Local peer group is essential for developing any expertise.
community participation making STEM a genuinely social endeavor.

Microworlds are artificially constructed rule-following possible worlds based on minimalistic building-blocks. They may produce finite or infinite worlds.

Are they the same as what we call models? Is modeling as same as constructing a microworld? It is an important question, let us pass this question for some other time.

There are other rule-following cultural practices, not usually considered part of STEM game, such as classical music and dance. Playing such seemingly different games also support STEM imagination. For example, Marjul Bihargu's exposure to Indian classical music during his childhood days helped him, according to him, develop mathematical imagination.

This interpretation has the advantage of viewing what we do in STEM, whether with media (symbolic operations) or matter (engineering and technology operations), stand on similar roots. The view of theoretical modeling and mathematics as a microworld construction game on the one hand and engineering and technology to make corresponding physical microworlds, on the other hand, provide a sufficiently comprehensive picture of the roots of STEM. The possibility of creating physical microworlds give STEM participants tremendous confidence in how close they are in understanding the actual physical world.

Whether we play language games in STEM or engineering games, we can create common operations of STEM game. Construction and de-construction are common operations of STEM game.

To Conclude

Microworld as a game field for learning as proposed by Seymour Papert is extended here to all of the STEM activities. This is done deliberately to make the point that the context for learning should not be different from the context of everyday games. Expert game metaphor clearly guides us to expect the teachers of the game to be the players themselves. And students will learn the game by playing, and there exists no more straightforward way of doing it.

STEM is rooted in cultural practices, such as language, which is rule-based. However, other cultural practices may not always apply as rigorously as STEM does. STEM's adherence to rigor is manifested in seeking definitions to eliminate multiple interpretations. Multiple interpretations is a game spoiler in STEM. STEM pursuit requires removing ambiguity as much as possible.

There are several other aspects of the STEM game that we could not cover here, which are better described by Thomas Kuhn as disciplinary matrix. Formation of social groups, as clubs, is part of any cultural activity. Science clubs, whether it is Royal Society or Indian Association for the Cultivation of Science, were created to promote STEM culture. After independence, though, we established more and more Government owned institutions, which restricted broader participation. The existing colleges and universities graduated students based on a syllabus, which did not focus on the rule-following games of STEM. Neither the admission tests, like JEE, nor the graduation exams look for student's familiarity with practicing STEM games; content knowledge is tested not culture. One-third of human life is spent on a misdirected preparation. Instead, if we focus on rules, we will learn how to create context rather than memorise content.

One intervention game that can transform the existing situation: reform admission tests to check for STEM knowledge. One intervention that will transform existing schools and colleges, which will metamorphose classrooms into STEM studios. This will also create the need for coaching shops which will transform STEM clubs, maker spaces, tinkering spaces. Commercial agencies adapt to change in the rules (policy) much faster than the conservative school and college system. Can we make this reform? But, should we? Are we convinced? Let us engage and examine these questions critically as the first step.

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Lectures

D.D. Kosambi Lecture
ICTS has introduced a new lecture series, named after the mathematician and statistician Damodar Dharmanand Kosambi, who made pioneering and foundational contributions to the methods and study of ancient Indian history. He was the first professor of mathematics at the Tata Institute of Fundamental Research. (1946-62). The ICTS D.D. Kosambi lectures will be delivered by eminent scholars in the social sciences and the humanities.

The Fissures of Modern Hinduisms: Religion and Historiography
24 May 2018 • Speaker — Pratap Bhanu Mehta
(Vis-Count, Ashoka University)

Nature’s Optics and our Understanding of Light
13 June 2018 • Speaker — Michael Berry
(McMillan Wills Professor of Physics (Emeritus) at the University of Bristol, UK)

Quantum mechanics and the geometry of spacetime
24 May 2018 • Speaker — Juan Maldacena
(Institute for Advanced Studies in Princeton, NJ)

Order, Disorder and Entropy
28 August 2018 • Speaker — Dais Frenkel
(University of Cambridge, UK)

A Finite Discussion on the Infinite
9 September 2018 • Speaker — Tanvi Jain
(Indian Statistical Institute, New Delhi)

Making Things, Doing Science
19 August 2018 • Speaker — Arvind Gupta
(Children’s Science Centre, UKCMA - former)

Some New Results on Rationality
1 October 2018 • Speaker — Claire Voisin
(College de France)

From Bits to Qubits: A Quantum Leap for Computers
26 September 2018 • Speaker — Susan Coopersmith
(University of Wisconsin-Madison, Wisconsin)

What is Common Between Falling Cats and the Quantum Hall Effect?
10 August 2018 • Speaker — Alexander Aharony
(Stony Brook University, New York)

Chandra. The Journey of a Star
5 August 2018 • Speaker — Giuseppe Massarelli
(GUSSA, Torino, Italy)

Black Holes and the Structure of Spacetime
25 May 2018 • Speaker — Juan Maldacena
(IAS, Princeton)

Entropy, Information and Order in Soft Matter
27 August – 2 November 2018 • Organizers — Bulbul Chakraborty, Pinaki Chaudhuri, Chandan Dasgupta, Maryjohn Dikshita, Saurajit Karakar, Vishyakumar Krishnamurthy, Jorge Kurchan, Madan Rao, Srikanta Saxty and Francesco Sciortino

Summer School on Gravitational-Wave Astronomy
13–21 August, 2018 • Organizers — Parameswaran Ajith, K. G. Arun and Balu R. Iyer

Integrable Systems in Mathematics, Condensed Matter and Statistical Physics
16 July – 10 August, 2018 • Organizers — Alexander Aharony, Ruikun Dey, Fabian Essler, Manas Kulkarni, Joel Moore, Vishal Vasan and Paul Wiegmann

Bangalore School on Statistical Physics – IX
27 June–13 July, 2018 • Organizers — Abhishek Dhar and Sanjib SahaSundar

Dynamics of Complex Systems 2018
16–30 June, 2018 • Organizers — Anil Apte, Soumitro Banerjee, Pranay Goyal, Partha Guha, Noolina Gupta, Govindan Rangarajan and Somdatta Sinha

Non-Hermitian Physics - PHHQP XVIII
4–13 June, 2018 • Organizers — Abhishek Dhar, Andrei Houch, Manasi Kulkari, Bhubani Mandal, Vijayraghavan Rajamani, Avadh Saxena and Mihály Zsoldos

Summer School for Women in Mathematics and Statistics
7–18 May, 2018 • Organizers — Silva Athreya and Anita Naolekar

Discussion Meetings

Complex Algebraic Geometry
1–6 October 2018 • Organizers — Indrani Binev, Mahan Mj and A. J. Parameswaran

Quantum Fields, Geometry and Representation Theory
16–27 July, 2018 • Organizers — Arvind Balasubramanian, Saaraa Bhamik, Indrani Binev, Abhijeet Gade, Rajesh Gopakumar and Mahan Mj

Geometry and Topology for Lecturers
16–25 June, 2018 • Organizers — C. S. Aravinda and Kalikrishnan Dey

Adv/CFP at 20 and Beyond
21 May–2 June 2018 • Organizers — Pallab Basu, Arvind Dhar, Rajesh Gopakumar, R. Loganayagam, Gautam Mandal, Shiraz Minwalla, Pradipta Samal and Spenta R. Varia

RAD@Home Discovery Camp
7–13 May, 2018 • Organizers — Ananda Hota, Chiranjib Konar and Sravanthi Vaddi