

Redesigning Science Communication: Towards a New Theory and Method of Science Communication

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Indian children are like all children. Once they start to speak intelligibly, they invariably express wonder at the world in which they find themselves, usually by addressing rapid-fire questions to the adults who are close to them. Unfortunately, few of them go on to a school that actively supports such questioning. The American scholar, Noam Chomsky, who did attend such a school, from the age of one and a half to twelve years, calls it "a real experience" [1]. But that is not something that most Indian kids get. Unable to challenge the dictates of their elders, or to work on their own, or to think things through for themselves, they turn into drudges. My purpose here is to imitate the dharma of the child who feels himself free to challenge any assertion. I will do so by reflecting on some instances of science communication, both good and not so good.

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Abstract

This address will discuss tools for bringing science to the masses and will specifically describe the structure of the family of science centres. These include the planetarium, the exploratory, the science museum and the science city. In what way these institutions can work towards making the layperson science-friendly? Experience shows that despite the progress of science and technology, the mental attitudes of most Indians continue to be rooted in the past. The need for establishing the scientific temper had been stressed by no less a person than Jawaharlal Nehru who had hoped that once India became a free country its citizens will be able to think rationally. Ways and means are suggested here through which the family of science centres can help fulfill that dream.

Introduction

This meeting is about bringing science to the masses, creating a mindset in which the typical citizen will be able to appreciate the social force that we call science and technology, and preparing our nation to meet the challenges that lie ahead in a competitive world increasingly dominated by science and technology. The subject is vast and here I wish to limit myself to the approach using science centres that are increasingly becoming popular in our cities.

I have had the benefit of interacting closely with science centres in India, in particular with the National Council for Science Museums (NCSM), a government sponsored autonomous body that has so far supervised the creation of the majority of science museums in the country. I also had the benefit of watching the growth and development of planetaria in Mumbai and Hyderabad. In addition, I had been involved in the consulting process that has led to the setting of the Science City in Gandhinagar, near Ahmedabad. What I have to say will be based largely on this experience.

I would like to begin my address in a historical mode, beginning with how I first came in contact with the concept. For, I feel that through this mode I can convey what I have to say in the most effective fashion.

The Engineering College Exhibitions

I was brought up on the campus of the Banaras Hindu University, during the years 1938-57. My father was the Head of the Mathematics Department and so we had a staff quarter on the campus. The B.H.U., as it is called, had achieved a national reputation in the 1940s and its Engineering College in particular attracted bright students from all over India. Indeed, the college was known to be one of the best in India. There were some students who came from remote places but whose families were known to ours and these students kept in touch with us throughout their college days. Because of their interaction, my brother and I used to be invited, along with our parents to the Annual Day gathering of the Engineering College.

I was in school in the standard V, when I think we were taken by my parents to the Exhibition that used to be arranged by the students of the Engineering College for the invitees to the annual gathering. These generally included the college faculty and other interested persons from outside. We were thrilled by the exhibits, which were made by the students as part of their projects. They used scientific laws to make technological applications, in hydrodynamics, electricity and magnetism, sound, thermodynamics, etc. I had not encountered these applications in my school curriculum, but my introduction to these aspects of science, howsoever elementary, made me enthralled to see what was possible. To some one not knowing the basic science behind the exhibit, the result looked like magic. To me and my brother these annual visits to the Exhibition became things to look forward to. The gadgets differed from year to year as each batch of new students would want to show their originality rather than copy previous year's exhibits.

Gradually, however, as my own understanding of physics advanced, the 'magic' part of those exhibits wore out. But it was still worthwhile visiting the exhibition, if only because it showed the many different ways in which the same laws of physics found technical applications. In this context one may recall the apocryphal anecdote that when Michael Faraday showed his newly created dynamo to Queen Victoria who had come on a visit to his laboratory, the Queen asked: "But Mr Faraday, what is the use of this gadget?" To which Faraday is supposed to have replied "Your Majesty, we do not ask what is the use of a newborn baby." Indeed the device is today responsible for generating power on a grand scale. In another version of the anecdote, it was Prime Minister Gladstone who had visited Faraday and asked the same question. This time Faraday's answer was: "Sir, some day you will be able to collect taxes on its applications."

