The ‘Public’ and the ‘Outreach’: Public Outreach of Science in India

DIPYAMAN GANGULY [1,2]

[1] Senior Scientist & Swarnajayanti Fellow, CSIR-Indian Institute of Chemical Biology, Jadavpur, Kolkata, 700 032, West Bengal, India

[2] Convener, Rural Scientific Outreach Initiative, Center for Observational Astronomy, Kolkata, 700 004, West Bengal, India

Email: dipyaman@iicb.res.in

Corresponding editor: RAMRAY BHAT

DIALOGUE
Science, Scientists, and Society

Dialogue - Science, Scientists, and Society. Volume 1.

PERSPECTIVE

The ‘Public’ and the ‘Outreach’: Public Outreach of Science in India

DIPYAMAN GANGULY [1],[2]

[1] Senior Scientist & Swarnajayanti Fellow, CSIR-Indian Institute of Chemical Biology, Jadavpur, Kolkata, 700 032, West Bengal, India

[2] Convener, Rural Scientific Outreach Initiative, Center for Observational Astronomy, Kolkata, 700 004, West Bengal, India

Email: dipyaman@iicb.res.in

Received 19 February 2018; Accepted 21 May 2018; Published 26 June 2018.
DOI: 10.29195/DSSS.01.01.0007

Corresponding editor: RAMRAY BHAT

Abstract

In the 21st century, as the global scientific pursuits provide an enormous amount of new revelations about the natural world, the gap between lay public and the scientific community widens more than ever. On the other hand, scientific endeavours all around the world increasingly depend on popular support for such efforts, as the policy decisions are largely driven by popular perceptions. Frequent instances of a disturbing public show of ignorance about rather established scientific knowledge, almost all over the world, may well be dismissed as rather outliers or means for political or economic gains. But one may argue that these phenomena can also be attributed to the usual public outreach methodologies. This essay aims to dissect out the prevalent public outreach strategies, by closely examining the nature of the key components, i.e. the ‘outreach’ and the ‘public’, to examine this argument. The essay also provides a discussion on the alternative thoughts on more effective programs to enhance public understanding of science and scientific temper, like setting up of rural hands-on science education centers as widely as possible and initiation of nationwide citizen science programs.

Keywords. Citizen science; public outreach; rationalism; science; scientific method; scientific temper

Introduction

Almost two decades ago, an editorial piece in the Science magazine by Hiroo Imura sincerely warned us that the more we progress in terms of scientific discoveries and technological innovations there is bound to be an ever-growing disparity between the understanding that the scientific community will enjoy and the knowledge that the public will manage to grasp (Imura 1999). He recommended policies for rigorous public outreach programs globally, taken up by the scientific academies and governments. Notably, if the 21st century can be characterized by an unconceivable pace of scientific revelations in all domains of natural sciences, it can also be seen as a century when an enormous amount of effort has been put in to bring scientific parlances and ideas within the reach of the public. Increasing technological ease provided by the innovative digital networking of global citizens has also been very helpful in this respect. But these efforts have also led to another set of problems, again alluded to by Imura in the same piece — scientific knowledge of unparalleled enormity and complexity becomes a burden on the early learners (Imura 1999). One can guess that this is perhaps true also for the adult 'public' reached out to later in their lives. The public show of defiance toward rather established scientific knowledge, from natural evolution to climate change, at times even the shape of the planet, by groups of people almost all over the world, confuses the scientific community. [1-5] One can always dismiss these phenomenologies as comical outliers or nefarious means adopted for political or economic gains. But one may also ask if the very nature of the public outreach efforts can also be held responsible for these counter-intuitive outcomes. Let us try to understand the complexities behind the outcome, by patiently dissecting the prevalent public outreach methodologies, while closely examining the nature of the very words 'outreach' and the 'public'. It is imperative in a modern society to inculcate scientific attitude among the uninitiated citizens, to let them appreciate the natural world and logical links of their own selves with the natural phenomena —and this is the major motivation for science outreach. The discussion is of even more importance given that the future of fundamental scientific research will increasingly depend on public funding and thus public perception about science should be in line. Because policymakers in a democratic country do and should respond to the core imaginations of its citizens and thus incorporating the practice of science into this core imagination is bound to influence the policymakers as well. Thus, serious thoughts should be invested into 'how' to recognize the most effective way to achieve a much wider public understanding about science and a rational approach to the natural world and life on this planet.