Although one may write Faraday's law of electromagnetic induction or other laws of electrodynamics and study them theoretically, nothing leads to a better impact of what they mean than through direct experiments. Indeed understanding and applications of science have always proceeded through experimental demonstrations. This is where science centres have a major role to play.

Types of Science Centres

I wish to divide the range of science centres into categories differentiating them by their functions, although all of them seek to advance the public understanding of science in their own ways:

1. Planetaria
2. Exploratories
3. Science museums
4. Science cities

It is not the case that these are mutually exclusive; for there could be planetaria in science cities or exploratories in science museums. In any case let me outline briefly what I mean by these categories.

The planetarium

The planetarium concept has steadily evolved over the years, aided also by the advances in technology. Thus from the original multi-projector mode with an operator pressing buttons on a console and commenting at suitable places one has a fully automated digitized version that can be run in a prerecorded mode. The show itself has evolved from simple projection of stars on a dome to action-replays, photographs and movie-strips etc.

An exploratory

An exploratory is a science lab in which students can perform experiments on their own. Thus there may be well maintained apparatus ready for performing a specific experiment; yet with the possibility of some improvisation on the part of the young scientist. Indeed improvisation is important since performing a preset experiment does not convey the spirit of science, its thrill of probing the unknown. For example, the simple experiment of measuring the weight of a block of matter by spring balance can be further adapted by suspending the block in water. What happens to the weight? Next, if some other liquids are available, how does the weight change in different liquids? Can it disappear altogether? Next comes the question: Can one simulate in the labs the conditions of weightlessness experienced by an astronaut in space? So one can start with a spring balance and reach out to the outer space.

Even the supposedly abstract mathematics can be brought to reality by simple experiments. I came across an experiment in a primary school in the U.K. where ten-year olds were given a sheet of paper each and asked to draw the figure of any triangle using the ruler. Next they were asked to cut out the outline of each triangle. Then they were to cut across the triangle such that the three vertices came out as three separate wedges: at each vertex the wedge formed the original angle of that vertex. Next they were told to put all three wedges side by side with their edges touching, leaving two edges free. And to their surprise, the free edges formed a straight line as could be seen by placing the ruler against them. Not only that, each child got the same answer even though their original triangles were drawn separately. Why did this happen? To check that the result was not a fluke, they could redraw the triangle and repeat the exercise. This way they could appreciate the fact of Euclid's geometry better than the 'proof' of the theorem that the three angles of a triangle add up to two right angles.

At a more senior level, one can play with the Mobius strip. Again, making one with paper and cutting it along the middle line gives a strikingly different result than cutting a similar paper cylinder. It is only when one has played with it that one can appreciate a concept better.

A science museum

A science museum is a much bigger enterprise than an exploratory in the sense that it can cover not only contemporary science but also its historical evolution and future projection. It can have static and dynamic exhibits and special exhibitions from time to time with specific themes. Whereas an exploratory is more student-directed the science museum caters to the all and sundry. It may have interactive exhibits, although not full-fledged experiments in the sense of an exploratory. Through such push-button exhibits, the viewer can learn a lot more than from a static exhibit.

The science city

On the largest scale one has the concept of a science city that houses several science museums, perhaps a planetarium, as well as sources providing entertainment but depicting technology. A 3D cinema (I-MAX type), rides simulating travel to the Moon or Mars or in a space shuttle, creation of sensation of weightlessness, illusory directions of gravity, etc. are some examples. In a sense a science city is like an amusement park with the difference that here education takes precedence over entertainment.

I will now mention a few ways in which the planning of these various systems can lead to effective communication of science to the masses.

The planetarium

The planetarium is the most effective medium of describing our location in the cosmos, the dynamics of the Earth-Sun-Moon system, the planets and satellites, comets and meteorites and other members of the solar system. What is important now is to tell the viewers about other planetary systems – the extra-solar planets – being found since 1991. The impression that our planetary system is unique should now be corrected.