[1] Web source: http://www.sciencemag.org/news/2017/06/trump-dumps-paris-climate-deal-reaction

The 'Outreach'

The goal of public outreach efforts, in general, has been spreading awareness about established scientific knowledge among the public, with an underlying hope to inculcate a spirit of rationalism in the populace. Now let us try to understand the general methodological architecture of the process of public outreach events, in the context of India. In the most prevalent model, we find a few 'interested members of the public' being gathered together, to listen to discussions on different aspects of scientific endeavours, by one or two so-called popular science speakers or demonstrators. These events are organized within a very short distance from a city or town, at least within a distance that can be travelled back and forth within a day or so. In other words, the outreach event must be within the reach of the 'rationalism inculcators', who are often placed in cities and major towns.

What one should compare with these efforts is the public outreach of religious thoughts. But the prominent methodology adopted over the ages has been of a scale that the public outreach of science could never have imagined. Of course, science and rationalism are still in their adolescence compared to the co-evolution of religion along with human society over thousands of years. Yet one can feel that science and rationalism had a lot to learn from the expanse of religion. Even in the remotest human settlements in India, what one finds is a place of god, no matter how modest the setup is. The man-made roofed structures that the children of that remote habitat get to know, other than the roofs that protect their family or friends, are these places of god. Then if they are fortunate, they may have places to buy provisions from, to meet teachers, to read books or to catch a bus from. So one can imagine that the spread of rationalism and scientific awareness stands nowhere in terms of scalability. The only hope science has is in the teachers that these children get to know and learn from. That is another tragic story.

A much more apparent problem with a public outreach of science in India is the usual captive audience it manages to gather. The nation-building agenda of the early leaders of independent India did include the spread of scientific awareness. As a result, a large battalion of science outreach activists have been in the public sphere and that contingent has kept on building on its numbers over the years, although at a much slower rate than what was needed. Even then, the outreach activities run by a majority of them suffer from a ritualistic adherence to their base and methods. They lament for the unreachability of the intended goal, of widespread irrationalism, but seldom question their methodology. Here the author is tempted to anecdote his own experience about organizations involved in science outreach activities in the state of West Bengal. West Bengal has a legacy of such organizations and activities and it has got a

[2] Web source: http://www.independent.co.uk/news/world/americas/scott-pruitt-epa-global-warming-good-humanity-trump-climate-change-environment-protection-agency-a8200196.html
[3] Web source: http://www.sciencemag.org/news/2018/01/india-s-education-minister-assails-evolutionary-theory-calls-curricula-overhaul
[4] Web source: http://www.newsweek.com/flat-earth-conspiracy-america-726761.
[5] Web source: http://www.sciencemag.org/news/2016/01/neil-degrasse-tyson-and-bob-are-throwing-down-over-flat-earth

number of them now, dotted all around the state in almost all small and big towns and cities. But if one happens to visit them after long intervals, the faces seem not to change much. One organization spawns several others, often differentiated by only minor methodological rhetoric (!). But the size of the client base remains very restricted. Indeed the only spread that Indian science awareness campaigns have seen over the years has been in the number of registered societies, but not in the number of people reached out to.

Outreach sessions arranged by these organizations gather audiences from the 'outreachers' themselves, part of the 'public' already initiated to these activities before and an ever-changing contingent of local students who are not yet close to their exam schedule. The gatherings are mostly organized during some rare celestial events or to commemorate one or the other scientific stalwarts from the past. Somewhat related to these awareness campaigns, a number of health awareness camps get their motivation from emergent epidemics of diseases or some rare notable event related to public health. Thus the design of the outreach programs often comes out to be very ritualistic. Both the composition of the 'public' as well as the method of the 'outreach' fail its intended purpose.