Debunking astrology

But in a country like India where even the sophisticated urbanite can be a believer in astrology, the need to debunk this belief is essential. There are ways and ways of presenting facts to the public and making them think for themselves. Here are some instances:

1. It is asserted when most of the planets come in the same part of the sky that catastrophes will occur on the Earth. On closer probing the reason for this is said to lie in the combined gravitational field of all those planets. But what difference will it make if all planets other than the earth come on the same side and try to pull us away from it? A simple calculation based on Newton's inverse square law can be performed to show that the difference made by them is less than the change in the Earth's own pull on us when we stand up from a sitting position.
2. The eclipses have their own myths in different countries. In India the myth is that the demon Rahu eats the Sun when there is total solar eclipse, while it is the demon Ketu who eats the Moon at the total lunar eclipse. In either case these myths prompt the credulous to hide themselves indoors when these phenomena take place, thus missing out on spectacular sights.

A planetarium based demonstration can show how and why the eclipses occur, how the 'nodes' get mistakenly identified as the demons and how the entire sequence of events is controlled by physical laws.

3. The comets have been thought of as harbingers evil. In days before Edmund Halley and Isaac Newton, the comets seemed occasional visitors to the solar neighbourhood and since bad events (earthquakes, cyclones, deaths of leading personalities, etc.) keep occurring every year somewhere or the other, the comets got blamed for them. The formation and motion of the comet, the nature of its tail, its composition, etc. are now well studied by astrophysics and this can be conveyed through a planetarium demonstration. In fact even though there are unsolved problems about comets, there is nothing mystical about them.
4. Apart from myths about these special events the belief in planetary astrology is very strongly rooted in India. Can the planetaria do something about them? I have discovered that simply labelling astrology as a superstition and calling it unscientific does not help dissuading the believers. One needs more subtle ways of getting them to think for themselves. One can show them how irregular the planetary tracks look on the sky when simulated over a few years; and stress how the superstitions arose from the belief that unlike stars, the planets could move arbitrarily at 'will'. It was the power of this will that they were believed to exercise over the mortals on the Earth. The mystery of these apparently irregular motions was long ago resolved by Kepler's laws of planetary motion and by the mathematical computations of orbits of planets based on Newton's laws of gravitation and motion. It can be very effective to demonstrate that the trajectory of a spacecraft launched from the Earth and landing on Mars can be mathematically computed and that the spacecraft arrives at the planet exactly at the predicted time. Physical information about the planets like Saturn including close-up images taken by spacecrafts will also help removing some of the mysticism about the planets.

Introducing such elements into the planetarium programme may turn out to be more difficult than it appears. For, it may happen that the management of the planetarium may be made of believers in astrology and the scientist in charge of the programme will be taken to task for introducing such thoughts!

Frequently asked questions

Going over from the corrections of mental attitudes frozen from the past centuries to a more futuristic vision, the planetarium can be used to project space missions to the Moon and the planets. I feel one should use the planetarium to deal with the query frequently raised in lay circles as to whether the Apollo 11 mission of Moon-landing was a hoax. One can raise the doubts and then clarify them in scientific terms. Likewise one can think of several frequently asked questions in astronomy and answer them in a planetarium programme.

Simulating the sky

But in the last analysis, a planetarium is a superb device for simulating the star-studded sky. Given sufficient ingenuity, one can see how this aspect can be made more interesting than simply showing constellations. How did the sky looked on some historic occasions? Which stars can one see and not see from the North Pole or from the South Pole? What was the position and path of Halley's comet in 1759 when it was first sighted in London after Halley's prediction of its arrival? What happens when there is a transit of Venus? What is midnight sun? How is it seen to move across the sky? What were the stars that Magellan saw when he went round the world? What does the sky look like during a heavy meteor shower? What

would the meteoritic impact have been like that left a big crater in the Earth, like the Meteor Crater or the Lonar Lake?