We can now go back to the roofed building where the children, the future 'public', may get exposed to principles of rationalism and scientific thoughts - the 'school'. In fact, if one considers comparing the influence of organized public outreach activities and school teaching on the development of rational thoughts among the school-going children, the latter will appear to be far more efficient. Whether the outcome of the aforementioned influence is enough for the children is arguable in a different forum. But as one can easily discern, the curricular science teaching in schools has no intrinsic ability to inculcate rational thoughts and scientific temper. It, though somewhat unintentionally, rather engages children into science as a means for future financial sustainability. The fact that still, this very school-teaching does inculcate primary rational thoughts in a large number of children is a testimony of human spirit of inquisition and rational thoughts, and not of curricular prudence.

Another major public-funded effort toward public scientific outreach is establishing science centers or museums. Science museums have a quite long history and in general, their inception was rather to showcase human scientific achievements, and in some cases national might, to the citizens. As intended the only experience that they offer to the visitors is plain awe, quite akin to the places of god. Added to this are the peculiar futuristic architectural elements incorporated while building such centers. Moreover, such centers all over the world, including India, are mostly located in big cities. Thus one can hardly argue that such science centers and museums have effectively contributed to the widening scientific temper among the uninitiated citizens. It is true that designing science centers is an active field of research and new ideas keep flowing in. But when the author of this article once had a perfunctory look at those upcoming ideas, they too seemed to fail the proclaimed purpose. The new centers will have better ways to direct visitors to one exhibit or another, perhaps based on a rational string of thought – but at all the exhibits, the visitor presses some button and something 'unthinkable' happens within a glass box, and the visitor reads in an attached note why that 'unthinkable' happening is not anything supernatural. These are definitely a great deal of improvement on yesteryears' science center design. But the present author remembers, as a kid, he always preferred not to read that note and think about it. He always moved

towards the next exhibit to find out what wonders the next button may bring. And he can vouch that most of his juvenile co-visitors at all such occasions did the same. Well, he cannot deny the possibility of a behavioural contagion because he never witnessed them visiting the exhibits in his absence.

Finally, one should remember the immense role that the media plays these days in influencing the popular perception of science. In fact, the print media is perhaps the most powerful disseminator of scientific information to the public. Their reach is enormous and the popular trust they enjoy is formidable. When we look at the nature of the public in the next section, it will be more apparent how the potential outreach of media surpasses all other means. But at times the very strength of it becomes a deterrent for the development of scientific temper among its readers. A newspaper, where a news article on the latest evidence for successful cancer immunotherapy and an advertisement promoting a fast and painless cancer cure based on the planet's magnetic field appear next to each other, it does immense harm to the scientific temper of its readers. Because these two pieces of information come to the reader with the same level of trustworthiness. Thus journalists walk a very thin line while their financers are incorrigible. The same applies to the new age social media, which has a great popular reach and yet is characterized by an uncomfortable universality of content sourcing. Moreover, even the more dependable sources on the internet, like blogs on scientific findings written in a way more accessible to the lay public have also been shown to have an inherent undesirable influence. A recent study has actually found that popular pieces directed towards lay readers make the readers agree more readily with the scientific concepts as compared to a piece which is accessible to an informed lay reader but directed toward domain experts (Scharrer *et al.* 2016). This plausibly results from the oversimplifications attempted in popular pieces without representing the rationale and approach that derived the conclusions. A related issue is the public assumption that 'a scientist said it' is same as being 'scientific', as stressed upon by Massimiano Bucci in a recent editorial in the journal Public Understanding of Science (Bucchi 2017). Thus in the absence of methodological insight, the popular depictions appear more agreeable, which in reality harms the scientific spirit and appreciation of scientific methods.

The 'Public'

Now that we have reviewed the prevalent outreach methodologies, let us try to understand the composition of the clients for the outreach, the so-called 'public.' As we already discussed, the usual science outreach activities have variable reach for the clients, depending on the methodology adopted. But what is more important is the client composition which is greatly biased by the already existing perception of science in general. In other words the 'public,' that the usual ways of science communication end up reaching out to, may not be a true random representation of the total population. Unfortunately, we do not have any data on wider public perception about science for India. So let us try to borrow a classification for the 'public' from such a data which was generated in the United Kingdom. The study was done by Ipsos MORI Social Research Institute commissioned by the UK Ministry of Universities and Science in