There are several absorbing topics like black holes, gravitational lensing, supernova explosion, the changes in a star as it evolves, etc. that can be depicted through a planetarium show. These topics link the physics of understanding an astronomical phenomenon to the details of its observations.

The exploratory

The exploratory provides an excellent opportunity of 'do it yourself' approach to science in which a school student learns scientific laws by observing them at work. Many schools in India, for want of adequate funds or being overburdened with large classes, cannot provide the luxury of experimenting (which is really a necessity!) to its students. An exploratory will serve to fill the gap.

Centralized facilities

Indeed I can visualize centralized exploratories located in different parts of a city serving such schools in their areas. An institution like this would maintain its experimental apparatus in good condition and would keep updating it. For this purpose it would be supplied with adequate budget and staff by the city school system. In this way several schools can take part in turns using the facilities for its students within their appointed hours. Such an arrangement will ensure that the labs are used almost round the clock during school hours, say from 8 a.m. to 6 p.m., Monday to Saturday.

Toys and experimental kits

However, one item that is increasingly gaining popularity could be named 'toys from trash'. These are scientific toys made with stuff that is normally discarded after its projected use. Wonderful items have been made this way that not only provide entertainment through their dynamic operation, but also have the merit of 'do it yourself at low cost' (DIYLC). In the Muktangan Science Exploratorium in my centre IUCAA in Pune, there are numerous such toys. Given the low incomes in India such DIYLC toys have much relevance, apart from their scientific content. There are also books now in market giving methods of designing experimental apparatus at low cost (again from discarded items of everyday use) which encourage students to do their school experiments this way. No one can deny their value against a background in which the child is asked to 'learn' science by simply reading about the experiments and not doing them himself or even seeing them performed by the teacher in the class.

The Science Museum

We have a chain of science museums under the overall management of the National Council of Science Museums. The Nehru Science Centre in Mumbai is a large one of its kind and has exhibits transcending various branches of science. It has also a large 'hands on' component, divided age-wise, so as to cater to children of different age groups. It is an experience watching children 'playing' with these exhibits and deriving pleasure as well as knowledge.

The scientific explanation

Such exhibits look like magic: indeed phenomena till they are explained by laws of science are like magic. I will return to this aspect again later. But given an exhibit, how do you answer the "Why?" asked by the child? To give the answer straight away is to deprive the child from the thrill of finding out for himself / herself. Perhaps, a questionnaire can be designed round a set of exhibits that the child may proceed along step by step answering...each question being simple enough to be within the child's scope of understanding and knowledge. But at the end of these leading questions a reasonably bright child should spot the answer to the riddle "Why?"

Some exhibits may answer questions raised elsewhere. A child may ask: "What happens to the Sun that rises in one direction (the East) and sets in another (the West)? How does it reappear after the night in the same direction?" A model with the spinning ball of Earth near the ball of Sun will help the child understand what is going on. And then one may ask a trickier question: "I once saw the Sun rise in the West...Can you imagine now that was possible?" I once wrote a popular astronomy book with this very question and this foxed many readers, until I gave out the answer. I was travelling East to West in a jet aircraft at high enough latitude to be able to counter the Earth's spin from the West to East.

The history of science

A science museum is an ideal space for projecting the history of science. Students usually get their 'dose' of science in a cut and dried form, getting to know the final product without being aware of the 'labour pains' for its genesis. Indeed the progress of science has not been smooth and straightforward. When groping for the unknown, it is not necessary that you will get the correct concept the first time. There have been wrong turnings that delayed true progress. Even a genius like Isaac Newton stood in the way of the wave interpretation of light and delayed its acceptance for several decades. This example also typifies the situation that a scientist does not always have an objective approach but like any other human being, possesses hunches and prejudices as well as other human emotions like hate, envy, greed, etc. Despite all these drawbacks the creative scientist is able to advance the subject. Then there are phase transitions in our understanding either made by single individuals like Einstein in relativity and /or a group of contemporary individuals as in quantum theory.

This story of science needs to be told, either in terms of specific episodes or as a saga of an era. A museum can do this through tableaux and animated exhibits. The information technology has provided many effective tools for projecting such a message.

Exhibitions

A science museum can use contemporary developments to project the status of any given field by special contemporary exhibitions. When Dolly was cloned, one could describe the state of the art in cloning, together with its advantages and dangers. The natural disasters like tsunami or earthquakes should likewise be projected as an exhibition.

Then there are exhibitions that can be repeated from time to time with minor modifications. For instance an exhibition explaining the work of Nobel Laureates, or the evolution of the computer, or advances in treating cancer and other difficult diseases, the use of technology in medical and surgical science, projections of future technologies, is a way of drawing the layman into sharing the appreciation of scientific advances. Equally important are exhibitions warning us on the indiscriminate use of technology, e.g., the threat to the ozone layer and the issue of global warming, pollution of various kinds, the destructive capabilities of nuclear arsenal, etc..

Membership

To increase the involvement of the local population a science centre or a science museum should encourage membership of its activities. Thus a programme of science films or science fiction movies, occasional science quiz competitions, entry to a topical exhibition, or simply correspondence with the experts at the museum by e-mail, free entry on paying membership fee, may be part of the 'perks' that a member receives. Being a member generates a feeling of belonging to the place and this may increase active participation of the member in its activities.

The Science City

The science city may be a big affair, like a Disneyland, only with its thrust on promoting science and science-friendly attitude. It is the kind of place where a family may want to come in the morning and spend the whole day. To keep them engrossed in the place there has to be a judicious mixture of instruction with entertainment. It is easy to err on either side! In one's enthusiasm one may have a large number of educative facilities and very few to amuse and entertain and the visitor feels like being in a glorified school. On the other hand, too many entertaining attractions will make the visitor give the science a miss altogether. Since the concept of a science city is relatively new, let me air some possible items that could form part of it. I should mention that the first science city and the only one fully functioning in India is in Kolkata. Its popularity has made other states in India ask for science cities in their areas.

Entertaining attractions

So an I-Max type theatre is fine so long as it shows films with some science content, with an occasional science fiction film. One can have a pavilion where one can participate in a simulated travel to the Moon. Or, one can have simulator for travel in a space shuttle. One can also imagine becoming micro-sized and moving in one's own bloodstream. There can be a small Jurassic Park telling about the creatures that once roamed the Earth. The under-water world provides its own charm.

There can be a futuristic pavilion showing inventions in the making and what they will achieve for making human existence more comfortable. It will not be without effect to demonstrate what life in a polluted world will be like if one did not heed the present warnings. And simulating a nuclear holocaust will bring its own sobering thoughts. There are plenty of themes demonstrating the strong link between science and society, themes that can be translated into model pavilions. The main thrust of the science city should be on the younger visitors, schoolchildren and college graduates. For, theirs is the generation that will be in the driver's seat in the next two decades.

At the other end of the age group of target users, we may consider adult audiences. Here one encounters set attitudes and superstitions held as firm beliefs. How can we deal with such cases? It is not too late to initiate dialogue with them through the medium of a science city. Since even they understand that a scientific temper stands for a rational evaluation of what we see and experience, they will not be averse to encountering examples that make them think for themselves. What I mention next concerns the young as well as the old. For, to my chagrin I am finding that far from being more modern than their parents in their outlook, the young people of today are equally superstitious. This is why I am highlighting two major threats next.

Back to astrology

I have already referred to astrology as a very strong superstition in our country. People consult astrologers before taking any important decision, such as when to move into a new house, when to make a major purchase like a car, whether it is OK to set out on an important trip on a given day, etc. Politicians are great believers and like to have the OK from their personal astrologer before taking oath of office. Ministries have been known to be sworn in at very odd hours because that was the only period considered safe by some astrological yardstick. To cap it all, a few years ago the University Grants Commission, the parent funding agency of all universities decided to introduce astrology as a part of science curriculum!