2011. [6] This study could classify the citizens based on their perception of science into six distinct categories: *concerned* (having strong views about the limitations of science), *indifferent* (less informed about science and no strong opinion against or for), *late adopters* (claiming disinterest in earlier phases of their lives, e.g., in school and becoming strongly intrigued by scientific thoughts later), *confident engagers* (strong positive attitude about science), *distrustful engagers* (distrustful to practicing scientists and regulatory authorities despite having strong positive attitude toward science) and *disengaged sceptics* (not sure about any role that science may play in their lives, at the same time distrustful of practicing scientists or regulatory authorities). One can imagine that almost a similar citizen classification will be apparent if one did the study in India. Definitely, relative populations represented in each category will vary a lot. But let us put that difference aside and try to guess how the existing public outreach efforts do in terms of reaching out to these six categories of citizens.

We have already reviewed that and we know that the people reached out to are mostly late adopters, confident engagers and distrustful engagers. One can also be sure that the majority of Indian population will be represented in the categories left out. In fact, even in the UK, almost 42% of the study population belonged to either the concerned or the indifferent group, far exceeding the fraction comprising both the engaged groups. [6] The study could also discern the difference in sourcing science-related information among these categories. Obviously, there was not much surprise – concerned and indifferent had their inputs mostly from newspapers and television, late adopters and disengaged sceptics from the internet. Both the engaged groups were open to varied sources that enriched them about science. Now the disengaged are not disengaged from all other public happenstances. Thus no one can deny that the inability to engage the disengaged to science will lead to an ever-widening and irreconcilable rift between science and the so-called 'non-science' in the public sphere.

When one tries to analyze the prevalent methodologies of public outreach of science, these insights into the subset characterization needs to be considered with great attention. The author is of the opinion that there should be a detailed assessment of the public perception of science in India. Similar studies have been done all over the world. We already discussed the UK study of 2011. European Union also conducted a separate study among the European population (special Eurobarometer study in Science & Technology, June 2010). [7] These international studies do provide some very crucial insights into the problem and in the absence of an Indian study; they should guide the concerned Indian agencies. It must be stressed that the clientele for the prevalent outreach programs conducted by scientific communities and science activists fall short of reaching out to the key sections of the public. One can imagine that a continuous engagement of an already motivated and engaged section

[6] Public Attitudes to Science: Summary Report – Ipsos MORI Social Research Institute (Commissioned by Ministry of Universities and Science, United Kingdom). 2011, https://www.gov.uk/.../bis-11-1255-public-attitudes-to-science-2011-summary.pdf

of the population into these activities lead to a somewhat ritualistic observance of public outreach programs.

Having considered all of this, can one imagine a detour in the outreach avenues to further the goal of spreading scientific awareness and developing a scientific temper among the Indian citizens? It is imperative to get engaged into such imaginations, because even when we are sceptic about the extent of our success in improving the popular perception about science and rationalism in the country, we cannot deny that there is a fairly large contingent of motivated and skilled science popularizes and activists that independent India has managed to gather over past decades. A large number of practising scientists have also been continually engaged in such efforts, although the size of the practising scientific community in India is unthinkably small in comparison to the nation's population. Having said that, we should also realize that the very concept of science educators/communicators leads to a conceptualization of 'science' and 'public' as two discreet entities where a supervised mediation is called for. This can actually weaken the normative assertion for the scientific and rationalist spirit and may provide enough reasons for failing to engage the 'disengaged.' So can we imagine ways of outreach where the role of the 'educators' will be limited but science with the entirety of its spirit can be accessed and appreciated by the 'public'?

What if Science Reached the 'Public' Rather than the Science Educators?

This author believes that a great extent of the issues with an effective public outreach of science can be circumvented if we decide to revamp our methodology. The major problem is the limited reach of the science educator pool to the vast majority of the public. What if we start thinking about ways in which science itself, not the science educators, can systematically reach the populace? When one talks about science and its appeal to a rational human being, one must discern that it is the scientific methodology, not the scientific wonders, that appeals to one the most. One is tempted to reiterate the famous saying by Marie Curie - 'I believe that science has great beauty. A scientist in his laboratory is not a mere technician: he is also a child confronting natural phenomena that impress him as though they were fairy tales' (Labouisse 1937). When a science educator reaches out to the public by talking about human accomplishments in the scientific pursuit and the consequent unravelling of certain truth about the natural world, for an initiated audience it becomes a way to further enrich their already existing appreciation of science. But these efforts fail to impress upon that 'fairytale' feeling, which would have been much more successful to engage the uninitiated, be it children or adults. This can only be accomplished when one is made to rediscover any natural phenomena following a scientific methodology, which unfortunately the usual ways for public

[7] Special Eurobarometer. Science and Technology (Commissioned by European Commission). 2010, ec.europa.eu/commfrontoffice/publicopinion/archives/ebs/ebs340en.pdf

outreach lack. But this approach can truly take science to the public, excite their imaginations and inculcate the appreciation of the rational approach to the natural world.

The most efficient way to accomplish this is to let children perform experiments on their own and arrive at scientific conclusions following a rational way of deduction. But the curricular science teaching cannot manage to incorporate these elements to the extent it should be done. Major efforts are underway globally to rejuvenate teaching methods, but for obvious practical reasons, this is not something that can be accomplished easily. This can be done by building a new breed of science centers all around the country, which will serve as resource laboratories for the school-going children. But it has to move away from the conventional model of such centers. We have to imagine science centers on a shoestring budget, with provisions for very simple experiments to be done by the visiting students. The present author believes that public funds can easily come up with tens of thousands of such science centers in all parts of the country if while making them the only consideration remains the inculcation of scientific methodology through the simplest of experiments, the real core goal of the project. The architectural extravagance commonly associated with such centers does not serve any real purpose; rather such centers should be designed keeping the locale in mind. (Think about the tiniest places of god!). Why cannot one think of a science center in a mud-hut? Imagine children visiting such a center close to their house, getting to play with few convex lenses and prisms, take a bunch of leaves and have a look at them through a simple microscope, take a telescope out on a starry night and feasting their eyes, any day they want. Imagine their parents, accompanying the children on one of those days, learning from their children about how to look through a microscope or a telescope, what to expect when sunrays are made to pass through a convex lens and why. That is how science can reach the public. Add a small library with a collection of introductory books in the center itself, written in vernacular languages on different scientific disciplines, for the children to ponder over and find out rational explanations for the phenomena they just observed. A science museum adorned with colourful buttons can never have the same impact on the masses. The scale that is reachable in terms of the actual intended goal for such a center is unthinkable for a glass facade of a science center in the city.

Another promising approach towards a greatly effective science communication is to engage the public in actual scientific activities. This approach is the basis for the 'citizen science' programs adopted all around the world in the past decade or so (Bonney *et al.* 2016). Such programs are formulated in a way that allows engagement of the lay public in collection and processing of data towards a scientific goal steered by a group of practising scientists. Citizen science programs have been initiated in a great variety of scientific domains from ecology and biodiversity to astronomy. A number of such programs have already yielded desired outcomes in terms of important scientific insights. Instances where lay citizens take part in serious scientific activities and make significant contributions are not new to science and started with amateur naturalists. Names of Charles Darwin and Alfred Russel Wallace can also be presented as examples. But the amateur naturalist endeavours were driven by individual motivation. Citizen science programs have an inherent dependence on large numbers of individuals being directed towards a common well-designed scientific goal. Such efforts are also not new, for example, the Christmas Bird Count (CBC) Program by the National Audubon

Society in the USA that started in 1900, has a century-old annual bird count data that exists till this day.[8] The CBC program engages volunteers in counting birds in the western hemisphere during a specific period of the year (December 14–January 5) and is one of the longest-running conservation biology projects in the world. Other such programs include Breeding Bird Survey by US Fish & Wildlife Service (Robbins *et al.* 1979), Cornell Nest Record Card program,[9] Birdhouse Network program,[10] Seed Preference Test by Cornell Lab of Ornithology,[11] National Institute of Invasive Species Science program,[12] Monarch Larva Monitoring Project,[13] etc. More recent data collection programs have engaged citizens to aid in scientific discoveries in diverse contexts, *viz.,* geographical distribution and effects of pollen color of a flower (Austen *et al.* 2018), photo-based insect and plant records (Osawa *et al.* 2017), long term annual trend and seasonality of river nutrient abundance (Abbott *et al.* 2017), smartphone-based ocean transparency data (Seafarers *et al.* 2017), tracking of migratory birds (Wilson 2017), sampling butterfly legs for a genetics-based species identification (Wilson J.J), etc.