In this context I can narrate an experience in my own family. My teenager daughter wanted to buy a two-wheeler scooter when she became eligible to drive one. My wife took her to the local showroom where they discovered that there was a waitlist for the model my daughter was interested in. But they also noticed a large stock of the same model parked in the shed outside. So my wife asked the manager, why with so many in stock there was a waitlist. The manager replied that they were reserved and waiting to be purchased by the people who had ordered them. These prospective customers were waiting till the "Pitru Paksha", the Ancestral Fortnight, was over. [For those not familiar with Hindu traditional beliefs, that fortnight is reserved for religious ceremonies for propitiating the souls of one's dead ancestors, and during this period it is recommended that no major action/decision in life be taken.] So my wife asked if she were to buy one right away, would he let her have one of these in stock? "Gladly!" replied the manager, if she was willing to take the 'risk'. He could replace the model for the assigned owner when he returned after the 'prohibitive' fortnight was over. So my wife jumped the queue and came back with a scooter right away. One person's superstition can be to another's benefit!

Then there are well educated families who will arrange weddings only if the horoscopes of the couple match. There are occasions when otherwise suitable matches, including of a pair in love with each other, are not allowed to proceed for fear of Mars or Saturn. What can a science city do to counter such misinformation?

I feel an exhibition directed against astrology is long overdue – an exhibition which will begin by telling people what the planets really are, how and why they move, how predictable their motions are, how man can rendezvous with them etc. In short an attempt should be made of informing the present knowledge and confront the superstitions with facts. One can also inform the viewer how tests of astrological predictions have repeatedly demonstrated their failures. A science city is an ideal place for such an exhibition.

Debunking miracles

Another feature that a science museum could host would be a counter to the prevailing cults of 'godmen'. These are self-proclaimed holy persons; in India typically a man will have the title 'Baba' after his

name and a woman will call herself 'Ma', these epithets meaning 'father' and 'mother' respectively. A common feature of these persons is to show their extraordinary (supernatural?) powers by performing miracles. It is such miracles that attract the gullible. How can a science city act against this phenomenon, which is on the increase in India?

An excellent approach to handle this problem was shown a few years ago in a people's science movement in India. It had government support, but it relied more on non-governmental organizations. It organized a troupe of workers who went from village to village dressed as a Baba with his followers, performing 'miracles'. They were shortly followed by another troupe who debunked the very same miracles, explaining where sleight of hand was involved and where simple physics principles or chemical reactions played the crucial part. The message was: "Beware of such acts of deception and do not assume the existence of divine power behind them." Such practical demonstrations went a long way towards educating the masses. Indeed since then some godmen have been caught in the act!

Such theatrical performances can be staged in a science city and I am sure they will not only be instructive, they will be entertaining as well. NGOs dedicated to the eradication of superstitions can play a leading role in such performances.

The scientific temper

Emphasizing the need to cultivate a scientific temper, India's first Prime Minister Jawaharlal Nehru wrote this in his famous book *Discovery of India*:

The impact of science and the modern world have brought a greater appreciation of facts, a more critical faculty, a weighing of evidence, a refusal to accept tradition merely because it is tradition...But even today it is strange how we suddenly become overwhelmed by tradition, and the critical faculties of even intelligent men cease to function...Only when we are politically and economically free will the mind function normally and critically.

Nehru said this a few years before India's independence, when he was fighting the ruling British for the independence of India. He was voicing the hope that as the members of an independent nation, Indians will be free from pressures of a colonized people and will be able to determine their own destiny through rational thinking. This has not happened even though more than half a century has elapsed since that event. In the meantime the world has advanced, the tree of science has prospered, the society is tasting its technological fruits, but attitudes frozen in the bygone days of two centuries ago continue to dominate the mindset of most people.

This is where practical and demonstrable effects achieved in science centres of various kinds and sizes can play a very necessary role. Although I have based all my examples and arguments on the Indian experience, I am sure, other countries have similar problems to share. What I have said in the Indian context can therefore be translated for other countries with suitable modifications. I have described a family of science centres of various sizes and functions: all of them in their own way can play a vital role in bringing the mindset of the inhabitants of the twenty-first century up to where it should belong: to the twenty-first century.