In addition to the domain of nature conservation and biodiversity, the citizen science approach is prevalent in the field of astronomy since long. A great number of amateur astronomers all around the world pursue the activities driven by individual efforts but collect data on emergent as well as stable celestial phenomena to international professionally managed data archives. These data then are used by professional astronomers for scientific discoveries. The individual efforts are of special interest in this domain, as amateurs have actually discovered a number of comets, bursting stars (nova) in the galaxy, which are then duly credited to their names. Long-term contributions are made by amateur observers who record the brightness of specific stars (variable stars) or count sunspots and submit the data to an international public archive maintained by American Association for Variable Star Observers.[14] A fairly large contingent of amateur radio-astronomers are also very active all around the world and a sizeable fraction of them was engaged in the Search for Extraterrestrial Intelligence (SETI) program in which the National Aeronautics and Space Administration (NASA) also engaged in the 1970s.[15] More organized programs in astronomy include the Galaxy Zoo project where public is engaged in classifying celestial images gathered by the Hubble Space Telescope (Lintott *et al.* 2008) and the very recent 'Crayfis' project where the goal is to engage public into a cosmic ray source localization program using smartphones (Whiteson *et al.* 2014). In

[8] Web source: Christmas Bird Count Program by the National Audubon Society, USA: www.audubon.org/conservation/science/christmas-bird-count

[9] Notes & News: A North American nest-record card program. Journal of Field Ornithology. 1965, 36: 66-67. (accessed from https://sora.unm.edu/sites/default/files/journals/jfo/v036n01/p0065-p0066.pdf)

[10] Web source: Birdhouse Network program, Cornell Lab of Ornithology, Cornell University: http://www.birds.cornell.edu/Page.aspx?pid=1478

[11] Web source: Seed preference Test, Cornell Lab of Ornithology, Cornell University: www.birds.cornell.edu/bbimages/email/care2/BirdNoteWinterFeeding.pdf

[12] Web source: National Institute of Invasive Species (NIISS). Fort Collins Science Center Report. 2006, United States Geological Survey (accessed from https://pubs.usgs.gov/fs/2006/3036/report.pdf)

[13] Web source: Monarch Larva Monitoring Project (MLMP): https://mlmp.org/default.aspx

fact, an online portal called Zooniverse is in place for recruiting volunteers in ongoing citizen science programs in the domains of physics, space science, medical science, biology, climate sciences, and even in social sciences. [16]

The citizen science programs are expected to have an inherent 'outreach' and 'awareness' outcome in addition to the apparent scientific goals. People have actually acknowledged that citizen science programs can in some way democratize science. This is undeniable as these programs are by nature 'deliberative' and 'participatory' with a great deal of involvement of the citizens in the scientific methodology itself, although measuring the actual effect in terms of scientific awareness and rational temper of the involved citizens is difficult (Bonney *et al.* 2016; Sauermann and Franconia 2015). In some citizen science programs effort was put in to decide upon these outcomes. For example, the Galaxy Zoo project did find that the volunteering citizen scientists wanted to further develop on the project by themselves and create their own infrastructure and methods (Fortson *et al.* 2011). Similar phenomena were also apparent in another citizen science project in astronomy, 'Citizen Sky' steered by the American Association of Variable Star Observers —within six months of engagement, the understanding and the attitude toward science among the participating citizens was significantly influenced (Aaron *et al.* 2013). Exposure to actual scientific methodology should induce longer-term rational behaviour and the ability to judge pseudo-science from science. In terms of design, the citizen science programs can be data collection projects, large-scale data processing projects, curricular recruitment or more inclusive community science projects (Bonney *et al.* 2016). General induction of public understanding of science can be imagined in all these different designs but with variable effectiveness. More importantly, this approach obliterates the distance between science and the public, obviating the mediation by educators and circumventing the already discussed issues with this mediation process.

Ongoing Rethinking in India

The Indian subcontinent has seen numerous individual efforts in addition to the publicly funded organized programs for public outreach of science. Most notable among them being Kerala Sasthra Sahitya Parishad (KSSP) and a number of organizations spread nationwide that are affiliated to All India Peoples Science Network (AIPSN). [17 & 18] An important contribution of these decade-long efforts has been popular science books in vernacular languages published by the aforementioned organizations, as well as by public agencies like National Council of Science & Technology Communication (NCSTC) and National Institute of Science Communication and Information Resources (NISCAIR). [19 & 20] Public agencies have also been

[14] Web source: American Association for Variable Star Observers, https://www.aavso.org/
[15] Web source: SETI (The Search for Extraterrestrial Intelligence) - NASA History Office: https://history.nasa.gov/seti.html
[16] Web source: https://www.zooniverse.org/

supportive of private efforts toward science communication by providing financial and logistic support. But one must recognize that most of these efforts follow more conventional approaches, as we have discussed already.

The citizen programs in the field of amateur astronomy are notable in India, although the geographic footprints of these programs are much limited. Notable long-standing citizen-driven organizations like Jyotirvidya Parisanstha in Pune and Skywatchers' Association in Kolkata have been gathering, training and guiding amateur astronomers to make a serious contribution to the field. [21 & 22] But most of the data collection ventures that the Indian amateur astronomers are involved in are international programs. But it is time for Indian practising scientists to come up with more indigenous programs in different fields of science that have the ability to engage the public in large numbers.

Even in the conventional public outreach dissemination programs, the scientific content is limited to well-established scientific notions, largely representing the international scientific community, while the practising Indian scientific communities are largely underrepresented in such deliberations. Now efforts are being made to organize public symposia where practicing Indian scientists present their own research in an accessible way to the citizens, for example, the 'Science at the Sabha' program organized by the Institute of Mathematical Sciences in Chennai. [23] Individual efforts are being taken toward more concerted programs undertaken by practising scientists from all domains of natural sciences. More such efforts will lead to a better connection between the practising Indian scientists and the lay public, leading to the development of trust and support for Indian science in general, apart from the positive impact on the 'awareness' aspects.

Another recent development is the Atal Tinkering Laboratory program where laboratory equipment is provided to schools under a Government-funded national program, to encourage students in technological innovations. [24] But while designing and running such a lab under this program, one must also lay emphasis on introducing the students to rational thinking and scientific methodologies that can derive the established scientific principles, apart from the mandated intention of enthusing them into more utilitarian technological innovations. Taking science centers to the remotest places of the nation are rare as per knowledge of the present author, but a large number of district-level science centers have been established all around the country, although they do retain the inherent issues of alienation that we already discussed. But we have witnessed great personal efforts towards that end. Most notable among

[17] Web source: http://www.kssp.in/
[18] Web source: http://aipsn.net/
[19] Websource: http://www.dst.gov.in/scientific-programmes/st-and-socio-economic-development/national-council-science-technology-communication-ncstc
[20] Web source: http://www.niscair.res.in/
[21] Web source: JyotirvidyaParisanstha(JVP), http://jvp.org.in/
[22] Web source: Skywatchers Association Kolkata, http://swakolkata.org/
[23] Web source: www.imsc.res.in/triveni/2018/

them are the phenomenal efforts put into the 'Toys from Trash' project led by Arvind Gupta and his team, who introduce children to a world of toys made from trivial trash based on some simple scientific principles [25] – something that needs to be widely propagated and replicated all around the country. Rural centers in the underprivileged remote areas of the country, incorporating location-specific environmental and architectural elements, equipped with simplest of tools to allow local school-going children to run experiments based on their textbook knowledge, will be a great way to induce scientific temper among the future citizens and engage more people with the process of scientific progress in general.

As prudently summed up in a recent treatise on the necessity of public outreach, and more importantly public understanding of science, the question of why one needs public engagement in science has already been replaced by the question on how to most effectively do it (Stilgoe *et al.* 2014). The effectiveness of a certain approach toward this goal should be assessed based on the more general outputs on public engagement with policy directions on science, participation of the hitherto disengaged fractions of the public, incorporation of the already engaged sections of the public into the process of scientific discoveries through citizen science programs, induction of scientific temper in the populace that perpetuates through generations, and finally a population resistance to irrational social behaviours and pseudo-science.

Acknowledgements

The article has benefited immensely by critical reading and suggestions by Sandip Paul and Saikat Chakrabarti (CSIR-Indian Institute of Chemical Biology, Kolkata), Gautam Basu (Bose Institute, Kolkata), Biswajit Bose and Amrita Goswami (Center for Observational Astronomy, Kolkata) and Joysankar Bhattacharya (Indian Institute of Management, Indore). The author also thanks all the members of the Rural Scientific Outreach Initiative subcommittee of the Center for Observational Astronomy, Kolkata, for the never-ending brainstorming in related issues over the last few years which led to this article.

[24] Web source: http://Aim.gov.in/atal-tinkering-labs.php
[25] Web source: http://www.arvindguptatoys.com

References

Aaron Price C., Lee H.S. 2013. Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching* 50:773.

Abbott B.W., Moatar F., Gauthier O., Fovet O., Antoine V., Ragueneau O. 2017. Trends and seasonality of river nutrients in agricultural catchments: 18 years of weekly citizen science in France. *Science of the Total Environment* 624:845.

Austen E. J., Lin S. Y., Forrest J. R. K. 2018. On the ecological significance of pollen color: a case study in American trout lily (Erythronium americanum). *Ecology* 99:926.

Bonney R., Phillips T.B., Ballard H.L., Enck J.W. 2016. Can citizen science enhance public understanding of science? *Public Understanding of Science* 25:2.

Bucchi M. 2017. Credibility, expertise and the challenges of science communication 2.0. *Public Understanding of Science* 26:890.

Fortson L., Masters K., Nichol R., Borne K., Edmondson E., Lintott C., Raddick J., Schawinski K., Wallin J. 2011.Galaxy Zoo: Morphological classification and citizen science. *arXiv* 1104:5513.

Imura H. 1999. Science Education for the Public. *Science* 284:1771.

Labouisse Curie E. 1937. Madame Curie: A Biography. (Translated by Vincent Sheean).

Lintott C.J, Schawinski K., Slosar A., Land K., Bamford S., Thomas D., Raddick J., Nichol R.C., Szalay A., Andreescu D., Murray P., van den Berget J. 2008. Galaxy Zoo: Morphologies derived from visual inspection of galaxies from the Sloan Digital Sky Survey. *Monthly Notes of the Royal Astronomical Society* 389:1179.

Osawa T., Yamanaka T., Nakatani Y., Nishihiro J., Takahashi S., Mahoro S., Sasaki H. A. 2017. Crowdsourcing approach to collecting photo-based insect and plant observation records. *BiodiversitY Data Journal* 5:e21271.

Robbins C.S., Bystrak D., Geissler P. H. 1979. The Breeding Bird Survey: Its first fifteen years, 1965-Resource Publication 157. 1979. United States Geological Survey.

Sauermann H., Franzoni C. 2015. Crowd science user contribution patterns and their implications. *Proceedings of the National Academy of Science USA* 112:679.

Scharrer L., Rupieper Y., Stadtler M., Bromme R. 2016. When science becomes too easy: Science popularization inclines laypeople to underrate their dependence on experts. *Public Understanding of Science* 26: 1003-1018.

Seafarers S. D., Lavender S., Beaugrand G., Outram N., Barlow N., Crotty D., Evans J., Kirby R. 2017. Seafarer citizen scientist ocean transparency data as a resource for phytoplankton and climate research. *PLoS One* 12:e0186092.

Stilgoe J., Lock S. J., Wilsdon J. 2014. Why should we promote public engagement with science? *Public Understanding of Science* 23:4.

Whiteson D., Mulhearn M., Shimmin C., Cranmer K., Brodie K., Burns D. 2014. Observing ultra-high energy cosmic rays with smartphones. *arXiv.* 1410.2895.

Wilson J.J., Jisming-See S.W., Brandon-Mong G.J., Lim A.H., Lim V.C., Lee P.S., Sing K.W. 2015. Citizen Science: The First Peninsular Malaysia Butterfly Count. *Biodiversity Data Journal*3:e7159.

Wilson W.H. 2017. The Dynamics of Arrivals of Maine Migratory Breeding Birds: Results from a 24-Year Study. *Biology (Basel)* 6:38.